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By

Reut Stahi-Hitin

מאת

רעות סטאחי-חיטין

מתחים על רקע דתי בהוראת האבולוציה בישראל:
התנסויות ומחשבות מהשטח

Religious tensions surrounding evolution education in Israel:
experiences and thoughts from the field

Advisor:

Prof. Anat Yarden

מנחה:

פרופ' ענת ירדן

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אלול התשפ"ב

בע"ה

תודות

התזה הזאת נכתבה בתנאים לא פשוטים, ואשמח להודות לכל מי שאפשרו לכך לקרות.

ראשית, ברצוני להודות לפרופ' ענת ירדן. תודה שהכלת את המורכבות ואפשרת לי להתקדם בקצב ובדרך שלי. האכפתיות, הסבלנות והדאגה– קודם כל לשלומנו, היו למקור תמיכה משמעותי עבורי.

לחברי הועדה המלווה, פרופ' יוסי נוסבוים ופרופ' ניר אוריון, על העצות המעניינות ועל שחלקתם איתי מנסיונכם.

לחברי קבוצת הביולוגיה במחלקה להוראת המדעים, על הרעיונות והחשיבה המשותפת.
ליטי ורון על הניתוחים הסטטיסטיים והסבלנות הרבה.
לכל המורים והחוקרים שהשתתפו במחקר, על הקדשת הזמן ושיתוף הפעולה.

להוריי היקרים, על האמונה והנחישות שטבעתם בי, ועל כך שפיניתם כל כך הרבה מזמנכם כדי לאפשר לי לכתוב.
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לאיש שלי, ניצן, על שאפשרת לי להתמודד עם הכל, על העידוד והתמיכה לאורך כל הדרך. שלי - שלך.

להלל נסים, ילד מדהים שלנו. צלחנו אתגרים וקשיים רבים במקביל להתקדמות העבודה הזאת. תודה שנשארת איתנו, והוכחת שכמו שאתה מצליח להתגבר על כל המכשולים, גם אני מסוגלת. העבודה הזאת מוקדשת לך.

Declaration

This thesis summarizes my independent research. Two minor parts were conducted in collaboration with other researchers: The teachers' professional development course (Results section "PD course"), was developed and instructed by Dr. Merav Siani and me in a full collaboration. In addition, collection of data of students' acceptance of evolution questionnaires (results section entitled "Acceptance of evolution among Israeli students") was done in collaboration with Prof. Orit Ben-Zvi Assraf from Ben-Gurion University in the Negev. The data were analyzed and summarized by me.

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List of abbreviations

MATE	Measure of Acceptance the Theory of Evolution
NOS	Nature Of Science
PD	Professional Development
ReCCEE	Religious Cultural Competence in Evolution Education
SRSII	Science and Religion Self-Identification Inventory

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Peer reviewed journal articles:

Stahi-Hitin R. & Yarden, A. (2022a). Should high-school biology teachers relate to students' religious faith when teaching evolution? The perspective of Jewish teachers, *International Journal of Science Education.* https://doi.org/10.1080/09500693.2022.2070936

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Siani, M., Stahi-Hitin, R., & Yarden, A. (2022). Student opposition to learning evolution and how teachers deal with this following a teacher training course. *Journal of Science Teacher Education*, 1-22.

Stahi-Hitin R. & Yarden, A. Teachers' and scientists' attitudes toward relating to religion when teaching evolution. *Evolution: Education and Outreach*, Accepted.

Peer reviewed conference presentations

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Stahi-Hitin R. & Yarden, A**.** (2021). Evolution education in light of the conception of religious science teachers and scientists towards evolution and religion. Paper presented at a virtual workshop entitled "Future Directions in Evolution Education".

Stahi-Hitin R. & Yarden, A**.** (2021). Should high school biology teachers relate to students' religious faith during evolution class? Paper presented at the National Association for Research in Science Teaching (NARST) Annual conference. (Virtual conference).

Stahi-Hitin R. & Yarden, A**.** (2022). The importance of religious role models accepting evolutionary theory for religious students. Paper presented as part of a related paper set entitled "The Influence of Religious Identity in Evolution Education" at the National Association for Research in Science Teaching (NARST) Annual conference; Vancouver, British Columbia (virtual presentation).

Abstract

Evolution is one of the most controversial scientific issues among the general public worldwide, mainly because of the presumed conflict between religion and evolution. This conflict also arises in school biology classes, where students' acceptance of evolution decreases as their religiosity increases. As many teachers in Israel avoided teaching evolution before it became an obligatory subject, I was interested in understanding whether the conflict regarding evolution is also relevant among the Jewish population in Israel since the implementation of evolution as obligatory subject in the curriculum. I found that teachers encounter religious based opposition to evolution among all sectors, especially among religious and traditional schools, which aligns with the low acceptance of evolution among Israeli high school religious and traditional students, relatively to secular students. However, I found no significant difference between sectors in the scores of matriculation exam questions of evolution, similarly to previous studies that found that knowledge of evolution doesn't necessarily increase its acceptance.

In order to examine ways of approaching this opposition, a unique population of religious teachers and scientists who study and teach evolution, was interviewed regarding their conception of the conflict, as they express the possible co-existence between religion and science. I found that among this population, both religion and science are compatible, and both are important parts of their lives. Religious teachers and scientists who rejected evolution in the past, eventually accepted it after they were exposed to religious explanations that emphasized the compatibility between religion and evolution. However, should discussing students' religious faith be the role of a science teacher?

This question was presented to teachers and scientists, and I found that most participating teachers are willing to relate to students' religious faith in a science class, emphasizing the students' need to relate to their inner world to enable meaningful learning. While most participating scientists rejected the idea, emphasizing the importance of separating science from religion. Based on their experience, religious teachers and scientists offered different practices on how teachers can relate to religion in a science class, yet they emphasized the limitations and challenges of doing so, which are very important to consider when designing

educational programs regarding the issue. This research's findings demonstrate that the need to relate to students' religious faith is coming from the field, and as many times teachers answer students' religious arguments with scientific explanations, teachers should be supplied with knowledge and tools regarding how they can answer students' religious based opposition to evolution. Therefore, based on this research findings, two implication programs were developed: a professional development course and an introductory lesson to evolution, both were shown to have a positive effect.

My research adds to the global interest in evolution education by shedding light on this topic in a Jewish population, which has been little studied. In addition, the research is offering teachers the opportunity to relate to students' religious opposition with sensitivity, and in doing so, potentially promote their students' positive perspective of science, thereby enhancing evolution and science education for all.

1. Introduction

One of the identity theories proposes that individuals construct a sense of self partly through the categorization of themselves and others as in-group (i,e., belonging to the same group) or out-group (belonging to different groups) (Stets & Burke, 2000). Individuals will notice similarities and differences between groups of people, and those groups that they see as more similar to themselves will be categorized as in-group while those who are dissimilar as out-group.

Considering that religiosity is usually an important part of personal identity of religious people, and the presumed common notion that to accept evolution one must become an atheist (Lyons 2010), it is likely that if religious affiliated people perceive evolution as a belief that belongs to non-religious or "atheists" - which are out-group members- they are likely to leave out evolution as part of their belief system and identity. This theory may explain the wide dimensions of rejection of evolution around the world (Miller et al., 2006), even though theological solutions to the presumed conflict can be found in many religions (Zimmerman, 2018). Below is a review of the literature which discusses this phenomenon, toward defining the goals of this research.

Evolution education around the world

"Nothing in biology makes sense except in the light of evolution", stated the evolutionary biologist Theodosius Dobzhansky in an essay that was published in 1973 (Dobzhansky, 1973). According to the National Science Teachers Association (NSTA), evolution is a major unifying concept in science and should be emphasized in K–12 science education frameworks and curricula. Evolution has been recommended to be integrated throughout the undergraduate biology curriculum (AAAS, 2011), and Furthermore, knowing evolution is an important component of scientific literacy needed by well-informed citizens and for those prepared for college and STEM careers (NSTA, 2013).

Each citizen has to understand the importance of evolution-related subjects that relates to everyday life. Biological evolution provides an effective explanation of why animal testing of human products makes sense, how bacteria become resistant to antibiotics, the transfer of diseases between species, and many more. Thus, not

accepting biological evolution limits the ability of people to make informed decisions about a wide range of phenomena many of which have personal ramifications. (Nadelson & Hardy, 2015). Citizens who don't accept evolution may not be able to fully appreciate the complex connections of all organisms on Earth and thus the extent to which the extinction of one species, or the pollution of one environment, which might affect both biodiversity and global human health (Barnes, 2014).

Nevertheless, rejection of evolution is a broad phenomenon around the world. In a survey of 34 countries, public acceptance of evolution was examined by whether the public agree or reject the statement "Human beings, as we know them, developed from earlier species of animals". Public rejection of that statement was found to be lower in Europe than in other parts of the world, such as Turkey, the United States or Cyprus (Miller et al., 2006). Over 30 years of public polls show that consistently, approximately half of the Americans reject evolution (Gallup, 2017). Due to anti-evolution propaganda in Turkey, evolution was not included in that country's curriculum (Muğaloğlu, 2018). A study conducted in several Muslim countries revealed acceptance of evolution at between 8% in Egypt and 40% in Kazakhstan (Hameed, 2008).

Researchers describe the rejection across different populations, even among biology students and teachers. Up to 50% of undergraduate students in introductory biology classes can reject important aspects of evolution (Rice et al., 2011). Even among high school biology teachers, rejection rates can reach up to 33% (Moore & Kraemer, 2005; Rice et al., 2011). Approximately half of students at a large research university did not accept that evolution could occur without the intervention of an intelligent designer (Brem et al., 2003). Among junior- and senior-high school biology majors, one study identified that 28% did not accept that life on Earth shares a common ancestor (Ingram & Nelson, 2006). Most of the global research among students was done among Christian and Muslim population, while the Jewish student population was hardly studied.

The public controversy regarding evolution and religion has been raised several times in courts of law in the United States; in 2005, the federal court decided that intelligent design is religious in nature and cannot be taught in public schools' science classrooms (Plutzer et al., 2020). Nevertheless, a national survey of American biology teachers in 2007 found that 13% of them explicitly advocate creationism or intelligent

design by spending at least 1 hour of class time presenting it in a positive light (Berkman & Plutzer, 2011). However, a more recent study in the United States showed a trend in the last 10 years toward dedicating more time to teaching evolution, together with a decrease in the number of teachers who emphasise intelligent design as a valid scientific explanation (Plutzer et al., 2020). This is an important and positive change, but it begs the question: does this change also indicate an increase in students' acceptance of evolution? To discuss this question, I will review the factors that could potentially influence the acceptance of evolution.

Factors influencing the acceptance of evolution

Student acceptance of evolution is defined as the extent to which a student is confident that evolution is the best scientific explanation for the diversity of life (Barnes & Brownell, 2016). Researchers found different factors that may interfere with the acceptance of evolution among students, teachers, and the general population. Barnes (2014) divided these difficulties into two types:

(1) Cognitive factors

Evolution education researchers have documented numerus misconceptions in different populations, from middle school students to college undergraduates and preservice teachers. Research indicates that students conflating mutation with adaptation, conflating species adaptation with individual adaptation and have difficulty in understanding processes that are abstract and require understanding of large time scales (Bishop & Anderson, 1990; Brumby, 1984; Dodick & Orion, 2003; Ferrari & Chi, 1998). Research has shown that some of these misconceptions stem from an essentialist perception of biological entities that leads individuals to devalue the prevalence and persistence of within-species variation, and, thus failing to understand any mechanism of evolution that operates over such variation (Shtulman & Schulz, 2008). Because of the complexity of biological evolution, people are likely to be challenged to understand the process, which may influence their levels of evolution acceptance (Nadelson & Hardy, 2015).

A few studies have found weak relationships between acceptance and understanding of evolution (Cavallo & McCall, 2008; Deniz, Donnelly, & Yilmaz, 2008; Shtulman & Calabi, 2008). Most studies have shown that students do not show

a statistically significant increase in their acceptance of evolution scores after being taught about evolution (Short & Hawley, 2015; Walter et al., 2013). Among teachers and preservice teachers, no correlation was found between their knowledge of evolution and its acceptance (Nehm et al., 2009). BouJaoude et al. (2011) found that Muslim students in Egypt (where evolution is included in the high-school curriculum) reject the theory. On the other hand, in Lebanon (where evolution is not included in the high-school curriculum), Lebanese Christian and Druze students accept it more readily. Therefore, inclusion of evolution in the curriculum does not seem to alter students' acceptance of the theory (BouJaoude, 2018).

(2) Cultural factors

The main cultural factor that is relevant to our discussion is religious culture. "Religious culture" is defined as *"The sociocultural norms related to religion. Religious cultural norms can include shared values, attitudes, traditions, holidays, and celebration*s". "Religious beliefs" can be defined as *"the specific beliefs one holds about the existence and influence of a deity, and being "religious" as having faithful devotion to an acknowledged ultimate reality or deity"* (Merriam-Webster, 2018).

Students' religious beliefs have been shown to be the main factor predicting whether they will accept evolution (Truong et al., 2018; Unsworth & Voas 2018). The notion that to accept evolution one must become an atheist is the most threatening aspect to the learning of evolution (Lyons 2010). Many researchers found that as religiosity increases, acceptance of evolution decreases (Allmon, 2011; Alters & Nelson, 2002; Barnes & Brownell, 2017; Eve et al., 2010; Winslow et al., 2011), although recently Barnes et al. (2021) demonstrated that students' perceived conflict between religion and evolution is a better predictor of acceptance than religiosity or understanding.

Studies have suggested that students' rejection of evolution and their feelings of exclusion in the biology classroom are, in part, the result of cultural differences between mostly secular instructors and mostly religious students (Barnes & Brownell, 2016; Hermann, 2012; Southerland & Scharmann, 2013). Academic science has a disproportionately large number of people raised with no religion, potentially producing many more people who do not believe in God (Ecklund & Schitle 2014). Evolutionary biologists have the lowest rates of religiosity among any discipline ever polled, with 4.7% who report being theists or deists (Graffin & Provine, 2007).

However, the rates of religiosity among evolutionary biologists and the general US population are highly disparate, with 67% of Americans believing in some kind of religion (Gallup, 2017). These studies present the phenomenon that most of the participants scientists are non-religious, but it is important to note there is a minority among scientists who has some religious affinity: how do they settle between the presumably contradictory domains: science and religion? This is an open question and understanding religious scientists' perception will be part of this research objectives.

Whereas the public struggles with how to situate their religious beliefs with claims of evolutionary theory, many biologists are unlikely to experience the same struggle (Alters & Nelson, 2002). Many instructors hold the personal belief that evolution and religion must be in conflict; some of them teach evolution as fundamentally atheistic and even make disparaging remarks about religion during class (Barnes & Brownell, 2016). Many religious students also assumed that most biology instructors were not religious and did not know of scientist role models who reflected their own religious identity and accept evolution (Barnes et al., 2017). Observing this phenomenon through the lens of the identity theory that was presented above (Stets & Burke, 2000) emphasize the different separate groups: atheists people who accept evolution, and religious people who reject evolution. When instructors did not acknowledge students' religious beliefs, the religious students in the class felt left out. That way, the students may decide biology and their religious value systems are incomparable (Hermann, 2012). When religious students are required to learn evolution, they may get the impression that the teacher wants to change their whole belief system, which may dampen their motivation to engage in studying evolution (Barnes & Brownell, 2016). Therefore, it is important that teachers be aware of the religious diversity in their classroom and make a clear distinction between religious and scientific knowledge, to promote an understanding of scientific theories without attempting to change religious beliefs (Teixeira, 2019).

As part of their attempt to deal with the controversy surrounding evolution based mainly on religious grounds, teachers use several approaches: (a) avoid teaching evolution, thereby avoiding the controversy in the classroom; (b) teach evolution but tell the students that they do not have to believe in it; (c) teach evolution along with the accompanying controversy by including non-scientific ideas; (d) teach evolution while being aware of the controversy but not addressing it (Hildebrand et

al., 2008). All four approaches can be found worldwide, and some of them have been researched (Scharmann, 2005; Staver, 2003). For example, The avoidance approach was common in Israel before 2016, as most teachers chose not to teach evolution mostly because of their or their students' religious conceptions (Orin et al., 2001),

Each of these approaches may address different education goal. When teachers decide which approach to implement, they better think of their goals when teaching evolution, and is increasing students' acceptance one of them?

Should acceptance of evolution be a goal of evolution education?

A historical survey shows that education has had diverse aims over the years but can generally be summarised as developing the individual for his/her own benefit, or for the benefit of the whole society (Reiss ,2007). As this research deals mainly with school science, it is important to make the distinction between teaching in schools, versus teaching in higher education institutes (university, college), as there are different characteristics to each one (Hebert, 2001).

When discussing the goals of school science education, Jenkins (2004) claimed that "The central task of a compulsory school science education for all is surely to introduce students to the key features of how scientists understand the material world. It is not to train students to think like scientists, save when they are addressing scientific problems, nor is it primarily to engage them in socio-political issues that have a scientific dimension." Reiss (2007) summarized different goals of science education (scientific literacy, individual benefit, social justice, etc.) and offered a 4-dimentional graph in which each of the aims of science education is mapped in space with the following axes: (a) From benefits for selected students to benefits for all students; (b) From benefits now to defer benefits as adults; (c) From individualism to communitarianism; (d) From knowledge to action. Using this model, teachers and educational systems can help shape the goals of evolution education, while one of the essential questions is whether educators should help their students understand evolution only, or should they also help their students to accept evolution?

Whether or not it is an educator's job to help students accept evolution has long been debated in the literature (Nadelson & Southerland, 2010b; Sinatra et al., 2003; Smith, 2010). Some evolution education researchers have proposed that student

acceptance is an important aim of evolution education (Nadelson & Southerland, 2010b; Rutledge & Sadler, 2011; Sinatra et al., 2008). Smith and Siegel (2016) argued in support of acceptance of, and belief in evolution being important and legitimate instructional goal in evolution instruction.

Biology educators may believe it is their duty to help students understand evolution, while persuading them to accept evolution may be seen as unethical, as it is not their responsibility as science educators. In addition, it may be likely that educators lack training in teaching the nature of science (NOS) as it is related to evolution and religion, which may make them feel underprepared to engage in this discussion (Southerland & Scharmann, 2013). Barnes and Brownell (2016) showed that some of biology instructors are willing to engage in students' religious beliefs, if this would help their students accept evolution, but many others refused to address potential compatibility between evolution and religion, because they did not feel that discussions about religion had a place in the biology classroom. Many instructors had their own beliefs that evolution and religion must be in conflict; some of them taught evolution as fundamentally atheistic and even made disparaging remarks about religion during class (Barnes & Brownell, 2016).

However, biology educators may believe that persuading their students to accept evolution is a form of indoctrination, and that their duty lies only in helping students understand evolution (Smith & Siegel, 2019). When observed through the lens of constructivism, some researchers emphasize the need to consider students' prior knowledge so that meaningful learning will occur, which may lead to a deeper understanding (Jones & Brader-Araje, 2002). On the other hand, some researchers claim that relating to evolution education through the lens of constructivism may cause students to accept pseudo-science explanations and deny them a proper science education (Mugaloglu, 2014; Taşkın, 2020).

The debate was also addressed in 2005 when an editorial in the journal Nature suggested that scientists should relate to 'intelligent design' or creationism in their science classes and claimed that scientists should learn how religious people accommodate science with religion and challenge this in their classes with scientific truth. In that way, students may be able to accept the scientific explanations much more easily and pass this acceptance on to their communities (Nature editors, 2005). Rejecting this suggestion, Dawkins and Coyne (2005) stated that the science

classroom is not the place to teach students how to settle the conflict between science and religion; rather, it is a place to teach science. The official stance of the National Association of Biology Teachers agrees that teachers should not deal with non-scientific matters regarding evolution (National Association of Biology Teachers, 2019).

However, many researchers have shown that acknowledging students' religious faith helps increase student acceptance of evolution (Lindsay et al., 2019; Truong et al., 2018). Reiss (2013) distinguished the question of whether religion has a place in science education, from the question of whether it has a place in science: "It is perfectly possible to conclude that religion has no place in science but that it does in science education. The reason for this is simply that science education is a broader field of study than is science. Just as we might conclude that ethics has a role to play in science education (Jones et al., 2010), even if it doesn't in science, we need to examine whether religion has a role to play in science education" (Reiss, 2013). In addition, Eve et al. (2010) showed that since the acceptance of evolution is affected by social and psychology factors, teaching good science alone is not enough to increase students' acceptance of evolution.

Engaging in students religious beliefs might be one of the most important things to consider when teaching scientific subjects that are perceived to be in conflict with many aspects of the different religions (Southerland & Scharmann, 2013). Studies show that acknowledging potential compatibility between evolution and religion can increase student acceptance of evolution and decrease the perceived conflict between evolution and religion (Barnes & Brownell, 2018; Truong et al., 2018).

What solutions that address the conflict are offered in the literature?

Before discussing the possible solutions, it is important to note that despite the common notion that religious beliefs conflict with evolutionary theory, many philosophers, theologians and scientists have discussed a range of possible ways to view potential compatibility between evolution and religion (Pear et al., 2015; Sacks, 2011; Yasri et al., 2013). In addition, 16,000 religious leaders (Christian, Jews, and Buddhists) signed a letter supporting potential compatibility between evolution and religion, known as "the Clergy Letter Project" (Zimmerman 2018). Therefore, there

are religious solutions to the conflict, although they are unlikely to be commonly known among the general public. The controversy around evolution and religion is one particular example of the larger relationship between science and religion (Yasri et al., 2013), which presents a complex history of interaction that includes frequent controversy and mutual suspicion, but also ongoing cooperation and accommodation (Shane et al., 2016).

According to previous research, if educators want to help their students reconcile their religious beliefs with evolution, it is important for them to understand their students' cultural backgrounds and to learn how evolution can be taught in a culturally sensitive manner (Barnes & Brownell, 2017). Different approaches were offered in the literature for increasing students' acceptance of evolution. For example, Tolman et al. (2020) found that utilizing a reconciliation module effectively increased evolution acceptance while allowing students to maintain their religious views. Several studies offered that teachers must relate to students' cultural background while teaching science, since bridging students' backgrounds with science is necessary for the success of those traditionally underrepresented in the discipline, by reducing incongruences between home and school and increasing the authenticity of science learning (Brown & Crippen, 2017).

Cultural competence teaching is described as "the ability of a teacher to successfully teach students who come from different cultures other than his / her, while mastering certain personal and interpersonal awareness's and sensitivities, learning specific bodies of cultural knowledge, and mastering a set of skills that, taken together, underlie effective teaching" (Tanner & Allen, 2007).

As mentioned above, religious students may come into the biology classroom with the preconception that evolution and religion must be in conflict, and if this perceived conflict would be addressed in the classroom, it is likely that they will feel more included and respected in the learning environment. Cultural competence training for evolution instructors could result in improved instructor relationships with religious students, which may improve student perceptions of evolution instructors, and improve their attitudes toward evolution (Barnes & Brownell, 2017). As a result, those students may have higher motivation for learning, which may cause better engagement and achievements. Together with the positive effect it can have on religious students, culturally competent evolution education could also have positive

impacts on non-religious students - it can reduce non-religious students' negative stereotypes about religious people in biology (e.g., religious individuals cannot do credible science, an individual cannot be both a biologist and religious) (Barnes & Brownell, 2017).

Barnes and Brownell (2017) developed a framework by which they intend to bridge the gaps between secular and religious cultures when learning evolution at the college level: Religious Cultural Competence in Evolution Education (ReCCEE). In their essay, Barnes and Brownell describe a suite of practices that can promote culturally competent teaching and are shown as affective learning practices by previous studies.

ReCCEE practices: (1) acknowledge that some students may perceive a conflict between their religious beliefs and evolution; (2) Explore students' personal views on evolution and religion - discuss and encourage the exploration of students' personal views on evolution and religion; (3) Describe to students the bounded NOS and different ways of knowing; (4) Outline a spectrum of viewpoints on religion and evolution - explain that there are diverse viewpoints on evolution and religion and those viewpoints are not restricted to atheistic evolution and special creationism. Discuss the possibility of theistic evolution; (5) Provide students with religious role models who accept evolution- a significant factor facilitating a transition from creationism to evolutionism in Christian biology majors was these students' interactions with their religious biology professors who reassured them that there is no need to be a conflict between religion and evolution; (6) Highlight the potential compatibility between evolution and religion - explicitly discuss the potential compatibility between evolution and religion.

It has been shown that the ReCCEE practices can reduce students' perceived conflict between evolution and religion, increase students' acceptance of evolution, and help create more inclusive undergraduate biology classrooms (Barnes et al., 2017), even an instruction of six minutes (Truong et al., 2018). A recent study that was conducted among in-service teachers in Israel, indicated that using the ReCCEE framework increased some formerly "resistant" learners' willingness to learn about evolution and include it in their own teaching. In addition, using the ReCCEE practices created a liberal and relaxing atmosphere that enabled the teaching of

evolution—even human evolution—within a group of culturally diverse and antagonistic participants (Alkaher at al., 2020).

A few studies in Israel have presented educational programmes in which the Jewish sources are deeply discussed in science class or in teacher's professional development (PD) programmes, which were effective at decreasing students' opposition to evolution (Allouch, 2010; Pear et al., 2015; Pear et al., 2020). These programs were best suited for religious schools, where the students are familiar with the study of religious texts. However, if teachers from different sectors will be interested in relating to students' religious faith in science class, there are no such programs or practices that are suitable for them.

Context of the study

As already noted, rejection of evolution is a widespread international phenomenon among all different religions and sectors, even though most studies have focused on Christian and Muslim populations. Here I focus on the Jewish majority in Israel, where acceptance of evolution has been found to vary among this religion's different sectors. Israel is a multicultural country. Most of the population is Jewish (74.1%), 21.0% is Arab (Muslim, Christian and Druze), and 4.9% consists of other minorities. The Jewish population is composed of 44% who define themselves as secular, 22% as traditional, 24% as religious (modern Orthodox), and 10% as ultra-Orthodox (Israel Central Bureau of Statistics, 2020).

Here I focus on three Jewish sectors which can be ordered according to their affinity to religion along a hypothetical continuum: at one end are the secular Jews, with the lowest affinity to religion, in the middle are the traditional Jews, with a somewhat modest affinity to religion (see more details about this sector below), and at the other end lie the religious Jews. The latter sector has the highest affinity to religion and is generally composed of modern Orthodox and ultra-Orthodox. Only the modern Orthodox Jews participated in this study. Those who define themselves as traditional Jews clarify that their perception of life is connected to their Judaism (Buzaglo, 2003). 'Traditionists live in a secular socio-cultural environment: they consume what is considered to be a secular culture and the

public sphere in which they conduct their daily business is a "secularized" space' (Yadgar, 2011).

Because most of the Jewish population in Israel (56%) has a tendency to relate to their religion, the Jewish tradition is of social importance in that country. A survey that examined Jewish Israeli citizens' beliefs showed that 80% of them believe in god (Arian & Keissar-Sugarmen, 2012). Israel's Jewish national educational system is divided into two main streams: national state schools, usually attended by secular students, and religious national state schools, usually attended by religious students. The curricula of both streams are similar, except that a larger portion of the curriculum is devoted to religious studies in the religious national state schools. Since traditional students are neither religious nor secular, they may attend schools in either of the two main streams.

When Israeli Jews from different sectors were asked to choose whether humans and other living things 'have evolved over time' or 'have existed in their present form since the beginning of time', about half of them (53%) chose the first option, indicating an acceptance of evolution, while 43% chose the second option, indicating rejection of evolution. The percentages of those who accepted evolution in each sector were: 83% secular Jews, 35% traditional Jews, 11% modern Orthodox Jews, and 3% ultra-Orthodox Jews (Pew Research Center, 2016).

According to the officially published biology curriculum for Israeli state high schools, in 1967, evolution was a required subject for biology majors, but between 1991 and 2015, it became an elective subject (Israel Ministry of Education, 2017). When given a choice, only a small percentage of the teachers in Israel chose to teach evolution (Agrest, 2001). Most of the teachers chose not to teach evolution mostly because of their or their students' religious conceptions (Orin et al., 2001), and many science teachers indicated a conflict between evolution and creationism (Dodick et al., 2010). The theological tensions surrounding evolution affected its implementation in the compulsory curriculum for biology (Siani & Yarden, 2020) until its eventual inclusion as an obligatory subject for high-school biology majors in 2016 (Ministry of Education in Israel, 2017).

Since then, evolution has been mentioned explicitly as one of the main topics of the curriculum (~15 teaching hours/60 hours of teaching ecology/200 hours in total dedicated to teaching three required topics – the living cell, systems in the human

body and ecology). As before evolution was implemented as obligatory part of the curriculum, most teachers avoided teaching it due to religious conception, it is highly important to examine what is happening in Israel's biology classes regarding the teaching and learning of evolution.

2. Goals and research questions

As already noted, evolution is one of the most controversial scientific issues among the general public, mainly because of a presumed conflict between religion and evolution. The general objective of this thesis is to describe evolution education in Israel, focusing on students' religious-based opposition to evolution, and to offer solutions to the challenges that came up from the field, mainly through the experiences and thoughts of teachers and scientists. The thesis is divided into 3 parts, according to the following research goals, which are marked A-C, and their related research questions (RQs) 1-9.

As this subject was hardly studied in Israel since the implementation of evolution in the obligatory curriculum in 2016, the first goal of this study was to describe and characterize evolution education is Israel (Goal A), by collecting data from three sources: First, by examining the experience of Israeli biology teachers, as before 2016 most teachers in Israel chose to avoid teaching it, and public-school biology teachers are at the front line of the public controversy surrounding the teaching of evolution. Second, students' perspective was examined by examining the average score of acceptance of evolution among Israeli high school students, and by comparing the matriculation exam's answers of different sectors in Israel. The related RQs are:

1. Do high-school biology teachers experience students' religious-based opposition to evolution? If they do, do they think that religious faith may interfere with students' understanding of evolution?
2. What is the level of acceptance of evolution among Israeli high-school biology majors?

3. Are there any distinct differences between religious and non-religious schools in their achievements in the matriculation exam's evolution questions?

The second goal of this research (Goal B) was to examine solutions that may help in answering the challenges that came up in the first part, focused on understanding the conceptions and attitudes of teachers and scientists toward the religious tensions surrounding evolution education. Despite the presumed conflict between religion and evolution in the general public, there is a unique group of religious people who accept, study, and teach evolution. In order to understand whether the religious based opposition is inevitable among religious people, I examined the conception of religious teachers and scientists toward religion and evolution, and the factors that influenced their conception. The conceptions of religious teachers and scientists are relevant to the discussion since they demonstrate the possible co-existence between religion and science in their own life, thus their conception may help understanding how religious students can reconcile their religious faith with evolution. The related RQs are:

4. How do religious biology teachers and scientists conceive the possible relationship between religion and science in general, and evolution and creation in particular?
5. What do religious biology teachers and scientists feel influenced their conception of the possible relationship between religion and science, and what additional factors might have influenced their acceptance of evolution?

There is a seemingly gap between scientists and the general public's attitudes regarding evolution and religion, and as scientists are shaping the discussion regarding evolution in the literature and the media, but teachers are those who stand at the front line of the controversy in class, I was interested in understanding the following RQ:

6. What are the attitudes of Israeli teachers and scientists toward relating to religion in a science class?

As teachers indicated their need for knowledge and tools regarding religious-based opposition to evolution, religious teachers and scientists were asked what practices should be implemented if a teacher decides to relate to religion in a science class. As religious people, they are aware of the presumed conflict and its possible solutions, and their experience in the field – as scientists or as teachers –may help in shaping practical ideas of how to relate to religion in a science class together with considering the concerns of the opposers to relating to religion in a science class. The related RQ is:

7. What practices do religious teachers and scientists think should be used when relating to religion in a science class?

The third goal of the research (Goal C) was to develop implementation programs based on the findings and recommendations that arose from the previous parts of this research. Two programs were developed: The first was a 4-hour program that dealt with the religious tensions surrounding evolution education, that was taught as part of a 30-hour course for in-service biology teachers. In addition, a 2-hour introductory lesson to evolution dedicated for high-school students was developed in order to enable teachers deal with students' religious based opposition. Data regarding students' acceptance of evolution was collected in one of the classes before and after the lesson, to examine whether the teaching unit was effective in decreasing students' opposition to evolution. The related RQs are:

8. How do the teachers participating in an evolution teacher training course deal with their students' opposition to learning evolution, before and after the course?
9. Does a culturally competent introductory lesson to evolution affect the acceptance of evolution among traditional students?

Answering these research questions may contribute to the growing literature by providing a comprehensive description of the religious tensions in evolution education in Israel, focusing on the Jewish population that was hardly studied. In addition, it contributes to the practice of teaching evolution in Israel by enabling teachers to help their religious affiliated students decrease their religious based opposition.

3. Methods

The methods section is divided into three parts: the first part describes the population that participated in each of the research questions (RQ). The second part describes the research design of each RQ, and the third part describe the data analysis of each RQ. The fourth part describes the research limitations. The research project was reviewed by the ethics committee of the Weizmann Institute of Science. The submission is in accordance with the regulations of the IRB-Education committee.

3.1. Population

RQ 1

Ninety-seven Jewish high-school biology teachers filled out the research questionnaire. Each teacher who answered the teachers' questionnaire was given a serial number according to the order of their response. The teachers were divided according to their school's sector—secular (national state school), religious (religious national state school) or traditional. A traditional school was defined as a secular school that included a majority of traditional students, according to teachers' perception of their students' population. Of the participating Jewish teachers, 48% taught in secular schools, 28% in religious schools, and 24% in traditional schools; 82% taught in senior-high school (30% of them also taught in junior-high school), and 18% taught only in junior-high school. The respondents taught in various areas in Israel that differed in their geographical location and socio-economic status of the population. Examining the participating teachers' sectors in retrospect, it appears that the study population well represented the different sectors in the Jewish population, with 61% secular teachers, 30% religious teachers, and 9% traditional teachers. The distribution among sectors was representative of Israel's demographics, as presented above (Israel Central Bureau of Statistics, 2018).

RQ 2

The sample of this part of the research was composed of 778 high school biology majors from 19 schools in Israel. The schools were chosen for their willingness to cooperate, they all belong to the secular sector and present relatively high scores in the matriculation examinations (Mathematics: 82.6, Std. 7.06; Biology:

85, Std. 6.26). Evolution was included in the subject of ecology and was studied during 11th grade in the participating schools.

RQ 3

The sample of this part were Israeli High-school students from secular and religious national state schools, who were tested in the biology matriculation exam during summer 2017 and summer 2018. Table 1 shows the number of students that were examined in each sector for each academic year.

Table 1. The number of students according to sectors in each academic year.

Academic year	Total number of students	Number of students from secular schools	Number of students from religious schools
2016-2017	17254	14929	2246
2017-2018	17990	15737	2114

RQ 4, 5, 7

The participants of this part of the study were religious biology teachers (n = 10) and religious scientists (n = 10). Their academic degrees, ages, and Measure of Acceptance of the Theory of Evolution (MATE) questionnaire (Rutledge and Warden 1999) scores (see below) are shown in Table 2. All the participants defined themselves as modern Orthodox, except S7, who defined himself as ultra-Orthodox.

Table 2. Participants' profile (n = 20)

Code*	Education **	Age	MATE
T1	MSc (ST)	33	89
T2	PhD (ST)	54	92
T3	Ma (ST)	27	95
T4	PhD (ST)	80	86
T5	PhD (ST)	52	80
T6	BEd (ST)	38	95
T7	PhD (STS)	43	99
T8	MSc (BIO)	48	65
T9	MSc (ST)	63	85
T10	BSc (BIO)	63	65

S1	PhD (STS)	43	94
S2	MSc (BIO)	46	89
S3	PhD (BIO)	41	85
S4	MSc (BIO)	28	100
S5	MSc (GEO)	32	100
S6	PhD (ANT)	39	80
S7	PhD (BIO)	27	74
S8	Professor (BIO)	47	100
S9	Professor (GEO)	57	94
S10	PhD (BIO)	37	94

* T – teachers, S – scientists.

**The different disciplines of the participants: ST – science teaching; STS – science, technology, society; BIO – biology; GEO – geology; ANT – anthropology.

Seventeen of the participants learned evolution through formal academic education and biology lessons in high school. Three teachers—T5, T8, T10—learned evolution through informal means, such as general courses and museums.

RQ 6

In addition to the population of 97 teachers who answered the teachers' questionnaire, a sample of 124 scientists were surveyed in order to assess their attitudes toward relating to students' religious belief in a science class. The participants answered the scientists survey, which was published in a closed Facebook group of biologists from different universities in Israel. The scientists are active researchers or holds at least an MSc degree and they originate from different sectors in Israel.

RQ 8

The participants of this part of the research were 14 biology teachers who completed the teacher training course (Table 3). Of these, 7 teach in schools that belong to the Jewish non-religious sector, 2 to the Jewish religious sector, and 5 to the Muslim sector. Most of the teachers teach evolution at the high-school level. The numbers and letters in the left column of Table 3 are used in the Results section to attribute the teachers' quotes.

Table 3. The participants of the PD course (n = 14).

No.[a]	Gender	Residence	Degree	No. of years of teaching experience	No. of years teaching evolution
S1	M	Center	B.Ed.	10	3
S2	M	Periphery	MA	11	11
S3	F	Center	MSc	8	1
S4	F	Center	MSc	6	6
S5	F	Periphery	MA	5	1
S6	M	Periphery	BSc	4	4
S7	F	Center	MA	10	7
R1	M	Center	MSc	3	2
R2	F	Center	BSc	40	30
M1	F	Periphery	MSc	9	3
M2	F	Periphery	MSc	9	9
M3	M	Periphery	MA	11	4
M4	F	Periphery	BSc	2	1
M5	F	Periphery	BSc	3	1

[a] number combination identifying each teacher represents the sector in which they teach. S – Jewish non-religious school; R – Jewish religious school; M – Muslim school. All the teachers teach high school except for S3, who teaches junior high school.

RQ 9

The introductory lesson to evolution was taught by NF, who volunteered to participate in the research. NF defined herself as religious Jew, she was 33 years old, with 10 years of teaching experience in high schools in Israel. NF taught 11th grade, class of 13 students in a traditional high school in a central city in Israel.

3.2. Research design

RQ 1

I developed a short online questionnaire with open- and closed-ended questions that was aimed at examining biology teachers' experiences and difficulties while teaching evolution (Appendix 1). Questions 1–3 were demographic questions aimed at characterizing the school's sector, location, and whether it is a junior-high or high school. Question 4 was aimed at characterizing the students' sector as perceived by

the teachers, because as already noted, the school's official sector and the students' sector do not necessarily match. Question 5 was aimed at characterizing the teachers' sector as perceived by the students, based on the assumption that students' attitudes may be affected by their perception of a teacher belonging to their sector. To understand whether opposition to evolution appears in different sectors, questions 6–9 were aimed at examining whether the teacher teaches evolution, if he / she has encountered student opposition to evolution, and how this opposition was expressed. Questions 10–13 were aimed at revealing the teachers' perception of a possible influence of religious faith on students' understanding of evolution, and whether they are willing to relate to it when teaching evolution. To validate the questionnaire, four science education researchers examined whether it might answer the research goals. The four researchers gave suggestions to improve the questionnaire, then re-examined the improved version and approved the final version, which was used in the study. The questionnaire was distributed through teachers' social networks at the beginning of 2019, targeting 7^{th}- to 12^{th}-grade teachers.

RQ 2

To assess the participants' (n=778) level of acceptance of evolution, they were asked to answer the Measure of Acceptance the Theory of Evolution (MATE) questionnaire, that was developed by Rutledge and Warden in 1999, and was used since as a main tool to access students' acceptance of evolution in different populations (Rutledge & Warden, 1999). The questionnaire is a 20 item Likert-scale, each item gets 1-5 points so that possible scores for the MATE range from 100 (highest acceptance) to lowest 20 (rejection). The questionnaire was translated to Hebrew (Appendix 2) and was validated by three biology education researchers and one evolution researcher.

RQ 3

In order to compare religious and secular schools' students' success in answering evolution questions at the national level, the results of the matriculation exam (questionnaire number- 43381) from two academic years (2016-2017 and 2017-2018) were analyzed. The 2017 academic year was the first time in the recent years in which evolution questions were asked in the obligatory part of the exam for all students in Israel (in 2016 it was a pilot program for a small number of students).

Scores of evolution questions from each year (Appendix 3) were compared between religious state schools to those of the secular schools. The questions were part of chapter A of the exam, that included closed-ended questions. The exam of summer 2017 included 2 questions regarding evolution, while the exam of summer 2018 included one question regarding evolution.

RQ 4, 5, 7

Pre-interview questionnaire

The participants received an online questionnaire before the interview (Appendix 4) in which they were asked to answer demographic questions (to understand the variation in the sample), such as their age, education, self-religious definition, and whether they think there is a conflict between evolution and religion, ranked on a 1–5 Likert scale. To assess the participants' level of acceptance of evolution, they were asked to answer the MATE questionnaire (Rutledge and Warden 1999) which was described above.

Interviews with teachers and scientists

Religious biology teachers and scientists (n = 20, Table 2) were interviewed in a semi-structured in-depth interview of 90 minutes (on average) about their conception of evolution and religion and the factors that may have affected it, including whether they had rejected evolution in the past and their source of knowledge about evolution. The goal was to obtain in-depth explanations of their conceptions of the science–religion relationship in general and the evolution–creation controversy in particular (Appendix 5).

Views on the relationship between science and religion

There are various taxonomies that describe views toward the relationship between science and religion, while Yasri et al. (2013) provided a comprehensive review of the various taxonomies described in the literature and summarized the different views according to their similarities and differences in a synthetized taxonomy (Appendix 6). For analysis of the interviews, we used Yasri et al.'s (2013) taxonomy of the different views on the relationship between science and religion. The taxonomy grouped the views into those that considered science and religion to be

incompatible (Compartment, Science Trumps Religion [STR], Religion Trumps Science [RTS]), and those that found them to be compatible (Different Questions, Different Methods, Coalescence, Complementary); see details in Table 4.

Table 4. Summary of the views on the relationship between science and religion according to Yasri et al. (2013)

		Views	Description
Incompatible		Compartment	Conflict exists in the explanations provided by science and religion, but neither explanation should take priority.
	Conflict	Science Trumps Religion (STR)	When there are different answers to the same question, only science provides true answers.
		Religion Trumps Science (RTS)	When there are different answers to the same question, only religion provides true answers.
Compatible	Contrast	Different Questions	There is no conflict between science and religion because their role is to answer different questions.
		Different Methods	There is no conflict between science and religion because they construct knowledge in different ways.
	Consonance	Coalescence	It must be possible to combine science and religion because they provide the same answers to the same questions.
		Complementary	Both science and religion are useful for understanding all aspects of life.

In addition, Yasri et al. (2013) developed a short questionnaire to identify the different views of science and religion held by research subjects (teachers, students, etc.): the Science and Religion Self-Identification Inventory (SRSII). The questionnaire (Appendix 7) is made of 2 questions - the first is a Likert scale made of 7 statements while each statement represents one view to the religion-science relationship. The person chooses whether he - strongly agrees, agrees, not sure, disagrees or strongly disagrees, with each statement. The second question asks what is the statement that best describes each one's view.

After being interviewed, the participants were asked to fill out the SRSII, in order to triangulate our analysis of the interviews and to better describe the interviewees' view.

RQ 6

In order to understand what the attitudes of scientists are towards relating to religion in science class, we published a survey in a closed Facebook group of biologists from different universities in Israel (active researchers or at least MSc). The

Facebook group included ~600 participants thus the response rate was 20%. The survey included one closed ended question, similar to the one that appeared in the teachers' questionnaire: "Should biology teachers relate to religious issues in science class (when teaching evolution)?". The possible answers were: 1. Yes, if it will promote students' understanding; 2. No, in science class we learn only science. 3. Depends. In addition, the respondents were asked to explain their answer as a comment to the survey. A limitation of the survey is that the scientists were not requested to state their own sector (secular / traditional / religious).

RQ 8

A message was sent at the end of 2019 to all biology teachers in Israel on the National Biology Teacher Center mailing list, that the teacher training course "Teaching Evolution – Why and How?" would open at the beginning of 2020. Twenty teachers enrolled in the course, paying a symbolic registration fee. Of the enrolled teachers, 14 showed up to all the meetings and completed all of the tasks, while the other 6 showed up to only one meeting.

The course meetings started at the beginning of 2020 and continued for a few months. The course alternated four synchronous face-to-face meetings, lasting 4 academic hours each, with four asynchronous meetings. In each of the eight meetings, the teachers acquired content/scientific knowledge and PCK. During the asynchronous meetings, the teachers were asked to read articles, watch lectures online, answer questions pertaining to the previous synchronous meeting, and plan lessons according to the previous meeting. (The main themes of the meetings can be found in Siani et al., 2022).

The fifth and sixth meetings were dedicated to the issue of religious tensions surrounding the teaching of evolution. The fifth meeting was comprised, like the other synchronous meetings, of a scientific knowledge part, consisting of an expert lecture: "Theological solutions in the field of evolution" and a pedagogical part, in which we exposed the teachers to pedagogical tools that would help them deal with students' opposition stemming from religious beliefs. These included a few principles, such as: introducing students to religious characters who accept evolution; emphasizing the possible connection between religion and evolution explicitly; encouraging students to express their religious world view in class. In addition, during this meeting a discussion was held with the teachers regarding the way in which they deal with

opposition stemming from religious beliefs in their classes. The teachers were divided for this discussion into groups according to the sector in which they teach: Jewish secular, Jewish traditional, Jewish religious, and Muslim.

The data collected in this study is based on the artifacts submitted by the teachers during the course and in the summary task at the end of the course. Since the emphasis of this work is on opposition to learning evolution and how teachers address it, the submitted artifacts of the questions that dealt with these issues were collected: the first, second, fifth and sixth meetings (Appendix 8) and question 8 (Have you been teaching religious belief and evolution in the classroom? Has the course changed your approach? Why?) in the summary task (Appendix 9). We have also related to question 3 in the summary task. The relevant sections of the meeting schedule and summary task are emphasized in italics in Appendices 8 and 9. These data sources were most relevant and valuable for this research because they reflect the teachers' ideas and insights at three stages of the teacher training course: the beginning of the course; after the teachers have been introduced to scientific and pedagogical content regarding opposition stemming from religious beliefs in the fifth and sixth meetings; the end of the course, when the teachers have an overall view of the topic of evolution and the opposition to learning it.

RQ 9

A 90-minute introductory lesson to evolution (Appendix 10) was developed in order to hopefully address the challenges that teachers indicated they experience regarding students' opposition to evolution. It was developed intentionally to be short in order to enable teachers to implement it in their teaching sequence.

The lesson is built from a few stages, while the main goal is to fracture student's dichotomy between evolution and religious mainly by floating their perceptions and make them see they may want to reconsider them.

The introductory lesson to evolution included four parts:

1. **Group brainstorming** about the question: What comes to your mind when you hear the word: Evolution? This part can be done using an online tool called "Mentimeter" (Appendix 11).
2. **The nature of science (and difference from religion).** A discussion in class will focus on dividing the students' association from the previous part, into

scientific ones and non-scientific. Next, the teacher will ask the students what the properties and goals of each group – scientific and non-scientific. After the students' suggestions, the teachers will explain the difference between science and different sources of knowledge, emphasizing that evolution is a scientific theory, though a lot of non-scientific beliefs and thought are being attributed to it (as we will see in the next part), and it is important to make the distinction.

3. **"Who believes in evolution?"** Groups of 2-3 student will receive 2 sets of cards: one set includes a short description of a person (Rabbi, scientist, etc.) that stated statements regarding evolution, and the second set of cards with the statements themselves. The students were asked to match between the person to the statement (example of answers from one group of students is shown in Appendix 12). Later, the teacher may give clues that will help making the right matching and will demonstrate the students that the most religious persons were very positive towards evolution. Subsequently, the teacher will discuss with the students what are their thoughts and conclusions following the activity.
4. **Evolution in a nutshell.** The teacher will present a short video that explains the mechanism of evolution, and then will discuss the scientific proofs regarding evolution, that included fossils, structural similarity between different creatures, embryonic comparison, and genetic comparison.

Following this introduction, the teacher may teach the rest of the curriculum in evolution.

The lesson was examined in eight, nine and tenth grades in public secular high school in the south part of the country, with majority of traditional students. After each time I taught the lesson, it was revised and improved, based on the students' reactions. Students from all classes showed very good reactions, interest, and high engagement.

The lesson was presented in the biology teachers conference. One of the teachers, NF, agreed to participant in the research as a pilot class. NF taught 11th grade, class of 13 students in a traditional high school in a central city in Israel. The

students were asked to fill a questionnaire that included three parts: (1) the MATE questionnaire; (2) a Likert question that examined the level of contradiction between religion and evolution, according to the students (while 5 represent high contradiction and 1 represents no contradiction); (3) the last 4 digits of their phone number (in order to track their responses in the post questionnaires, in addition to staying anonymous). The students filled the questionnaire before the lesson, immediately after the lesson, and 2 months after the lesson. In addition, the teacher was interview following the lesson. The lesson was also recorded and transcribed but and transcripts were not analyzed.

3.3. Data Analysis

This mixed-methods research study incorporated quantitative and qualitative approaches. The quantitative approach was based on the closed-ended questions of the teachers' questionnaire, MATE results of the different research populations, analysis of the matriculation exam scores, and a scientists' survey. The qualitative approach was based on the teachers' answers to the open-ended questions of the teachers' questionnaire, the teachers' and scientists' interviews and the submitted artifacts from the PD course.

Quantitative analysis

The statistical analysis of the quantitative part of the study was carried out using the Statistical Analysis Software (SAS) programme for descriptive statistics and for comparing frequencies (Chi-square comparing).

The answers to the MATE and SRSII questionnaires were coded into predetermined categories (Rutledge and Warden 1999; Yasri et al. 2013) and the MATE score was calculated for each individual participant, as well as for different subgroups of individuals that arose from the data (role, education, views of the relationship between science and religion, source of evolutionary knowledge, and past rejection of evolution). Correlations between the MATE scores of the different subgroups were examined.

Qualitative analysis

RQ 1

The qualitative analysis of the teachers' answers to the open-ended questions was conducted in stages. First, a 'thematic analysis' (Braun & Clarke, 2012) was conducted to obtain the main themes emerging from the teachers' answers. Initially, we (my mentor and me) conducted an open coding process, in which we identified the sub-categories emerging from the data; a discussion was then held between us. This process was reiterated four times on ~30% of the data, starting from >80% agreement, and continuing until 100% agreement between us was reached. Later on, a third researcher coded 25% of the data. The validation process was conducted with me, starting from 75% agreement between coders and following a discussion, 100% agreement was reached.

RQs 4, 5, 7

The qualitative analysis of the interviews with the teachers and scientists was a combination of inductive and deductive analyses (Cho & Lee, 2014). Inductive analysis was conducted in stages. First, the transcripts were read by me, who also performed an open coding process by writing memos on themes emerging from the data. Then, we (my mentor and me) read 10% of the transcripts and created initial categories from these themes. Citations that answered the categories were pulled out into a table that enabled a crosswise analysis of each question. Subsequent reading of each transcript enabled to identify additional themes. Then, all the transcripts were coded according to the initial codes.

The deductive analysis was conducted in order to define the participants' views toward the relationship between science and religion, according to the pre-determined categories that appeared in the classification of Yasri et al. 2013. The interviews were read several times and all the citations from the interviews in which the participants talked about their approach toward science and religion were pulled out and the authors coded them independently according to Yasri et al. (2013)'s framework.

RQ 8

The analysis of the teachers' submitted artifacts to the questions answered in the asynchronous meetings and in the summary task was conducted in stages. First, "thematic analysis" (Braun & Clarke, 2012) was conducted to obtain the main themes emerging from the teachers' submitted artifacts. Then each of us (my mentor and me) along with a third researcher conducted an open coding process, individually, with each identifying the subcategories through a comprehensive microanalytical coding process of all of the teachers' submitted artifacts. Then, a discussion was held among the three coders. This process was performed three times, until reaching 100% agreement between coders. An axial coding process followed, in which we found relationships between the categories and could thus merge them from the data. The third stage was finding the core category of the submitted artifacts. We found that the issue of science and religion was critical in the artifacts, and this was therefore chosen as the core category around which our research was generated.

Validity and reliability

To minimize any bias due to prior assumptions or experiences, the data were validated by two researchers to capture a wider view of the data analysis. Initially, we conducted an open coding process, in which each of us identified the sub-categories emerging from the data; a discussion was then held between us. This process was reiterated two times, which enabled the creation of the coding rubric. Then, I coded all the interview excerpts according to coding rubric. During The inter-rater reliability process, my mentor independently coded 15% of the coded interview excerpts. When disagreements occurred, the coders discussed the code until reaching an agreement. This process was held three times, at first the level of agreement between coders was 80%, until achieving 100% agreement between coders.

The mixed-methods approach enabled generalising the main ideas and processes of this study to a wider population. In addition, because location and socio-economic index of the population varied, careful generalisation of the results from the study population may be possible.

3.4 Limitations

There are several limitations to this study. First, the data from the teachers' questionnaire and interviews relied on self-reports of the participating teachers, and each teacher may understand the students' opposition to evolution differently (this may explain the finding that some teachers perceived religious arguments as opposition, and some didn't). Another possible limitation that stems from teachers' self-report in the teachers' questionnaire is the fact that the separation between secular to traditional students was based on the teachers' perception of their students' sector (as there is no official separation between secular and traditional), and each teacher may perceive differently the characteristics of each sector.

An additional limitation is that some of the participants' answers in the questionnaire and interviews might have been designed to please the researcher, or they may have not wanted to admit that their students show opposition as this might be perceived as a weakness. In addition, the factors that the participants indicated to have influenced their conceptions of evolution, were based on their retrospective self-report, which may have changed through time and experience.

These limitations should be borne in mind when drawing any conclusions from the results.

4. Results

This chapter includes 4 parts: The first part describes the research findings that enabled the characterization of evolution education in Israel, using different sources of data. The second part presents data that enable to answer the question of whether the opposition to evolution is inventible among religious students. The third part describes suggestions and thoughts toward how teachers can deal with religious based opposition to evolution, and the fourth part describes a partial implementation of these suggestions.

4.1. Characterizing evolution education in Israel

4.1.1. Teachers' experience

Teaching evolution in Israel

In order to answer the first research question, on whether high-school biology teachers encounter opposition to evolution, I first examined whether teachers from different Jewish sectors teach evolution. The teachers (n=97) were asked whether they teach evolution in their classes: 85% of the respondents to the questionnaire indicated that they teach evolution; 6 teachers (5 from the secular sector and 1 from the traditional sector) claimed that they do not teach evolution because it is not part of the obligatory curriculum; 5 of these teachers taught in junior-high school, where evolution is only mentioned briefly in the curriculum but in practice, is not required, especially because the students are not asked about this topic on the compulsory national exams. One teacher, who teaches in a religious school, wrote that '*First, I have to solve my own conflict with this subject*', and another religious teacher who teaches in a religious school wrote about a colleague who does not teach evolution at all because of self-religious difficulty. Another religious teacher indicated she guides her students to solve questions from the matriculation exam at home, instead of teaching in class, in order to avoid conflicts in class and also to save time. We assumed that these two cases of teachers who have an essential difficulty with evolution represent the minority; it seems that most of the teachers in Israel teach evolution.

Opposition to evolution

In order to answer the first part of the first research question, on whether teachers experience students' religious-based opposition to evolution, the teachers were asked whether they had encountered student opposition during the teaching of evolution. Half of the respondents to the questionnaire reported that they had, from either a few or many students (Table 5). Examination of the opposition by sector (secular / traditional / religious) revealed statistically significant differences between the three ($X^2_{(\text{degrees of freedom} = 4,\ n = 87)} = 21.177$, $p = 0.0003$); most of the teachers in secular schools experienced no opposition from students, whereas some of them experienced opposition from a few students. In traditional schools, answers varied, from teachers who experienced no opposition to those who experienced opposition from many students. Teachers in religious schools experienced the highest level of opposition, with the highest percentage indicating that they experienced opposition from many students; 9% of the teachers indicated that they had not experienced opposition in class while at the same time, reporting their students' declaration that they '*don't believe in evolution but believe in god*'. Thus, religious arguments were not always experienced by the teachers as opposition.

Table 5. Distribution of teachers' answers to whether they encountered opposition in class when they started to teach evolution (total sample and according to sectors, $n = 87$).

	Total (%) n = 87	**Secular (%) n = 42**	**Traditional (%) n = 20**	**Religious (%) n = 25**
No opposition	49.4	69.0	40.0	24.0
Yes, from a few students	34.5	31.0	35.0	40.0
Yes, from many students	16.1	0.0	25.0	36.0

I was interested in examining any possible correlation between the teachers' own sector and the opposition that they experience from their students (for example, is there more opposition if the students' sector differs from their teacher's sector?). An interesting pattern was found between the opposition of traditional school students and their teachers' religious sector. Recall that a traditional school is as an officially

secular school with a high percentage of traditional students, while the teachers' sector within it varies. In the sample of 97 teachers, 21 taught in traditional schools. I compared the level of opposition according to each of these 21 teachers' sectors. I found that the indications of opposition among religious and traditional teachers (n = 8) were lower than in the general population of the questionnaire, whereas among the secular teachers who taught in traditional schools (n = 13), higher opposition was indicated compared to the general questionnaire population (Table 6). Although it is hard to draw any firm conclusions because of the small sample size, it is important to note the finding in the face of a traditional student population, secular teachers tend to experience higher opposition to evolution than religious or traditional teachers.

Table 6. Distribution of answers by teachers in traditional schools to whether they encountered opposition in class when they started teaching evolution, according to the teachers' own sector (n = 21).

	Teachers' own sector		
	Secular n=13	**Traditional n=3**	**Religious n=5**
No opposition	3	2	3
Yes, from a few students	4	1	2
Yes, from many students	6		

When asked in the questionnaire how the students expressed their opposition, 41 teachers described various arguments that they heard from their students. The arguments were divided into four categories that emerged from the data, are summarised in Table 7. Looking at the percentage of arguments in each of these categories (Table 7), one can see that according to the teachers' perception, most students' opposition was based on religious–affective sources, and not on scientific sources. This might support the notion that any attempt to deal with such opposition should relate to the religious–affective aspect.

Several teachers indicated that although some of the students express their opposition explicitly and loudly during class, there is also a quiet opposition. For example, they reported that some students—who did not express opposition to evolution during the lesson—submitted exams with a scientifically correct answer to a

question on evolution, but beside it wrote: '*This is my answer, but I don't believe in it*'. In addition, a teacher in a religious school who was interested in finding out if there was quiet opposition in his classroom, polled his students and concluded that a higher percentage of students rejected evolution than the percentage of those who expressed opposition during the lesson. Thus, teachers should be aware of the fact that even if no opposition is expressed out loud in class, the students do not necessarily accept the subject.

Table 7. The expression of students' opposition to evolution as reported by 41 teachers (n arguments = 50).

Category	Explanation	Example	%
Religious	Arguments that included religious motifs, such as god, the bible, etc.	'*Evolution is not true; the Torah is true*'; '*God created the world*'	36
Beliefs	Arguments that included the term belief, not necessarily a religious belief.	'*The students asked me* "*what should I write in the exam – what you want to hear or what I believe?*"'	28
Emotional expression	Arguments that expressed emotions such as anger or disrespect.	'*It's obviously nonsense*'; '*it doesn't belong to us*'	22
Unwillingness to study	Arguments that expressed unwillingness to study and to listen, and even leaving the classroom.	*'A few students asked not to attend the class when I taught evolution'*	14

In order to answer the second part of the first research questions, the teachers were asked whether students' religious faith could prevent them from properly understanding evolution (Table 8). Fifty percent of the teachers said that they do not think so, and the other half was divided more or less equally into those who think that it could, and those who said that it might. There was no significant difference in the distribution of the answers between the different sectors ($X^2_{(df = 4,\ n = 97)}$ =4 .108, p = 0.392), but teachers in religious schools showed the highest agreement with the opinion that religious faith does not prevent the understanding of evolution (Table 8).

Table 8. Teachers' answers to the question: Can students' religious faith prevent them from understanding evolution? (total sample and according to sectors).

	Total (%) ***n* = 97**	**Secular (%)** ***n* = 47**	**Traditional (%)** ***n* = 23**	**Religious (%)** ***n* = 27**
Yes	21.6	25.5	26.1	11.1
No	51.5	53.2	39.1	59.3
Maybe	26.8	21.3	34.8	29.6

The teachers were asked to explain their answers to the previous question, and 75 teachers (out of 97 who answered the closed-ended question on the questionnaire) did so. Most of these teachers focused on two main ideas in their explanations, which I defined as two main categories (Table 9): the first was teachers' conception of the conflict, where 5 teachers who indicated that there is a conflict between evolution and religion said that religious faith would prevent the understanding of evolution; 26 teachers who indicated that there is no conflict between evolution and religion stated that religious faith would not interfere with students' understanding of evolution; and 9 teachers stated that it depends on whether the teacher knows how to explain that there is no conflict.

The second category of teachers' explanations to the closed-ended question on the questionnaire related to the difference between possible affective and cognitive influences of students' religious faith (Table 9): 9 teachers indicated that religious faith might not interfere with students' understanding of evolution, but could hamper their motivation to listen to and accept the subject, whereas 20 teachers emphasised that religious faith renders students closed-minded and defensive—which may eventually hinder their learning process, such that understanding will not occur. In a few cases, there was a difference between the teacher's answer to the closed-ended question and his/her explanation; in these cases, the classification was based on the explanation. Explanations that did not fit either of these categories (6 teachers) were classified as 'other'. The proportion of teachers focusing on conception of the conflict (40/75) was significantly higher than that of teachers focusing on the difference between the affective and cognitive influences (29/75) ($X^2_{(\mathrm{df}=2,\ n=150)}$ =15 .403, p = 0.0005, Table 9).

Table 9. Teachers' explanations for whether or not students' religious faith prevents them from properly understanding evolution (n = 75).

Category	Sub-category	No. of teachers	Examples
Conception of the conflict	Yes, since there is a conflict *	5	*'A deep understanding of natural phenomena and the nature of science raises conflicts with dogmatic theological views' (T4)*
	No, since there is no conflict **	26	*'There is no true conflict between the bible and evolution'(T12)*
	Maybe/no, depends if the teacher knows how to explain that there is no conflict	9	*'If the teacher knows how to explain that there is no contradiction—there is no reason it will make learning difficult' (T21)*
Affective vs. cognitive influence	Yes/maybe, the students won't learn because they are closed-minded.	20	*'Religious faith may cause students to lock themselves from any other explanation' (T27)*
	No/maybe, it won't affect students' understanding but might affect their motivation	9	*'The students may understand the evolutionary principles, but they won't accept them' (T5)*
Other		6	

*One teacher explained that there is a conflict but the answer to the closed-ended question was maybe.

**Two teachers explained that there is no conflict, but that students' understanding may/will be influenced because of misunderstandings about evolution and religion.

4.1.2. Acceptance of evolution among High school biology majors

In order to evaluate high school students' acceptance of the theory of evolution instrument, and to answer the second research question, 778 high school biology majors from 19 schools in Israel answered the MATE questionnaire (Rutledge & Warden, 1999). Analysis of the results shows that the average value of acceptance of evolution among these students is 77.07, thus pointing to a mid-high level of acceptance according to Routledge and Sadler (2007). The Cronbach's alpha value of the entire questionnaire was 0.88.

Factor analysis formed 6 groups (Table 10). The highest mean scores were obtained for the Age of the Earth group, The processes of evolution, and the Scientific validity of the evolutionary theory (>3.9). The scores given to the Evolution of humans and to the Evidence for evolution groups were only slightly lower (>3.7), while the scores given to the Scientific community's view of evolution group were ~3.5 (Table 10). Students' explanations to the statement "evolution is a scientifically valid theory" (Mean 4.049), and to the statement "there is a significant body of data, which supports evolutionary theory" (Mean 4.041) suggest that these statements deal with scientific issues of validity and knowledge that support it.

With regards to the age of the earth, most students did not agree that "the age of the earth is less than 20,000 years" (Mean 4.212). On the other hand, some students did not support the fact that "the age of the earth is at least 4 billion years" (Mean 3.767). As biology majors, they may had confused between the age of the earth and the origin of life which was mentioned in class to occur around 4.5 billion years ago. Overall, the results did not point on conflicts between students' views of religion and their views of science that may influence their views of evolution in particular and their evolution learning experiences. Furthermore, a significant and positive correlation was found between the value of evolution acceptance and students' grades in their matriculation examinations in mathematics and in biology (Table 10).

Table 10: The outcomes of acceptance of evolution questionnaires (MATE) distributed among secular biology majors in Israel (n=778).

Group	Items	Mean	Std Dev	Math score Correlation	Bio score Correlation
1. The processes of evolution	1, 9, 18, 19	3.914	0.256	<.0001	<.0001
2. Scientific validity of evolutionary theory	2, 10, 12, 13, 14, 20	3.907	0.289	<.0001	<.0001
3. Evolution of humans	3, 15	3.752	0.306	0.006	0.019
4. Evidence for evolution	4, 6, 8, 16	3.795	0.288	<.0001	<.0001
5. Scientific community's view of evolution	5, 17	3.533	0.267	0.0085	<.0001
6. Age of the Earth	7, 11	3.943	0.265	0.050	0.0513

4.1.3. Analysis of matriculation examination evolution questions

In 2016, evolution entered to the obligatory part of the syllabus and of the matriculation exam in Israel as a trial. Since 2017, all biology majors in Israel must answer at least one closed ended question about evolution in part A of the exam (Appendix 3). In order to compare the achievements of religious and non-religious state schools in Israel, and to answer the third research question, the databases of the matriculation exam answers of summer 2017-2018 were analyzed. The achievements of the evolution questions of part A of the exam were compared to the achievements of the rest of the questions in part A (total 20 questions). In order to compare between the two sectors, a Chi square for independence test was conducted.

In Table 11, it can be seen that the total average score of the whole close-ended part is a bit higher in religious schools (76.52) compared to the secular schools (76.98). This difference is not statistically significant (X^2 (1, n =17175) = 0.229, p=0.632). A comparison between the scores of each sector can be found in Table 11. When the total average scores were compared without the evolution questions, the average scores of both sectors are similar – secular schools average is 76.52 while religious schools average is 76.27 (X^2 (1, n =17181) = 0.07, p=0.789). Questions 16 and 18 are aimed to probe students' knowledge of evolution, while question 16 deals with the different mutations that affect evolution of species, and question 18 deals with the process of natural selection. Interestingly, it seems that questions 16 and 18 influence the total score of part A of the exam. When comparing the scores for question 16 between the two sectors, secular schools average score is 77.3 while religious schools score is 86. The differences are statistically significant (X^2 (1, n =17128) = 87.53, p<0.0001). In addition, when comparing the scores for question 18 between the two sectors, secular schools average score is 75.1 while religious schools score is 81.2. The differences are statistically significant (X^2 (1, n =17119) = 32.75, p<0.0001).

When examining the scores of each sector separately, in the religious schools it was found that the scores for both evolution questions 16 (86.01) and 18 (81.2) were significantly higher than their average score for the rest of the questions (X^2 (2, n =6736) = 69.73, p<0.0001). However, in secular schools the scores for both evolution questions 16 (77.3) and 18 (75.7) were almost similar to the average score for the rest of the questions (76.52). (X^2 (2, N=44686) = 10.6, p=0.005). It is important to note that

the differences between the two evolution questions and the total questions for secular schools is relatively small (1.6 points difference), and the statistically significant resulted probably in the numerus sample.

Table 11. Summary of the average scores of part A in the 2017 matriculation exam of each sector and a comparison between sectors.

Average score	Religious	Secular	gap R-S	X^2	*P*
Total 20 questions	77	76.5	0.5	0.229	0.632
Total without questions 16,18	76.2	76.5	-0.3	0.07	0.789
Question 16	86	77.3	8.7	87.53	<0.0001
Question 18	81.2	75.1	6.1	32.75	<0.0001

When the scores from the exam of summer 2018 were examined, the opposite pattern discovered. In this exam there was one question about evolution – question 7, that deals with the causes for mutations – whether are arbitrary or caused by the environment. In Table 12, it can be seen that the secular schools score was higher than religious schools in the total score for 20 questions of part A, the total score without question 7, and question 7 only.

A comparison between the scores of each sector can be found in Table 12. The total average score of the 20 questions is higher in secular schools (76.06) compared to the religious schools (73.11). This difference is statistically significant (X^2 (1, n =17851) = 8.6, p=0.003). The total average scores of secular and religious schools were compared without the evolution question 7. Secular schools average is 76.29 while religious schools average is 73.25, while the difference is statistically significant (X^2 (1, N=17851) = 9.2, p=0.002). Question 7 decreased the average score of the exam for both secular and religious schools. Comparing the scores for question 7 between the two sectors, shows that secular schools average score is 71.86 while religious schools score is 70.48. The differences are not statistically significant (X^2 (1, n =17851) = 1.7, p=0.186).

When examining the scores of each sector separately, in the religious schools it was found that the scores for evolution question 7 (70.48) was significantly lower than their average score for the rest of the questions (X^2 (1,N =4181)=3.946, p=0.047). In secular schools the score for evolution question 7 (71.86) was also significantly lower

than their average score for the rest of the questions (X^2 $_{(1,N=30971)}$ = 78.941, p<0.0001).

Table 12. Summary of the average scores of part A in the 2018 matriculation exam of each sector and a comparison between sectors.

Average score	Religious	Secular	gap R-S	X^2	*P*
Total 20 questions	73.11	76.06	-2.95	8.6	0.003
Total without questions 7	73.25	76.29	-3.04	9.2	0.002
Question 7	70.48	71.86	-1.38	1.7	0.186

When comparing the results between the two years, different patterns can be found. In the exam of summer 2017, religious schools had a higher score than secular schools in the questions about evolution, while in the exam of summer 2018, religious schools had a lower score in the total part of the exam and in the questions about evolution. During summer 2019 the only question about evolution was an open-ended question, which is harder to compare and analyze differences between sectors. Analysis of exams of later years is necessary in order to understand whether there is a pattern and to reach a firm conclusion.

4.2. Is opposition to evolution inevitable among religious students?

4.2.1. Religious teachers and scientists' conceptions of evolution and religion

In order to examine the participants' conception of the relationship between evolution and religion, and to answer the fourth research question, different methods were used.

First, in order to examine the participants' conception of the possible contradiction between religion and evolution, they were asked in their pre-interview questionnaire to rank the degree of contradiction between evolution theory and religious faith on a Likert scale: 1 – no contradiction, 5 – there is a contradiction. Eighteen participants answered that there is no contradiction, and two participants

chose 2 – slight contradiction, because of the philosophical interpretation of the theory.

In addition, we examined the individual participants' MATE scores, which appear in Table 13. The average score of all of the participants was 88.05 (Table 13), which is considered a high level of acceptance of evolution (Rutledge and Sadler 2007). Cronbach's alpha for the total questionnaire was 0.926.

Table 13. Average scores of the MATE questionnaire separated into levels of acceptance according to Rutledge and Sadler (2007).

Acceptance level	**Teachers**	**Scientists**	**Average MATE score**
Moderate (65–76)	2	1	68
High (77–88)	3	2	83.2
Very high (89–100)	5	7	95.08
Total	**10**	**10**	**88.05**

Participants' conceptions of science and religion

To examine the participants' conceptions of the relationship between science and religion, as well as evolution and creation (sixth research question), they were interviewed and filled out the SRSII questionnaire. Below I describe the religious and scientific conceptions of the participants, and then I describe their conception of the relationship between religion and science, as well between evolution and creation.

In their interviews, all of the participants indicated that both religion and science hold great importance in their lives, and most of them emphasized the need to characterize each discipline and its role in their lives, because they are fundamentally different. In addition, they indicated that they do not feel that they must accept one and abandon the other and truly accept both, and that the presented dichotomy is false. For example they said:

> *As a religious person, studying evolution strengthened my religious faith.* (T3)
>
> *I never had a feeling that I must choose only one of the ideas* [evolution or religion]. *What if people don't want to choose only one idea? Why force them to choose? I think this causes unnecessary problems.* (S1)

Religious conception

Nineteen of the participants described themselves as modern Orthodox, and one as ultra-Orthodox, and most of them had a similar religious conception, with a few exceptions. All interviewees except one (T10) emphasized that the purpose of the scriptures is not to describe science or history. The following statement appeared in similar versions in 19 interviews:

The Torah is not a science or history book, but provides moral guidance.

The participants mentioned the different values that they learned from the scriptures, as a deep moral story that teaches them how to live their lives—how to be closer to god, how to create social connections, the responsibility of man toward nature, etc. Eleven participants mentioned Rambam (Maimonides), who lived in the 12th century and is considered one of the most rational figures in Judaism, as a reference to the idea that the creation story, like many other things in the scriptures, cannot and must not be understood literally; those who do take these stories literally are missing the point.

> *The literal understanding is like imagining god building sand palaces. Every other image is so concrete that it makes the creation story wrong. Moreover, it is forbidden, since one of the Jewish principles of faith according to Rambam is that god "has no body and he is free from all of the properties of matter."* (T9)

All of the participants but one (T3) mentioned, during their interview, different rabbinical attitudes on this issue, emphasizing the participants' tendency to rely on religious sources of authority, which is common among religious people.

The controversy between arbitrary nature and divine providence was emphasized by the participants as one of the most fundamental questions in the relationship between science and religion. All participants said that they believe in divine providence, although they cannot understand or explain how it works because this is a philosophical interpretation, and no philosophical interpretation can be proven—not even an arbitrary one; both are legitimate philosophical explanations of nature that cannot be proven or disproven by scientific tools:

> *Things may look arbitrary, and that is OK. However, I can believe it is not arbitrary, because science cannot explain or prove that things are arbitrary since this is not science but philosophy.* (T4)

The participants emphasized the controversy between arbitrary nature and divine providence as a fundamental issue for every religious person, not only in the context of science and religion, but in almost all areas of life. Religious people live in both dimensions—the spiritual and the materialistic—and they are skilled at finding a divine influence in processes that appear to be random:

> *When we go to the doctor and still pray for our health, we don't really understand these two parallel dimensions—the physical and the spiritual. That is a question we all try to answer but we do not necessarily have all the answers. Evolution is just one example of how we cannot understand the connection between the two dimensions.* (S1)

Scientific conception

The interviewees' scientific conception was not explicitly addressed in the interviews. However, all of the participants mentioned some characteristics of science that expressed an understanding of the nature of science as a method that best describes reality in the present. Eleven participants said that science is tentative and is not an absolute truth, but it is important to note that this is not a reason to reject it. For example:

> *A scientific theory is not an absolute truth, but it is the best explanation that scientists can give today for various natural phenomena. It is true that in the future, more discoveries will expand our knowledge and the theory may change, but for now we are studying the height that humanity has reached—and it is a great thing!* (T7)

Eight participants declared that they trust science but are aware of its limitations, and four participants also emphasized the difference between observations and interpretations of scientific findings. Two teachers—T8 and T10—made exceptional statements that suggest that they doubt the scientific method. This seemed to be in line with their MATE score, which was the lowest among all participants (Table 2). These statement were:

> *Science is final for now. I do not say it is not true, but it does not scare me. They can say whatever they wish; tomorrow they will say something else.* (T8)

> *The attempt to find the age of the universe is based on many speculations. We cannot know exactly what happened. So if the scientific truth is based on a*

speculation, why should it contradict my faith? My faith is one of the speculations. (T10)

The relationship between science and religion

As already noted, after the interviews, the participants were asked to answer the SRSII questionnaire. This questionnaire was aimed to help in triangulating the participants' preferred attitude toward the relationship between science and religion with what was said during the interviews. In Table 14 it can be seen that all of the respondents agreed with more than one statement, with an average of three statements with strong agreement/agreement. The statement representing the *complementary* view had the highest agreement level. Namely, 17 respondents strongly agreed with it, 2 respondents agreed, and only 1 disagreed. In addition, *complementary* was chosen by most respondents (13) as best representing their personal view.

The second popular view was *contrast*; 11 respondents strongly agreed and 8 agreed with the statement representing the *different questions* view; 10 respondents strongly agreed and 6 agreed with the statement representing the *different methods* view; 7 participants chose *contrast* as best describing their personal view (Table 14).

Views that represent *incompatibility* between science and religion were ranked as disagree/strongly disagree by most respondents; 17 respondents disagreed with the statement representing the *compartment* view; 16 respondents disagreed with the statements representing *STR* and *RTS* views. However, 4 teachers agreed with these views—2 with the *compartment* view and 2 with the *STR* view. It is important to note that none of the respondents chose these views as best describing their personal view; rather, all of them chose the compatible views (Table 14, bottom row).

Table 14. The number of respondents to each statement of the SRSII questionnaire. according to the various agreement levels (n = 20).

	Incompatibility			**Compatibility**			
	Compartment	STR	RTS	Contrast (different:)		Consonance	
				Questions	Methods	Coalescence	Complementary
Strongly agree	0	1	0	**11**	**10**	2	**17**
Agree	2	1	0	8	6	1	2
Not sure	1	2	4	0	1	6	0
Disagree	**11**	7	6	0	1	7	0
Strongly disagree	6	9	**10**	1	2	4	1
Best describe personal view	**0**	**0**	**0**	**5**	**2**	**0**	**13**

In their interviews, the participants were asked about their preferred attitude toward the relationship between science and religion, as well as between evolution and creation. The three main attitudes that were mentioned in the interviews were *contrast*, *complementary*, and *coalescence*. Each of them is described below.

Contrast. Twelve participants emphasized the idea that each domain, science or religion, deals with different subjects and therefore should be understood according to its own rules. For example, one of them said:

> *Religion and science are not defined by the same principles and values and are measured in a completely different manner. My faith should not fit the criteria that my science should fit. What is my faith worth if a new discovery of a snake with legs disputes it?* (S5)

Coalescence. Four participants emphasized the idea that there is a complete fit between scientific findings and biblical stories. Three teachers (T2, T8, T10) and one scientist (S2) declared this view explicitly in their interviews, although they made some statements that indicated a mixture of approaches. For example:

> *I prefer the coalescence approach, but I think that to understand coalescence you should understand that each (science and religion) talks about different issues. I agree with the idea that man was created mature, with the rest of the world mature—not seeds and sprouts. There are developments all the time, and the world may have been created in that way. I don't know, it is one possibility…* (T8)

Complementary. Four participants emphasized that science and religion cannot be in conflict because they exist in different dimensions. One cannot replace the other; each has its role in life, and they complement each other to create a whole world view. For example, one of them said:

> *There are two levels of reality. There may be a god that supervises nature, but he acts through natural mechanisms and rules, and there is no contradiction between the two.* (T7)

When the participants' approach to the science–religion relationship as declared in the interviews was compared to their approach as declared in the SRSII questionnaire, inconsistencies were found (Table 15). Seven participants declared one approach in the interview, whereas they declared a different one in the questionnaire (marked with an asterisk in Table 15). It is important to note that those people strongly agreed on the questionnaire with both approaches—contrast and complementary—but when asked to choose one of them, they may have felt "pushed into a corner."

Table 15. A summary of the combinations of approaches that the participants indicated as best describing their personal view, according to the questionnaire and interview, and the number of participants who showed each combination.

According to SRSII questionnaire		**According to the interview**	
Approach	#Participants	Approach	#Participants
Contrast	7	Contrast	6
		Coalescence	1*
Complementary	13	Contrast	6*
		Complementary	5
		Coalescence	2**

*Interviewees declared one approach in the interview and a different approach in the questionnaire.

**These two teachers talked in the interview about the coalescence view, but also had motifs of the complementary view, and their answers were therefore not considered to be inconsistent.

4.2.2. Factors that influence the participants' acceptance of evolution

In order to answer the fifth research question, and to examine what were the factors that influence the participants' conception, the participants were asked what factors they feel influenced their acceptance of evolution. All participants (except T3) emphasized that their conception of evolution was influenced by the positive/negative approach to science of their family or teachers.

Family. Ten of the interviewees emphasized their parents' role in shaping their own conception of evolution. They said that they received from their parents and from home, an attitude of openness to learning and accepting science and religion. Some mentioned going to nature museums that had dinosaurs with their family, and the feeling they got from their parents that it does not contradict any of the religious values that they had grown up with. For example, one of them said:

> *I grew up in an educated home, in which these things were never an issue...I remember going to a museum with dinosaurs—wow! Bones of dinosaurs that lived 80 million years ago. Cool! We did not even think that something is odd.* (S10)

Even though most of the participants in this group grew up in an educated home with scientific tendencies, three of the interviewees (T3, T6, and S4) mentioned growing up in families with a neutral/negative view of science. Some of them mentioned that their family members explicitly objected to evolution. For example:

> *I grew up in a traditional, non-religious family. Once, I told my family that I was studying evolution and then my brother said: "Evolution?! That is a lie!" He was very upset with me. He is not religious, but there is something in the traditional conception that treats 'evolution' as a curse word.* (S4)

Despite the approaches of their families and their society, these three participants never rejected evolution. The three mentioned that they were very interested in science in their childhood, so this could have influenced them, as described by T3:

> *I always perceived science as a reliable discipline, and I always loved biology. So if I love biology and I love Judaism, they must be compatible. If a scientist said this is true—so it is true, and we just need to find the explanation.* (T3)

Teachers. Thirteen of the interviewees emphasized the role of their school and teachers in shaping their conception of evolution, and of science in general. Nine of them mentioned that their teachers had taught them to be open to new ideas, and that they could be religious and also be highly educated without fearing foreign ideas. For example, one of them said:

> *I had great teachers in high school who taught us to be open-minded. We were not limited by them, everything could be questioned.* (T4)

On the other hand, four participants mentioned that their teachers emphasized the conflict between evolution and religion. They will be discussed further on.

Additional factors that might have influenced the participants' acceptance of evolution were examined by comparing the average MATE scores of different subgroups of interviewees (Table 16). In each subgroup, the significance of the correlation between each criterion and the MATE score was calculated using the Wilcoxon two-sample test.

For three categories—role, education, and view of the relationship between science and religion, the difference between the total MATE scores of the two subgroups was not significant. The subgroup of participants who had always accepted evolution had a significantly higher MATE score than the subgroup of participants who had rejected evolution in the past. The subgroup of participants who received formal evolution education (such as through academia or high school) had a significantly higher MATE score than the subgroup of participants who learned evolution by informal means (such as books, museums, media).

Table 16. A comparison of the average mean MATE scores between different subgroups of participants according to different categories of comparison (role, education, SRSII results) and its significance.

Category (tool)	**Subgroup**	**Number**	**MATE mean score**	**STDV**	**Wilcoxon value (w)**	***p***
Role (pre-questionnaire)	Teachers	10	85.1	11.96	119.5	0.1504
	Scientists	10	91	8.94		
Education (pre-questionnaire)	Undergraduate, MSc	9	87	13.44	97.5	0.4253
	PhD – Professor	11	88.9	8.46		
View of the relationship between science and religion (SRSII)	Contrast	7	89.14	11.56	82	0.5317
	Complementary	13	87.46	10.66		
Past rejection of evolution (interviews)	Always accepted	14	90.72	10.36	37.5	0.0261
	Past rejection	6	81.83	9.54		
Source of knowledge in evolution (interviews)	Formal	17	91.23	7.42	7.5	0.0109
	Informal	3	70	8.66		

To learn about the factors that shaped their conception of science and religion and their acceptance of evolution, the participants were also asked in the interview about their past attitude toward evolution. According to their answers, two main groups were identified: those who have always accepted evolution (n = 14), and those who had rejected evolution in the past (n = 6, Table 16).

From rejection to acceptance

According to the interviews, 14 of the participants indicated that they had never felt any conflict between evolution and religion. Their religious view never made them feel uncomfortable with the idea that humans and other organisms evolve through time, mainly because they never thought that the scriptures should be understood literally. Six of the interviewees indicated that there was a time when they

objected to evolution, some during high school, and some even after graduating with scientific degrees. For example:

> *Even after I finished my MSc, I had never studied evolution properly, and I was more of a creationist. The idea that the world is millions of years old was quite hard for me. I remember looking at a dinosaur skeleton and I was skeptical about it. I thought most of it is reconstructed, most of it is not real. So, we can't predict the dinosaur's size with any certainty based on a few bones.* (T5)

When asked why they rejected evolution, they mentioned the following reasons.

a. Lack of knowledge. This was mentioned by 3 interviewees as the main reason that the general public rejects evolution. It was also repeated among the interviewees who had rejected evolution in the past, in their words, because they just didn't know what evolution was:

> *When you are opposed to something that you don't really know—you don't understand what you are opposed to. It doesn't come from knowing or thinking—it comes from a primitive lack of knowledge.* (S6)
>
> *I found an exam from when I was in high school, and there was a question on evolution, and beside the answer I wrote: "This is my answer, but I don't believe in it." It was because no one taught us evolution properly, we had to read the book by ourselves.* (T2)

b. Authority that emphasized the conflict. Four participants mentioned teachers in school or at university who emphasized the conflict during class, by delegitimizing religion or evolution:

> *The lecturer in the evolution course said that the bible is a fairy tale and we were very angry. I don't know why I was so anti-evolution, maybe because the lecturer was anti-religious so it felt that everything related to evolution is necessarily anti-religious.* (S6)
>
> *I had an ultra-Orthodox science teacher in high school so I'm sure it influenced* [my perception of evolution]. *I think it may have limited us.* (T5)

c. Social objection. Three participants mentioned the influence of the general society in which they grew up. They mentioned absorbing the idea that evolution rejects religion from different sources, such as youth organizations, friends, media,

etc., but they could not pinpoint a specific origin of that perception. For example, one of them said:

> *It is like something that you can't touch. You see a church, but you don't get to go in. It's not mine. It's not for me.* (S6)

Despite their past rejection of evolution, eventually, these participants accepted it. They indicated that exposure to scientific knowledge alone was not enough to eliminate their objection, because all of them had basic evolutionary knowledge; rather, it was exposure to various religious authorities that offered explanations for the compatibility of religion and evolution—books, lectures, courses, etc., which promoted their acceptance of evolution. Since the participants' rejection of evolution had led to the conception that evolution and religion must be in conflict, being exposed to various explanations of the compatibility between them had an important influence on promoting their acceptance. Specifically:

> *The first time that I heard that the timetable of the Book of Genesis is not day after day, and that the concept of time there is different than the one we know today, it helped me realize that I don't need to be afraid and that science and religion can be compatible.* (T5)
>
> *When I was exposed to religious books that expounded the idea that the genesis stories are allegories, and that the first commentators also thought so, I said to myself—OK. It* [evolution and religion] *is compatible. It solved the problem for me and from then I felt free, it was as if the fog had lifted and the world had opened up.* (S3)

It is important to note that all participants (except T3), those who had rejected evolution in the past and those who had not, mentioned one or several religious authorities upon which they rely—rabbis or commentators—who helped them shape their world view. Thus, the idea alone was not enough, and the religious authority that represented the idea was very meaningful:

> *I am willing to adopt the approach of the Jewish philosophers who explored the issue deeply enough and concluded that there is no contradiction between religion and science. I don't rely only on myself; they are authorities for me and I can rely on their opinion.* (T5)

4.3. Examining solutions

4.3.1. Teachers and scientists' attitudes toward relating to religion in a science class

In order to answer the sixth research question, different sources of data were used: first, 97 teachers from different sectors were asked in the teachers' questionnaire described above, were asked whether teachers should relate to students' religious faith in a science class. Second, 124 scientists were asked the same question in the scientists' survey described above. In addition to the population of scientists and teachers from different sectors, 20 religious scientists and teachers were interviewed regarding the same question and their attitudes will be presented below.

(1) Teachers' attitudes

The teachers were asked whether teachers should relate to students' religious faith in science class in a closed-ended question on the questionnaire (Table 17). Eighty-two percent of the teachers answered 'Yes, teachers should relate to students' religious faith if it will promote students' understanding'; 13% of the teachers answered 'No, teachers should not relate to students' religious faith, in science class we learn only science', and 5% answered that it depends. The wide agreement between the teachers about the need to relate to students' religious faith was found to be statistically significant ($X^2_{(df = 2,\ n = 1\ 92)} = 48.694$, $p < 0.0001$). Wide agreement was also found across sectors with no significant difference between the answers' distribution ($X^2_{(\ df = 4,\ n = 96)} = 8.339$, $p < 0.079$). Nevertheless, it is important to note that the percentage of teachers who were not willing to relate to the issue was higher among secular schools (Table 17).

Table 17. Should teachers relate to students' religious faith in the science class? (Total sample and according to sectors).

	Total (%) ***n* = 96**	**Secular (%)** ***n* = 46**	**Traditional (%)** ***n* = 23**	**Religious (%)** ***n* = 27**
Yes, if it will promote students' understanding	82	72	91	93
No, in science class we learn only science	13	17	9	7
Depends	5	11	0	0

The teachers were asked to explain their answers to the previous question of whether they think teachers should relate to students' religious faith, and 58 teachers (out of 96 who answered the closed-ended question on the questionnaire) responded. Most of these teachers justified their positive answers by relating to the following ideas: (1) The importance of connecting to the students' inner world with cultural sensitivity and respect (emphasised by 22 teachers), for example: "*We live in a society in which religion and tradition are significant to its culture. You can't disconnect the science we learn in class from the students' culture. If we do that, it may alienate the student"* (T34); (2) Decreasing students' opposition by alleviating their conflict is important to enabling learning and understanding (emphasised by 14 teachers), for example: "*Only if the student does not feel that he has to fight and defend his conceptions will I know that meaningful learning is possible"* (T63); 8 teachers emphasised the importance of relating to different disciplines, for example: *"I think that religious faith is a construct of emotion while science is a construct of the brain; their combination may give a wider worldview"* (T19); 6 teachers argued that it is important to relate to the issue but did not justify their answer.

Among the teachers who claimed that teachers should not relate to students' religious faith, 5 explained their answers mainly by emphasising that religion and science are separate entities that should not be mixed. For example: *"When the student decides to solve his conflicts, he can do it by himself. I don't involve god in biological processes – it does not belong to the place or time"* (T4); 2 teachers asserted that such a discussion might help decrease the students' conflict, but that they did not feel that they have the qualifications to do this properly: *"Biology teachers are not trained to deal with this issue, so they may not feel comfortable enough and the students may feel threatened, which may cause them to hold steadfastly to their position"* (T51). One teacher said "This issue is too complex for students to understand" (T75).

Some of the teachers declared in their explanations to the closed-ended question on the questionnaire that according to their worldview, there is no connection between science and religion, but that they are willing to discuss religious faith in class, because they understand their students' needs, as the following teacher (secular teacher teaching in a traditional school) summarised: "*Personally, I think that*

in science class we should learn only science – but if a student says that there is no such thing as evolution because god created the world, and I tell him 'now you will listen to me because we are in a science class', I will never be able to teach him evolution" (T5). Relating to the lack of qualification for connecting science and religion mentioned by the teachers, T5 also stated that: *'If part of my qualification included issues that would enable me to help my students learn better, such as the opinions of Jewish philosophers and rabbis on evolution, I would learn it'* (T5).

(2) Scientists' attitudes

In order to examine scientists' attitudes toward relating to religion in a science class (as part of answering the sixth research question), 124 scientists answered the survey question – "Should teachers relate to religion in a science class?". As can be seen in Table 18, 92% of the scientists answered "No, in science class we learn only science", while only 7% of the scientists answered "Yes, if it will promote students' understanding". One representative response of a scientist is as follows: "*Even if the audience is religious or traditional, we must not combine science with anything which is not scientific. Scientific interpretation is fine, scientific disagreement based on evidence –OK. But to try to combine faith/tradition/myths etc. into science? Defiantly not. Anyone who wants will make his own accommodations at home."*

When comparing the attitudes of the teachers to the attitudes of the scientists, an opposite pattern can be seen (Table 18). While most of the teachers (82%) agreed to relate to religion in science class if it will promote students' understanding, most of the scientists (92%) rejected the idea. The difference between the populations was statistically significant ($X^2_{(\text{degrees of freedom} = 2,\ n = 221)} = 143.96$, $p < 0.0001$).

Table 18. Distribution of teachers' and scientists' responses to the question whether teachers should relate to religion in a science class (n (teachers)=97, n (scientists)=124).

	Teachers (%)	**Scientists (%)**
Yes, if it will promote students' understanding	82	7
No, in science class we learn only science	13	92
It depends	5	1

(3) Religious teachers and scientists' attitudes

Religious scientists (S 1-10) and teachers (T 1-10) were interviewed and asked whether teachers should relate to religion when teaching evolution, and why. The participants' responses are presented in Table 19, in an ascending order according to the willingness to relate to the issue. S8 was the only participant that rejected the idea of relating to religion, as religion and science should remain separate entities. When S8 was asked what if the issue comes up in class, he answered: *"than there better be a response"*. It is important to note that S8 was surprised to hear that opposition to evolution exists: "*This is very weird. I know opposition is common in the USA, but in Israel? I had thousands of students, many of them religious, and this issue never came up, maybe they are shy? But they do ask questions… I don't know. It is unpleasant to say that there may be a segregation between populations, and those who arrive to the university are at a different place"*.

Three scientists (S1, S2, S4) said the issue can be related to in class, with hesitations based on the challenge for the teachers, the importance of emphasizing the differences between science and religion, and the reliance on students' interest. S5, S6, S7, S9 said that it is important to relate to religion, but as a pre-lesson to learning evolution. One doubted the ability of the students to understand the complexity, and 2 scientists emphasized that the issue should be related to by a guest or someone qualified, not the biology teacher. All the teachers, together with two scientists (S3, S10) answered yes without hesitations, and were very decisive in their answers that it is very important that the teacher relate to religion.

Table 19. The participants' responses to the question: Should teachers relate to religion when teaching evolution? (n=20)

Response	**Why?**	**Said by**
Basically no	*"If I oversaw the curriculum, I wouldn't want science and religion to appear together since they are two separate things, and when you talk about religion in a science class you interrupt the ability to understand that they are unrelated."*	S8
Yes but…	*"On the one hand, I don't think the issue should be ignored. But on the other hand, how a teacher is supposed to deal with such a sensitive issue?"*	S1
	"I don't think its problematic if the differences between religion and science are emphasized"	S2
	"If the students will be interested - I will relate to the issue"	S4
Important but…	*"In order to decrease antagonism, I think there should be a pre-lesson –science, philosophy, Jewish thought, you name it"*	S6
	"In order to investigate the relationship between science to religion you need to be mature enough. So, I'm not sure how much students will understand, but it is important they will know that there is not a war between science and religion"	S7
	"I don't think that biology teachers should relate to this issue, since they represent science. And this separation must be preserved"(S5)	S5, S9
Absolutely yes	*"I think you must relate to this issue, otherwise you don't fulfill your mission and you won't be able to teach evolution. I generally agree with teachers that reject the idea of relating to such ideas in a science class, but you can't ignore it when discussing evolution and issues with ethical dilemmas. I think it is important also for general education of secular students, since they will be exposed to the idea of the conflict somewhere in the future, so they should know there are solutions to this question." (T4)*	S3, S10, T1-T10

The participants explained their willingness to relate to religion mainly because of three main reasons (Table 20). Some of the participants related to more than one reason in their answers. The first is the importance of connecting to the students' inner world, which was mentioned by 11 participants. The participants emphasized that by relating to the students' thoughts, feelings and cultural baggage, learning in class can be more meaningful for the students. Eight participants said teachers should relate to religion in order to prepare the students for the future. They emphasized that since the students will probably encounter this conflict somewhere in the future, it will help them if they understand that this conflict has some suggested solutions. Two scientists (S2, S7) mentioned people who used to be religious, that after leaning evolution their religious perception was undermined, as no one taught them that there are religious solutions to this conflict. Five participants explained that the issue should be related to in order to decrease students' opposition. Note the fact that this reason

was mentioned only by teachers, which may indicate that scientists are less aware of the opposition in class.

Table 20. The participants' responses to the question: Why should teachers relate to religion when teaching evolution?

Category	**Example**	**Participants**
Connecting to student life\inner world	*"I want the students to understand that science is not external to their lives but an important thing in their lives, and in order to do that I must connect it to their life"* (T3) *"In the learning materials it says that a certain organism is 5 million years old, while the students' world view is 5000 years old. We must relate these unsuitability's, that why I always relate this issue"* (T8)	T2, T3, T5, T7, T8, T9, T10 S1, S4, S9, S10
Preparing the student for the future	*"I want the students to leave the lesson with a confidence, so that if they will be asked about the issue in the external world, they will be able to cope with it because they learned it".* (T9) *"I know people that left religion because they discovered evolution in a later stage in life and said that's it, we don't believe in god. They dismantle their family, left their home".* (S7)	T3, T4, T5, T7, T8, T9 S2, S7
Decreasing students' opposition	*"I think that we should relate to religion, since there is no chance I will teach say "evolution" in class, and there will be absolute consensus without any opposition from the students"* (T1)	T1, T2, T4, T6, T7

Although most of the participants agreed that religion should be related in a science class, some of them raised possible challenges of doing so. Three participants emphasized the influence of the teachers' own identity as perceived by the students, while T3 and T9 lean on their experience as religious teachers, and S5 describes a possible situation in which the secular worldview of the teacher may be an obstacle.

"The ability of the students to bridge the gap is much easier when the person standing in front of them has a similar way of life as them" (T9)

"When the students see that I, as a religious person, teaches evolution, it is first surprising for them, but it is also decreasing their opposition." (T3)

"If the teachers themselves do not perceive religion as important, the explanation may ridicule religious faith, or won't be precise enough, or won't reach to the students' soul – it may push away the students" (S5)

The concern raised by S5 is supported also by a description of T8, that described a professional development course she attended, in which the issue of discussing the compatibility between science and religion in a science class arose. Secular teachers objected and said: *"There is evolution, and there is creationism. They are completely*

different, and you can see the world only in one of the ways. There can't be a scientist who is religious". If the perception of conflict is the only one the teachers know, they can't be blamed for not mentioning other approaches.

Five participants (S8, S9, S10, T4, T7) emphasized that relating to religion in class according to the Coalescence approach (that claims there is an overlap between the scientific findings of evolution and the creation story, following Yasri et al. 2013) may hold an educational challenge. Their arguments relied on the idea that each discipline is substantially different and there cannot be a complete fit between them, and that this approach always relies on the present science, while science is tentative.

"I don't search in the scriptures anything that we might have discovered in science. If someone finds and tries to do this mix – it is first an intellectual lie, since this is not science and not religion. And second – an educational danger for our children. You say that the world has existed for so and so years, there were dinosaurs, etc. but eventually if the scientific conclusions would change – than what? you are in trouble if you built your religious view on foundations from a different discipline." (S9)

"My research focused on RALBAG (Jewish philosopher, 14th century), who matched one by one the Torah to the Aristotle science (laughs). So, he did this in the 14th century, and now there are people who do the same with modern science… You can say that the Torah has many faces, and each generation can discover in it the science of that time, you sure can. But you may also say: what in the torah have different message to us, and rather than how things actually happened?" (T7)

Four scientists (S1, S3, S5, S9) and one teacher (T9) suggested that teachers should be qualified to deal with this issue. Perhaps if teachers will be familiar with the different approaches to the conflict, they may help their students ease their opposition. S9 raised a difficulty of teachers' qualification: *"How will you prepare a science teacher to relate to this issue? I think that it may lead to indoctrination".* Another difficulty that was raised by S9 was that the solutions teachers may bring to the class will be too technical, while the real problem is essential: *"I think we should delve into the essential question, which is if we, as religious people, want to explore, use our brains and deal with issues which are not per-se religious? Or not? Because in my perception, everything is part of god's world – so dealing with science is part of man's duty in the world".*

4.3.2 What practices should be used when relating to religion in science class?

In order to answer the seventh research question, religious teachers and scientists were asked what practices should be used when relating to religion in a science class, and T7 said that: "*This is a different kind of lesson that should be conducted differently. Not even a Jicxo* [a method for cooperative learning]. *It requires a discussion, uncomfortable questions, and the teacher may not have answers. That is a much challenging position for a science teacher."* The rest of the participants were also aware to the complexity, as T7 presented it, and suggested nine teaching practices (Table 21). As previously, most teachers related to more than one category.

The first practice that was suggested by 6 teachers and 1 scientist, is the idea that the teachers can present the issue, but must not try to convince the students since they have their free choice and the teacher cannot force his/her worldview. As S9 also warned from indoctrination, this essential suggestion should be in the background of all the others. The second practice was suggested by 4 teachers and 1 scientist, emphasizing the importance of adaptation of the lesson and the materials to the students' culture, remembering that when the teacher wants to make something accessible for the students, they must think about the other side. The third practice was suggested by 5 scientists and 1 teacher, is defining the borders between religion and science during the discussion in class. Note that the first and second practices were suggested mostly by teachers, and focus mainly on the students, while the third was suggested mostly by scientists, focuses on the attempt to maintain science as a separate entity than religion.

The fourth practice was suggested by 5 teachers and 3 scientists, is collaboration with an expert – another teacher in school or a guest. It is important to note that the teachers that suggested this solution emphasized they also discuss the issue in class, and the additional lessons function for deepening and expanding on the issue. The scientists that suggested this solution emphasized that the guest should lead such a lesson, as in most cases the teachers themselves are not qualified to do it themselves.

The fifth practice that was suggested by 4 teachers and 2 scientists, is referring to the creation story. It is important to clarify that the creation story is emphasized as a religious source, and not as a scientific explanation, so this is not meant to relate to

creationism or to intelligent design. Those who suggested this practice said that the source of religious based opposition to evolution is the simplistic understanding of the creation story, that according to many canonic Jewish commentators and rabbis– this is a misunderstanding of the message of the creation story. Three participants (T3, T5, S5) suggested to mention this idea briefly, while 3 others (T2, T8, S10) said that only if they teach it in a religious school, they will read with their students the religious sources, from a new perspective. T8 emphasized that when she taught in a secular school, she felt it is not propre to discuss it *"I didn't want anybody to say I tried to convince the students to be religious"*. S10 suggested to learn deep into religious sources that go against simplistic reading of the story and try to find other messages in the creation story, rather than a historical description. T2 and T8 also refer to the creation story, but their purpose is different. They are trying to present to the students that there is an overlap between the scientific findings of evolution to the creation story (the Coalescence approach, Yasri et al., 2013).

The last 4 practices were suggested before as part of the ReCCEE practices by Barnes and Brownell (2017) and came up inductively here. The sixth practice emphasizes the need to present the multitude of approaches to the relationship between evolution and religion, especially the compatibility approaches that some rabbis represent (e.g., Rabbi Kook, Rabbi Sacks, etc.). This practice was suggested by 8 teachers and 2 scientists. The participants emphasized that they want their students to understand that in such complex issues, there is not one right answer. T7 described the experience of her students: "*After a lesson in which various approaches to the conflict were presented, the students said they were impressed by the presentation of alternatives rather than one absolute truth, as they usually being taught (according to them)."*

The seventh practice that was suggested by 4 teachers and 3 scientists, is emphasizing religious figures that accept evolution. Note that it is different from the first practice that suggested to present various religious approaches: here the idea is only to mention that there are certain figures (rabbis, religious scientists, etc.) that accept evolution. S7 for example, mentioned that once the lecturer in an evolution course mentioned that Darwin was a religious person - *"the lecturer said that we discuss here two dimensions that won't necessarily meet, and from that moment it solved many problems for me. I put this issue aside and study evolution."*

The eight practice was suggested by 3 teachers, is discussing the students' personal views, that emphasized the importance in understanding the students' difficulties by allowing them to present them in class, which may enable the teacher to address their specific difficulties better. The ninth practice that was suggested by two teachers, is relating to the NOS.

Table 21. The participants' suggested practices that should be used when relating to religion in science class.

Practices	**Example**	**Participants**
1. Presenting the issue but not trying to convince the students	*"I present a few attitudes toward the conflict, but I don't have unambiguous answers. The students are mature enough to consider and think about what I taught them, choose what they agree with – and decide for themselves".* (T7)	T4, T5, T6, T7, T9, T10 S10
2. Adapting to the students' culture	*"We should approach the students from where they are at. The fact that you have a certain knowledge, which you perceive as truth, doesn't mean someone else can access it without opposition. In order to make it accessible, we have to structure this knowledge with cultural sensitivity"* (T2)	T2, T5, T9, T10 S6,
3. Defining the borders between science and religion	*"The teacher should emphasize the difference between science and religion and not to mix between the two"* (S2)	S2, S5, S6, S8, S9 T3
4. Collaborating with an expert– teacher in school or a guest	*"The bible teacher and I conducted a few parallel lessons about evolution, in which the bible teacher gave the religious approach, and I gave the scientific approach."* (T4) *"Most of the biology teachers have no clue about this philosophic issue, so I think that the most qualified person in school – whether it is the Jewish philosophy teachers or the biology teachers –is the one who should deal with it."* (S9)	T2, T4, T5, T7, T8 S1, S5, S8, S9
5. Referring to the creation story*	*"I tell the students that according to my perception, the bible is not a book of science. Is the purpose of the bible to describe scientifically how the world was creating? No! The purpose is to teach us ethics, moral, etc.… Therefore, there is no contradiction since science and religion are separate dimensions."* (T3)	T2, T3, T5, T8 S5, S10
6. Presenting various religious approaches to the conflict, especially compatibility	*"When I was first exposed to the different approaches that discuss this issue, it made me feel very good. Suddenly I understood that many figures discuss this issue for hundreds of years, I'm not the first and probably not the last. There are answers".* (S6) *"If we give the students a printed page with different rabbinical reference that discussed the issue –they have what to lean on. Not "the teachers said that…what should I believe is that?", but rather "rabbi Kook said". It gives them much more confidence."* (T5)	T1, T2, T4, T5, T6, T7, T9, T10 S1, S6
7. Mentioning religious figures that accept evolution	*"Religious person's soul leans on tradition… The fact that I show the students that there is a Jew with a big beard that doesn't think evolution is heresy – it eases the students' opposition"* (T6)	T5, T6, T7, T9 S1, S7, S8
8. Discussing the students' personal views	*"After studying evolution, I ask the students what difficulties they have with what we learned, and we list all their questions, wonders and conflicts. Afterwards, I present them the various ways of answering them"*	T2, T7, T8

	(T7)	
9. Relating to the nature of science	*"Before I teach evolution, I first try to describe the background of the findings that lead to the discovery of evolution…I go deeply into how and what was explored, what we know and what we don't, I explain what a scientific theory is – many important principles that prepare the student to the understanding of the theory of evolution"(T2)*	T2, T7

*The participants emphasized they refer to the creation story as a religious explanation and not as a scientific one – it's not creationism or intelligent design.

Nine participants (mainly teachers) related to the proper time in the sequence of the teaching to relate to the religious issue (Table 22). T6 said he relates to religion "Once opposition appears in class", and S10 said, *"I think that both religion and evolution should be related to, but I don't know which one should come first".* Four participants said the issue should be related to before learning evolution, in order to decrease students' antagonism and to calm their opposition that according to some teachers, appears whenever the word evolution is said in class. That's probably why two teachers (T2 and T7) said they prefer to teach natural selection without mentioning the word evolution, and after the students have a basic knowledge – then they start discussing evolution. Three teachers said they relate to religion only after learning evolution, since knowing evolution is the basis for the subsequent discussions. T7 said that before starting to teach evolution she tries to ease the students' discomfort by mentioning that there are religious figures that accept evolution, which will be taught later on, after learning evolution.

Table 22. The participants' suggestions regarding the proper timing in the sequence of teaching for religion to be related.

Suggestion	**Explanation**	**Participants**
Before learning evolution	*"In order to decrease antagonism, before starting to teach evolution, I would say this: let's put the things on the table (relate to the things as they are?): this is the Torah. This is science. There are certain approaches that reject evolution, that claim this and that, and approaches that accept it, that claim this and that. When understanding the complexity of the issue we can study evolution"* (S6)	T1, T8, T9 S6
After learning evolution	*"In order to discuss whether evolution and religion can complement, we first have to understand what evolution is. Knowledge is the basis for everything. (T3)*	T2, T3, T4 T10

Before shortly, after in details	*I tell the students we are about to learn evolution, and to ease the discomfort I tell them that there are rabbis that discussed the issue and there are various approaches to deal with the conflict and we will talk about everything after we learn evolution."* (T7)	T7

4.4. Implementation programs

Based on the findings of the previous part of the study, two implementation programs were developed: the first is a 4-hours program relating to religious tensions when teaching evolution, that was given as part of a PD course for teachers about evolution. The second one was an introductory lesson to evolution that was aimed to answer students' religious based opposition to evolution.

4.4.1. PD course

The findings of this research reflect the teacher responses that emerged from the submitted artifacts—written responses to the different tasks given during the evolution teacher PD course and to the summary task, which enables answering the eighth research question. The responses to the tasks at the beginning of the course demonstrated opposition to learning evolution and the ways in which teachers dealt with it before the PD course. The teachers' responses to the sixth task and the summary task demonstrated the way in which teachers dealt with religious based opposition to evolution after the course.

To understand the opposition to learning evolution that teachers encounter in their classes, and to answer the first part of the eighth research question, the teachers were asked: What opposition to learning evolution do you encounter in your classes? (Select the three most prominent from a list of 10 arguments (Tsanza, 2014)) (Appendix 8 meeting 2). The arguments and the number of times they were chosen by teachers appears in Table 23. Not all teachers selected three arguments and that is why there are less arguments than there should have been.

The arguments were separated into three categories: "Opposition stemming from religious beliefs" in which the most prominent arguments selected by the teachers dealt with learning evolution and not about the creation of the world (Table 23, A1), and the fact that learning evolution is insulting (Table 23, A2). It should be mentioned that *all* of the teachers selected at least one argument that fits the category

of "Opposition stemming from religious beliefs", meaning that it is a very prominent issue in all classes. Fewer teachers selected arguments classified as "Opposition based on lack of understanding of NOS", where the most frequently selected argument dealt with not being sure about evolution as correct since it cannot be seen (Table 23, B1). As already noted, the third category "Opposition stemming from a social basis" was selected by only 1 teacher, which may mean that this category bothers only a small proportion of high-school students.

Table 23. List of arguments opposing evolution given to the teachers and number of teachers who selected each as an argument that they have heard in their classes.

Categories of student opposition	**Arguments for opposition**	**No. teachers**
A. Opposition stemming from religious beliefs	1. Why do we learn evolution but not the religious version of the creation of the world?	8
	2. I do not believe in evolution and learning it insults me personally.	7
	3. It is impossible to accept evolution and be a believer at the same time.	6
	4. The complexity of life requires a planner.	2
	5. Isn't evolution a religion in itself?	1
B. Opposition based on lack of understanding of NOS	1. How can we be sure that evolution is correct if it is not possible to see it in action?	6
	2. Evolution is just a theory, and a lot of scientists do not believe in it at all.	3
	3. Evolution cannot be right, since it contradicts the second law of thermodynamics.	0
C. Opposition stemming from a social basis	1. Belief that evolution caused the Holocaust.	1
	2. Darwin himself did not believe in the theory of evolution.	0

To answer the second part of the eight research question, i.e., how the teachers deal with opposition stemming from religious beliefs, we asked the teachers: How do you as a teacher deal with the students' opposition to learning evolution? (Appendix 9 meeting 2). The ways in which the participating teachers dealt with their students' opposition, before the session dealing with science and religion, are summarized in Table 24. In Table 23, the teachers mentioned two main categories of opposition to learning evolution: "Opposition stemming from religious beliefs" and "Opposition based on lack of understanding of NOS". When teachers faced the former type of opposition, they responded to their students by relating to "Religious beliefs",

"Scientific evidence" or "Explanation of NOS". When dealing with opposition to evolution that is based on a lack of understanding of NOS, teachers had two types of responses: "Scientific evidence" or "Explanation of NOS". Each of the categories of teacher responses was divided into a few subcategories, and examples of each are given in Table 24. The letter and number of the teachers who mentioned each of the subcategories can be found in the right-hand column of the table, showing the frequency of each subcategory, as well as the sector of the teachers who mentioned it.

An important finding of this paper was that even though most of the opposition presented in Table 23 was based on religious grounds, in many cases, the teachers dealt with the opposition by relating to "Scientific evidence" or "Explanation of NOS", and not necessarily religious beliefs. A religious response to religious based opposition may be expected, but that was usually not the case.

For example, when a teacher faced religious based opposition regarding learning of evolution but not about the creation of the world (Table 23, A1), he did not use a religious explanation but rather, an explanation presenting scientific evidence from past evolution (Table 24, A2a): *"I devoted the first lessons on the subject to persuasion and listed a number of convincing arguments from a number of scientific fields: comparative anatomy, paleontology and more"* (S1).

Another example of opposition stemming from religious beliefs was when a student raised the argument that the complexity of life requires a planner (Table 23, A4). In this case, the teacher answered with a NOS description explaining the scientific method (Table 24, A3a):

"Students think that evolution opposes religion. They do not understand that evolution theory is not a religion but a scientific theory that explains reality. The theory is based on the scientific method in which experiments and observations must be deeply performed in order to arrive at scientific evidence." (S3)

This example and many more show us that teachers respond to much of their students' opposition to learning evolution with evidence from the field with which they are acquainted: scientific evidence or explanation of NOS. Many times, the response is a scientific one and not a religious one, even though the opposition is based on religious grounds.

The following case is an example of a teacher relating to the religious beliefs of students who present religious based opposition —that it is impossible to be

religious and accept evolution (Table 23, A3). The teacher deals with this opposition by relating to the religious beliefs of his students (Table 24, A1c): "*I give examples of religious philosophers who accept evolution and most of the time, this gives a strong reference to the claim that there is no contradiction between religion and evolution"* (S6).

Another teacher deals with religious based opposition, without specifying the students' arguments, by relating to those beliefs and showing that they are not contradictory (Table 24, A1a): *"I explain that religion is faith and science is a theory and the two do not contradict each other, as it is not written in the Bible that Moses descended from Mount Sinai or that 1 + 1 = 2; thus the Bible lacks much content and humans have completed the puzzle thanks to their wisdom, curiosity and the understanding that God has given them*." (R1)

These last two examples show religious reference by the teachers to religious based opposition to evolution, in contrast to the examples shown beforehand that showed scientific or NOS reference to the opposition.

The last part of the research question discusses the ways in which the teachers dealt with their students' religious based opposition after the teacher training course. The answer to this part of the research question relies on teachers' submitted artifacts to questions in the sixth asynchronous session and in the summary task. In the latter task, the teachers were asked: (a) Specify how relevant each of the four synchronous meetings was for you. Refer to the scientific knowledge and to the pedagogical knowledge. (b) Which of the meetings was most significant to you? Some answers from the teachers were: "*In the fifth meeting, teachers suggested solutions tailored to the situation in the classroom, for example, not necessarily convincing a student to accept the evolution theory but teaching evidence*" (M1). "*For me it was most important to hear that other teachers in the course have the same problems as me in terms of how to teach the topic of evolution. For me, the most meaningful meeting was the one that dealt with the religious aspects of the topic*" (M4). *"In the fifth session, there were some interesting points, but the subject is less relevant to me personally because my classes are completely secular and this conflict hardly ever arises*" (S6). These quotes shows that the discussions held during the course on dealing with religious based opposition to evolution were meaningful to a significant proportion of the teachers.

In the sixth, asynchronous session, the teachers were asked (Appendix 8: (i) Is it worth dealing with issues related to religion in a science class? (ii) How did the fifth meeting help you deal with questions of religion and science in your class? In the

summarizing task, the teachers were asked: Have you been teaching religious belief and evolution in the classroom? Has the course changed your approach? Why? (Appendix 9 question 8).

Table 24. Teachers' responses to students' opposition to learning evolution

Categories of students' opposition	**Categories of teachers' responses to students' opposition**	**Subcategory of teachers' responses and example**	**Teachers who mentioned these subcategories**
A. Opposition stemming from religious beliefs	1. Religious beliefs	a. Science and religion are not contradictory. *"There is no contradiction between religion and evolution"*	M3, R1, S4, S5, S6
		b. Science and religion are connected. *"Evolutionary development occurred during the days of creation"*	M5, S7
		c. Using religious sources or theologians *"I asked the religion teacher to relate to this issue in his class"*	M3, R2, S6
		d. Giving legitimacy to the expression of religious beliefs *"the choice of whether to believe in this theory is ultimately up to them"*	M2, M3, M5, S1, S2, S6
	2. Scientific evidence	a. Examples from past evolution *"I listed arguments from comparative anatomy, paleontology"*	S1
		b. Examples from present evolution *"I gave the example of bacterial resistance to antibiotics"*	M1
		c. DNA evidence *"I gave scientific evidence, such as comparisons of DNA sequences"*	M2, S1
		d. Evolution does not have a direction. *"examples that show that there are also 'design errors' such as wisdom teeth in humans"*	S3
		e. Explanation of evolutionary principles *"First, we have to understand the evolutionary principles"*	R2
	3. Explanation of NOS	a. Explanation of the scientific method *"evolution is based on the scientific method, in which experiments and observations are made"*	R1, R2, S1, S3
		b. Philosophical separation of religion and science *"Evolution is a scientific theory and religion is faith"*	M2, R1, S6
		c. Practical separation of religion and science *"We must learn the scientific explanation of evolution because it is part of the curriculum but we don't have to accept it"*	M3, M4, M5
B. Opposition based on lack of understanding of NOS	1. Scientific evidence	a. Examples from past evolution *"I bring fossils to the class"*	R2, S7
		b. Examples from present evolution *"I talk about the evolution of the Coronavirus"*	M1, M2, M3, M5, R1, S1, S6
	2. Explanation of NOS	a. Explanation of the scientific method *"A lot of scientific knowledge is accepted although never seen, such as the world being round"*	S6

According to the teachers' submitted artifacts in the sixth session and in the summary task, the teachers who participated in the teacher training course could be divided into two groups (Table 25). It should be mentioned that some of the teachers' statements fell into several subcategories. The first group consisted of 9 teachers who underwent a transition during the course; 5 of them stated that they gained pedagogical tools to deal with opposition stemming from religious beliefs during the course; 3 of them said that they had gained confidence to deal with opposition stemming from religious beliefs; and 3 of them also stated that they had gained confidence in teaching evolution. The second group was comprised of 4 teachers who expressed an unwillingness to deal with opposition stemming from religious beliefs. Two of them had an atheistic world view, and two stated that dealing with students' opposition stemming from religious beliefs is not the science teacher's responsibility. One of the teachers, M2, is not included in these two groups because she did not change her approach to dealing with opposition stemming from religious beliefs, stating that: *"Before the training course I dealt with religion in class, and there is no change in my approach."*

M5 underwent a transition during the course, gaining pedagogical tools to deal with opposition stemming from religious beliefs: "*I talked about evolution and religion in class only after the training course. Before the course, I had no clue what to do, but by the middle of the training course I did introduce the subject, because now I had the tools to deal with it.".*

Similarly, S7 underwent a transition and gained more confidence to deal with evolution and religion, and even to initiate and actively raise the topic: "*I did not deal with the subject of evolution and religion. Many times it was not mentioned in class and if it came up, I addressed it briefly. Following the course, I will refer to it in the lesson and open up the subject*."

Even though the teachers were asked about teaching science and religion, 2 of them who underwent transitions during the course spoke about gaining confidence to teach evolution: *"At least now that I have knowledge regarding evolution in my head I can open a discussion. I have background on what to teach, how the research has revealed evolution, human evolution, what's common among animals. I have a scientific background and I can talk about it most confidently. I still need more*

courses to gain more knowledge in the field, but at least I feel more confident because I tell my students that I have undergone evolution training." (M4)

Of the teachers, 4 were unwilling to deal with opposition stemming from religious beliefs after the course, 2 of them claimed to be atheists and not willing to deal with religious opposition in the science class: *"I've never dealt with evolution and religion, nor do I mean to. I have an atheistic world view, I have no faith in religion at all, so for me there is also no contradiction*" (S4).

The other 2 were unwilling to deal with opposition stemming from religious beliefs because they felt that this is not part of a science teacher's duties in the science class: "*Although we got pedagogical tools to deal with the issue of evolution and religion, I do not think it is the role of the science teacher to talk about religious belief, just as I would not want the Bible teacher to talk about evolution*." (R1)

This means that the pedagogical tools that were part of the course did not change these 4 teachers' attitudes toward dealing with opposition to evolution stemming from religious beliefs. They continued to hold the position that they should not deal with such opposition in their science class.

Another interesting finding is that 2 of the teachers, 1 (S5) who underwent a transition during the course and 1 (S1) who was unwilling to deal with opposition stemming from religious beliefs, mentioned that they had become more sensitive to their students' religious beliefs during the course: *"As a result of the course, I understand that different sectors and populations behave in a very special way toward evolution and for that reason, a teacher has to speak sensitively and adapt the subject to these students in a special way*." (S5)

S5 was willing to put effort into approaching the field of evolution in a culturally sensitive manner: *"I have a student from the Bedouin sector in the 10th grade and I have no doubt that I will have to sit down and consult on how I talk about evolution in the classroom without hurting his feelings.*"

In contrast, S1 claimed that he had become more sensitive to the difficulties of students from traditional backgrounds due to the course but remained unwilling to deal with the topic: *"As a teacher, I am more sensitive to traditional students, but not to the extent that I choose to focus on this issue."*

Table 25. Influence of the evolution teacher PD course on the ways in which the participating teachers deal with their students' opposition stemming from religious beliefs.

Category	**Subcategory**	**Teachers who related to the subcategory**
1. Has undergone a transition during the course	Gained pedagogical tools to deal with religious opposition	M3, M5, R2, S3, S6
	Gained confidence to deal with religious opposition	M5, S5, S7
	Gained confidence in teaching evolution	M1, M4, M5
2. Is unwilling to deal with religious opposition	Has an atheistic world view	S1, S4
	Claims that religious aspects are not science teachers' responsibility	R1, S2

4.4.2. Introductory lesson to evolution

In order to assess the influence of the introductory lesson to evolution on the students' acceptance of evolution, and to be able to answer the ninth research question, 13 high-school students from a traditional school, were asked to fill the online questionnaire three times – before the lesson (pre), immediately after the lesson (post 1), and 2 months after the lesson (post 2). It can be seen in Table 26 that the mean MATE score of the class before the lesson was 52.45, while after the lesson it increased to 54.78 and two months afterwards – 58. The level of contradiction between religion and evolution, according to the students (while 5 represent high contradiction and 1 represents no contradiction) was 4.23 before the lesson, after the lesson it decreased to 3.55 and two months afterwards – 3.6.

Therefore, both parameters increased slightly, although both still represent a low acceptance of evolution (relatively to the Israeli students' mean score that I found to be 77.07 (page 45)). As the sample is very small, and as the number of students who participated in the study was reduced with time from 13, to 9 and to 5; additional examination is required.

Table 26. Students' scores on the MATE questionnaire and the level of contradiction they believe exists between religion and evolution (1-no contradiction, 5 high contradiction).

	Pre n=13		**Post1 n=9**		**Post2 n=5**	
	Mean	**(SD)**	**Mean**	**(SD)**	**Mean**	**(SD)**
MATE	52.54	(15.67)	54.78	(19.14)	58	(13.81)
Is there a contradiction between religion and evolution? (1-5)	4.23	(1.12)	3.55	(1.42)	3.6	(1.74)

In addition to the students' questionnaire, the class's teacher (NF), was interviewed. NF indicated that before she taught evolution using the introductory lesson to evolution, she always encountered religious based opposition, and said that she used to give the students a short answer just to silent their opposition. But after using the lesson she said:" *I think this was a very good introduction to the subject and I will use it in the future. The fact that you spread all the issues in the beginning of the lesson, define what is science and what is faith –helped the students organizing these different ideas. If you don't emphasize this separation, everything keeps being mixed up. in addition, the fact that different opinions of different people are presented, helped the students to understand and internalize the complexity".*

When asked what was the most successful part of the lesson, NF said: *"The game* [part 3 of the lesson] *in which the students guess who said the quates/phrases and then they discover the answers are different than what they thought. The quates themselves are strong and beautiful. In addition, the part in which you present different proofs for evolution, especially the morphological and genetical similarity, and the embryonic comparison. These are strong proofs for students."*

NF said that the students in this class are usually engaged in all lessons, but in this lesson, they were more engaged than usually, *"because of the game and their need to show up that they were correct, and generally the issue itself is a very "hot" topic, so it made them even more engaged".*

NF was asked whether this lesson may fit also for religious and secular schools, and she said it does. *"It may surprise you but even in secular schools there are students that the issue is not clear to them. They may not believe in religion, but they asked me – how can you, a religious teacher, teach this subject? It didn't work for them from a different perspective, and it was interesting"*

NF reported that she used the lesson for additional 3 times since then with other classes, and in addition she sent it to other teachers.

5. Discussion

Summary of the main findings

The importance of this research is by providing a comprehensive report of the religious tensions surrounding evolution education in Israel, since it was implemented as an obligatory subject in the curriculum. As many teachers in Israel avoided teaching evolution before it became an obligatory subject, I was interested in understanding whether the conflict regarding evolution that was being studied around the world, mainly among Christian and Muslim populations, is also relevant among the Jewish population in Israel. I found that teachers do encounter religious based opposition to learning evolution among all sectors, but especially among religious and traditional schools, which comes in line with the low acceptance of evolution among Israeli high school religious and traditional students, relatively to secular students. In contrary to these findings, no significant pattern in the scores of matriculation exam questions of evolution was found, which comes in line with previous findings that knowledge of evolution doesn't necessarily increase the acceptance of evolution. Therefore, the challenges in teaching evolution that were reported around the world are also relevant in Israel, and there is room for finding solutions that may help teachers face with these challenges in class.

In order to examine ways of approaching these challenges, the unique population of religious teachers and scientists who study and teach evolution, was chosen to be interviewed regarding their conception of the presumed conflict between religion and evolution, as they express the possible co-existence between both

domains. I found that among this population there is no perception of a conflict, but both religion and science are compatible, and both are important for their lives. As half of the participants indicated their teachers had influenced their acceptance of evolution, it emphasizes the important role teachers may have in shaping their students' approach toward evolution. One of the important findings of this research was that religious teachers and scientists who rejected evolution in the past, eventually accepted it after they were exposed to religious explanations that emphasized the compatibility between religion to evolution. However, the expected question that arose was whether science teachers should relate to religion in a science class to help their religious affiliated students accept evolution?

The debate on whether science teachers should help their students accept evolution was discussed in the literature, and here I found a significant difference between teachers and scientists' attitudes regarding the question of relating to religion in a science class. While most teachers accepted the idea, emphasizing the students' need to relate to their inner world to enable meaningful learning, most scientists rejected the idea, emphasizing the importance of separating science from religion. I showed that the need to relate to students' religious faith is coming from the field, while many times teachers answer religious arguments with scientific explanations, which doesn't necessarily answer the students' real conflict. Thus, I believe teachers should expand their toolbox and be supplied with knowledge and tools regarding how they can answer students' religious based opposition to evolution.

Based on their experience, religious teachers and scientists offered different practices on how teachers can relate to religion in a science class, but they also emphasized the limitations and challenges of doing so, which are very important to consider when designing educational programs dealing with the issue. In a PD course, it is important to have conversation with the teachers regarding their approaches toward the goals of evolution education, and to discuss the different approaches of facing the challenges.

The following discussion is divided into five parts: In the first part I focus the religious tensions surrounding the teaching of evolution in Israel, that were found in this research. The second part discusses the question whether opposition to evolution is inevitable among religious people, by examining the conception of religious teachers and scientists. The third part discusses the debate on whether teachers should

relate to religion in a science class, by examining the attitudes of teachers and scientists. In the fourth part I discuss the practices of how religion can be related in a science class that were offered in this research. The fifth part relates to the Implications on this work through a PD course and an introductory lesson to evolution, and the last part summarizes the research conclusions.

5.1. Religious tensions in evolution class in Israel

Occasionally, Israel's media publishes reports claiming that evolution is not being taught in Israel, in an attempt to present an anti-religious political stance. Before 2016, when evolution was an elective subject in the curriculum, many teachers chose to avoid teaching it in class (Agrest, 2001), but since the implementation of evolution as obligatory in the curriculum, teachers can no longer avoid it, and that is why the present study, that examined teachers' experiences since the implementation of evolution as obligatory, is necessary. Here I found that most of the participating teachers do teach evolution, although a minority of the teachers indicated they don't teach evolution because of the religious sensitivity. Therefore, I can assume that most of the teachers in Israel teach evolution. More support for this assumption stems from my examination of the results of the matriculation exam in biology between the years 2016 and 2019, showing that students from all sectors in Israel answered the questions about evolution.

Teachers from all sectors indicated that they have encountered opposition to evolution, which was mainly based on students' religious beliefs and emotional expressions, rather than scientific / cognitive arguments. This finding also comes in line with reports from the implementation PD program, in which all the teachers indicated they experienced students' religious based opposition (while most of them based their answers on scientific arguments, a finding that will be discussed further on). The reported opposition was found to be highest among religious schools but was also encountered in traditional and secular schools. This is in line with the Pew survey that found that rejection of evolution in Israel also occurs among some of its secular (14% rejection) and traditional (58%) populations, while the opposition is higher among religious population (Pew Research Center, 2016).

The opposition that was identified in all school sectors can be explained by the fact that in secular schools there are some traditional students, which were probably the main source of opposition; however, this might not be the only reason. Unlike other countries in which students learn religious content, such as creationism, from their family and informal religious institutions, students in all state schools in Israel study the biblical story of creation as part of bible courses in the 2nd and 10th grades as an obligatory part of the curriculum (Ministry of Education in Israel, 2018). This might strengthen the perceived conflict between evolution and religion, since the students may get different and seemingly contradictory answers to the same question of how life began, within the school framework: one from the bible teacher and the other from the science teacher.

One of the findings of the teachers' survey showed that among traditional students, secular teachers tend to experience higher opposition to evolution than religious or traditional teachers. This finding comes in line with the identity theory (Stets & Burke, 2000), which proposes that individuals construct a sense of self partly through the categorization of themselves and others as in-group (i,e., belonging to the same group) or out-group (belonging to different groups). Given that usually religiosity is an important part of the personal identity of religious people, it is likely that if religious affiliated people perceive evolution as a belief that belongs to non-religious or "atheists" - which are out-group members, they are likely to leave out evolution as part of their belief system and identity, even if it is possible for them to reconcile evolution with their religious beliefs. Additional support for this idea was found in the interviews with religious teachers and scientists, in which some of them emphasized the importance of teachers' religious affinity for the students: when a religious teacher teaches evolution, it may ease the students' conflict as they may perceive the teacher as a representative of the possible integration of both. However, a secular teacher, which sometimes identify as atheist in front of the students, may disregard religion which may leas to an increase in students' opposition to evolution. Obviously, teachers should not change or hide their belief system if they want to share it with the students, but it is important for teachers to be aware of this possible obstacle.

Barnes et al. (2017) found that religious students in undergraduate biology classes assumed that their instructors were not religious and were not accepting their

religious beliefs when the instructors avoided discussions about their beliefs while teaching evolution. This can explain my finding that some teachers indicated there is a higher percentage of students who rejected evolution than the percentage of those who expressed opposition out loud during the lesson. Students may not express their religious based opposition to evolution during class, especially if they feel that their teachers provide no legitimation to do so. Therefore, teachers may not be aware of their opposing students and as such, may not be able to help them. Moreover, research has shown that college science instructors often wrongly estimate, and usually underestimate, the number of students in their class who reject evolution (Barnes & Brownell, 2016). Therefore, it is important that teachers respectfully allow the students to express their beliefs in class. McCarthy (2018) claimed that part of being respectful to others is to be able to mutually critique one another's belief systems, which may lead to an individual's growth in cognition. This may be the case for individuals who choose to discuss their belief systems, but when it comes to the relationship between students and teachers in class, this idea may cause damage, because students are supposed to be able to learn while their belief system is not under persistent criticism by an authority, especially by their teacher. When such a criticism occurs, it may cause students' antagonism toward the subject and the teacher, as some religious teachers and scientists indicated in this study.

The opposition reported by teachers is also reflected in the MATE results that I identified among Israeli secular high school students – 77.07 (N=778) which is considered as a relatively high score (Routledge & Warden, 2007), while the average MATE score in religious schools was found to be 65.6 (N=244) (Dagan et al., 2022). The MATE was also examined here among a relatively low number of traditional students (n=13), showed the initial MATE score was 54, which is even lower than religious schools MATE (65.6). Although it is hard to draw any firm conclusions because of the small sample. In addition, it is important to note that 30% of this traditional class's students define themselves as Messianic Jews, which has an Evangelist perception of the creation, and they had a higher level of opposition respectively to the other students in class. This class is a unique multi-religious example, which doesn't represent a general traditional class in Israel.

In contrary to the findings from the teachers' questionnaire and the MATE results, which show that religious schools appear to have higher opposition and lower

acceptance of evolution, when I examined whether there are differences in the matriculation exams evolution questions scores – I didn't find any significant pattern that may indicate the success of one sector over the other. During the 2017 examination, secular schools had lower score than religious schools, and on the 2018 examination secular schools had higher score than religious schools. There is an obvious need for examination of more exams in order to be able to reach a firm conclusion, but this finding may indicate that the academic success in questions about evolution doesn't represent the students' conceptions toward the issue. Evidence for this idea was found in the teachers' reports of students who provided the correct answer for an exam question about evolution, but emphasized that they do not believe in the answer they chose. This phenomenon might indicate that the opposition to evolution does not necessarily result in a failure to understand evolution, but what do the teachers think about this phenomenon?

When the teachers were asked whether their students' religious faith might prevent them from understanding evolution, more than half of them answered that it would not. I noticed that the teachers' conception of the conflict between religion and evolution was an important factor in their answer: teachers who perceived no conflict declared that students' religious faith would not prevent their understanding of evolution, whereas those who perceived a conflict declared that religious faith would prevent this understanding. Teachers in religious schools showed the highest agreement with the opinion that religious faith does not prevent the understanding of evolution. This might stem from the fact that teachers in religious schools, regardless of whether they themselves are religious or not, more frequently face this conflict in class (compared to the other sectors), and therefore they are familiar with possible solutions to easing their students' conflict. When an individual perceives a subject as conflicting and is not familiar with any other explanation—it is reasonable to assume that religious faith will prevent an understanding of evolution. As already noted, many instructors have their own beliefs that evolution and religion must be in conflict (Barnes & Brownell, 2016). This emphasises the importance of teachers being familiar with the possible solutions to the conflict. Teachers who think that religious faith will prevent understanding might 'give up' on helping those students cope with the conflict. It has been shown that when science teachers understand the range of

perceptions of the relationship between religion and science, they are more likely to help their students cope with the conflict (Reiss, 2009).

Some of the teachers stated that students' religious faith may not interfere directly with their understanding of evolution but may render them closed-minded and decrease their motivation to study. These findings are supported by studies in which no correlation was found between knowledge and acceptance of evolution (Nehm et al., 2009; Nehm & Schonfeld, 2007; Sinatra et al., 2003). Low motivation for studying evolution due to religious opposition may be an obstacle to learning, and teachers should take this into account because motivation is a very important factor in all learning processes (Koballa & Glynn, 2007).

To summarize this part, teachers in Israel report they encounter students' religious based opposition to evolution, similarly to what is reported around the world (Deniz & Borgerding, 2018). As some teachers think this opposition may interrupt students' understanding and motivation, it is important to understand – is this opposition inevitable?

5.2. Is opposition to evolution inevitable among religious affiliated people?

Religious teachers and scientists' conceptions of science and religion

Since many studies show that as religiosity increases, the level of acceptance of evolution decreases (Allmon, 2011), religious people who accept evolution are considered to make up a relatively small and extreme group with "low probability of occurrence" (Paz-y-Miño-C & Espinosa, 2013). When examining their part among Israel's population, they compose 4% of the religious population (Pew, 2016). Here I chose to focus on this unique population, while the research population was composed of religious scientists and biology teachers who had a high average MATE score (88.05). This finding confirmed that the population chosen for the study fits the predetermined requirements for the study population in terms of religiosity and high acceptance of evolution. The participants indicated that both, religion and science are very important part of their life, and they don't feel they are supposed to choose one

over the other. This is in contrast to some who claim that: “Harmonious coexistence between science / evolution and religion is illusory. They are destined to interact in conflict due to the inherent incompatibility between scientific rationalism / empiricism and the belief in supernatural causation” (Paz-y-Miño-C & Espinosa 2013).

Relating to the participants’ conceptions of religion, almost all of them said that the scriptures are not meant to teach science or history and that they do not believe in a literal interpretation of the creation story. Almost all the interviewees quoted commentators and rabbis who talked about the complexity of the creation story and the moral values that can be learned from it. It may be concluded that the conception of the scriptures as a spiritual and moral guide and not as explaining or describing reality, as history and science try to do, is an important component in accepting evolution for a religious person. This may stem from the common Jewish idea that the scriptures should not necessarily be red literally. This finding may offer an explanation to the studies that found that Jewish scientists are accepting science and evolution more than the general population (Dunk et al., 2022, Ecklund & Schitle, 2007). Usually, those who believe that there is a conflict between evolution and religion—regardless of whether they are religious, secular, or traditional—believe that the creation story should be understood literally. It has been previously suggested that objection to science is due to a simplistic literal comprehension of the bible (Dodick et al., 2010). Therefore, mentioning that there are different theological explanations for the creation story may help promote the understanding that religion and science can be compatible, in order to help religious affiliated students to study evolution without a conflict.

Relying on sources of authority was offered as one of the fundamentals of every society (Graham et al., 2009). Specifically, religious Jewish people tend to rely on rabbinical sources of authority for all life aspects, as this is one of the common ideas of Judaism (“Assume for yourself a Rabbi” is mentioned twice in *Pirkey Avot*, which is part of the Jewish didactic ethical literature). Here I found that religious sources of authority were important in shaping the participants’ views of the relationships between evolution and religion. All but one of the participants emphasized different rabbinical figures who dealt with issues such as the non-literal understanding of the scriptures (such as Rambam), or the specific issue of evolution

(such as Rabbi Kook), while each participant emphasized the figures that fit his or her own world view. This finding suggests the possibility of presenting students with various rabbinical views, as some of the participants reported, because the understanding that there are religious authorities that accept evolution may ease the students' feeling of a conflict.

The controversy of arbitrary nature vs. divine providence was mentioned by the participants as one of the most fundamental arguments when discussing evolution and religion, because together with the scientific findings, a philosophical atheistic view is attributed to evolution (Lyons, 2010). As an outcome, the conception of divine providence may seem as contradicting evolutionary theory, even though it contradicts only one philosophical interpretation of it. It is important to remember that this conception does not stem from scientific findings but is just one of several possible interpretations to the relationship between science and religion, as suggested by Yasri et al. (2013). That way, the participants can accept the scientific findings and the mechanisms offered by evolution, and yet retain their religious view of divine providence. The participants indicated that evolution is just one example of the presumed gap between arbitrary nature and divine providence, which is relevant to all aspects of their lives. An educational conclusion from this finding is the importance of discussing the nature of science with students, as previously suggested (Dunk et al., 2019). This will enable them to understand science's roles and limitations, the differences between observations and interpretations, and the fundamental differences between science and religion.

Among the approaches to understanding the relationship between science and religion that are described in the literature (Yasri et al., 2013), I found that the participants had two main approaches—contrast (different questions / methods) and complementary. All the participants (except T10) agreed that there is a fundamental difference between the two disciplines. Most of them said it explicitly in their interviews or agreed to some extent with the contrast approach on the SRSII questionnaire. In addition, all of the participants (except T4) agreed to some extent that the two disciplines complement each other. This finding may show that both approaches can reside simultaneously in the same person. Stephen J. Gould's (a non-orthodox Jew) offered this idea in his Non-Overlapping Magisteria (NOMA) principle, which divides the magisterium of science to cover "the empirical realm:

what the Universe is made of (fact) and why does it work in this way (theory). The magisterium of religion extends over questions of ultimate meaning and moral value. These two magisteria do not overlap, nor do they encompass all inquiry" (Gould, 1999). Dodick et al. (2010) showed that religious people do not always hold only one approach to science and religion, but may have several approaches (Dodick et al., 2010). The findings of the present study strengthen their conclusion, because most of the participants agreed with more than one approach in the SRSII questionnaire. This suggests that religion and science can exist as two separate, and possibly complementary entities to create the reality of the participants. This comes in line with a study that found that scientists do not necessarily think science is in conflict with religion, but most of them see religion and science as operating in separate spheres (Ecklund et al., 2016). As some researchers (Williams, 2009) claim that the religious conception of creation is a misconception and is should be replaced with a scientific perception of the theory of evolution, it is important to understand that the perception of creation should not necessarily replace a scientific explanation. The perception of creation can be perceived as a cultural-spiritual domain in the persons' life, and many religious people live with both domains, just as the participants of this study.

The finding that most participants agreed with the complementary approach may indicate an interdisciplinary perspective of the issue. Nikitina (2005) suggested that hybridization of disciplinary views may ease tensions and differences between the disciplines and help bridge them. My findings emphasize the need to discuss the relationship between religion and science, even in a science class, despite the apparent need to separate them, since it enhances interdisciplinary thinking which occurs when people attempt to actually bridge different disciplinary perspectives into an integrated whole. A small non-significant gap was identified between the average MATE scores of participants who chose contrast (n=7) and those who chose complementary (n=13) in the SRSII questionnaire. This finding suggests a lack of preference for one or the other approaches when trying to cope with the science–religion relationship, as proposed by others (Dodick et al., 2010). It is possible that exposing students to both approaches will help them overcome the conflict between evolution and religion.

Factors that influenced the participants' acceptance of evolution

In the small unique population that participated in this study, no statistically significant difference was found in the average MATE scores of scientists vs. teachers, or between their various educational levels (BSc–MSc, PhD–Prof.) (Table 16). I cannot draw any conclusions from this result for the general population, but it shows that in this population of religious and scientifically educated people, the level of education does not affect the level of acceptance of evolution, although a positive correlation between educational level and evolution acceptance has been previously reported (Heddy & Nadelson 2012).

Most of the participants indicated that their evolutionary education was based on formal means, such as university or high-school courses. Three participants indicated that they had never learned evolution in a formal way, but mentioned informal means such as general courses, museums, books and nature films. When the average MATE scores of the two groups were compared, it was found that participants who studied evolution formally had an over 20-point higher MATE score than those who studied evolution informally. The difference was statistically significant in all categories and in the total MATE score (Table 16). This finding may be also explained by one of the limitations of the MATE questionnaire, as it includes a few questions that could measure evolution understanding rather than acceptance (Smith, 2010). Some of the formal group interviewees mentioned that it was only when they learned evolution formally that they understood it. It is important to mention that the teachers who did not learn it by formal means differed in their educational levels—undergraduate, MEd and PhD (in science or in science teaching). This finding emphasizes the importance of learning evolution properly in school, since for many people, this may be their last chance to learn it in a formal way.

Most of the participants had never rejected evolution, while 6 of them had rejected evolution in the past. When the average MATE scores of these two subgroups were compared, it was found that the score of the group that once rejected evolution was significantly lower than that of those who had always accepted evolution (Table 16). This finding may indicate that people who once rejected evolution will not always accept all of its aspects, even if they indicate explicitly that they now accept evolution. In contrast, participants who never rejected evolution had a very high level of acceptance, indicating that they never had any conflict with evolutionary principles.

The participants emphasized that their conception of evolution (acceptance / rejection) was influenced by their families' and their teachers' positive / negative approach to science, respectively. Past research has shown the influence of family and community on students' conception of evolution (Sbeglia & Nehm 2020; Winslow et al., 2011), and also that students' discourse with their friends and family outside class on topics such as evolution can lead students to perceive a conflict between religion and evolution (Winslow et al., 2011). Because teachers can have a positive or negative influence on students' conceptions of evolution and science in general, there is a need to provide teachers with enough knowledge and tools to influence their students' conception in a positive manner.

Six participants who had rejected evolution in the past gave three main reasons for that rejection: (a) lack of knowledge, (b) authority that emphasized the conflict, (c) social objection. These three factors may be connected, because students' lack of knowledge can result from teachers being unwilling to teach evolution due to religious opposition (Moore & Kraemer 2005; Rice et al., 2011), or instructors that teach evolution as fundamentally atheistic and even make disparaging remarks about religion during class (Barnes & Brownell 2016, Barnes et al., 2017).

The social objection mentioned by the participants referred to a feeling that they were supposed to object the idea, and that it does not belong to them as religious Jews; however, they could not pinpoint the source of this feeling. Previous surveys have shown that indeed, among religious populations, evolution is usually rejected by the majority (Pew Research Center 2016), and societal religiosity was offered as an important factor that may influence biology teachers and teaching worldwide (Silva et al., 2021). The participants who had rejected evolution in the past indicated that exposure to scientific knowledge alone was not enough to weaken their objection, whereas exposure to various religious authorities that offered explanations of the compatibility between religion and evolution (books, lectures, courses, etc.) promoted their acceptance of evolution. This important finding suggests that exposing students to the religious solutions that present compatibility between religion and science may help them accept the idea that there should not be a conflict between their belief and the currently available scientific knowledge on evolution. Some studies have shown that students do not present a statistically significant increase in their acceptance of evolution scores after being taught about evolution (Short & Hawley 2015; Walter et

al., 2013). The main cause for rejection of evolution by religious people is the presumed conflict between evolution and religion (Barnes et al., 2022; Muğaloğlu, 2018), although there are various religious explanations for the compatibility between religion and science in general, and evolution in particular (Dodick et al., 2010; Pear et al., 2015). Therefore, maybe the missing link may be exposure to the compatibility between religion and evolution?

Studies have found that presenting students with reconciliatory approach and compatibility between religion and evolution were important factors leading to increased students' acceptance of evolution (Ferguson & Jensen ,2021; Tolman, 2020). Accordingly, the exposure of students to scientific knowledge may help establish the strength of evolutionary theory, and exposure to the suggested solutions that present compatibility between religion and science, may help students accept the idea that there should not be any conflict between their belief and the currently available scientific knowledge of evolution.

To summarize this part, the challenges of evolution education have been discussed in many studies. The importance and novelty of this study is by focusing on understanding religious scientists' and teachers' conception of the relationship between evolution and religion, and exposing the factors that may have influenced that conception. This population demonstrates that settling between science and religion was possible for them, and participants who had rejected evolution in the past emphasized the importance of their exposure to the various religious sources that offer compatibility between science and religion. Thus, religious based opposition to evolution is not inevitable, as there are religious solutions to the conflict, but should teachers relate to them in a science class?

5.3. Should teachers relate to religion in a science class?

One of the main findings from the teachers' PD course was that at the beginning of the course, when some teachers encountered religious-based opposition, they dealt with their students' opposition using only scientific evidence, meaning that they avoided discussing their students' religious beliefs. Others dealt with religious-based opposition by relating to it, i.e., they were willing to face these religious beliefs

and deal with them in class. These two opposing approaches can be also found in the literature: According to some among the scientific community (Dawkins & Coyne ,2005) religion should not be discussed in a science class, as the science classroom is not the place to teach students how to settle the conflict between science and religion; rather, it is a place to teach science. Previous studies have found that teachers are willing to relate to the issue if they would have had more knowledge and tools (Siani & Yarden 2020). Thus, there is a seemingly gap between the academy (scientists) and the educational field (teachers) when discussing the issue of relating to students' religious faith in a science class. In order to examine this gap between scientists' and teachers' attitudes, Israeli teachers and scientists were asked whether teachers should relate to religion in a science class.

One might ask – why does scientists' conception is relevant to the discussion on whether and how to teach? As some scientists are stakeholders that participate in conferences and educational committees and publish in the media (articles, books, etc.), they take part in the public discourse. It was suggested before that one of the factors leading to the high proportion of individuals who perceive a conflict between religion and science are scientists, religious leaders and politicians who propagate the message of conflict in classrooms, religious institutions, popular culture, and the media (Barnes & Brownell, 2017). Therefore, as scientists may influence the discussion in the academia and among the general public as well, they were included in this educational question.

When teachers were asked whether students' religious faith should be related in a science class, most of the participating teachers, with no significant difference between sectors said yes, if it will promote students' understanding. Most of the teachers' explanations focused on the importance of relating to the students' inner world (their religious beliefs, cultural background, etc.), if they want to enable meaningful learning. When scientists were asked the same questions, most of them answered that religion should not be related in a science class - even if the students are religious. Their main argument was that anything which is not scientific should stay completely outside science class.

This significant difference between teachers' and scientists' attitudes may be explained by two possible explanations: First, studies found differences in religious cultures and religious beliefs between scientists and the public: scientists are more

secular, in terms of beliefs and practices, than the general populations (Ecklund et al., 2016). Graffin and Provine (2007) found that evolutionary biologists have the lowest rate of religiosity among any discipline polled. Whereas the public may struggle with how to situate their religious beliefs with claims of evolutionary theory, many biologists are unlikely to experience the same struggles (Alters & Nelson 2002). Thus, the differences between the attitudes of teachers and scientists may be attributed to a secular / atheistic point of view that scientists tend to hold more that the general public or teachers. Some of the teachers who rejected the idea of relating to religion in a science class define themselves as atheist, so they probably possess a personal secular view of the irrelevance of religion, especially in a science class.

A second possible explanation for the gap between scientists' and teachers' attitudes may be that scientists are less aware of the needs that appear in classrooms and the consequences of ignoring the subject, as the teachers are. That is why it is so important to relate to the teachers' point of view in this discussion. Reiss (2013) distinguished science from science education, emphasizing that non-scientific issues such as ethics are being related to in a science class, and offered religion should be related to as well. Further research may examine whether scientists are rejecting the idea of relating only to religion or also to ethics in a science class (such as animal teasing, eating meat, etc.), in order to examine whether their opposition derive from an attempt to maintain "sterile" science, disconnected from the society and the culture, or an atheistic point of view that may cause to rejection of everything religious.

Interestingly, the official goals of the high-school biology curriculum in Israel includes 7 goals. Among them, 3 goals focus on understanding (principles, essence of science, etc.), two goals focus on scientific practices and skills, and two goals relates to values: the first is the responsibility of man to nature, and the second is the importance of bio-ethical issues such as the sanctity of human life, animal testing, etc. (Biology curriculum for high schools, 2017). These issues are NOT scientific, but are "humanities" topics, yet they are considered an important part of the biology curriculum. This fact may support the first explanation, as the teachers may not reject non-scientific issues in a science class, but may reject relating to religion, maybe as a result of an atheistic perspective in which religion is not relevant in all aspects of life.

When religious teachers and scientists were asked whether teachers should relate to religion in a science class, all the religious teachers said that they should relate to the issue in their class. Their justifications, which were also mentioned by the teachers who filled the questionnaire from the previous section, were mainly the importance in relating to the students' inner world, preparing them for the future, and the importance of decreasing their opposition to enable meaningful learning, which is one of the fundamental principles of the theory of constructivism (Jones & Brader-Araje, 2002). Relating to the claim that constructivism may enhance the teaching of pseudo-science (Mugaloglu, 2014; Taşkın, 2020), I wish to emphasise that science teachers should teach nothing but the scientific explanations when teaching evolution. However, if students' religious faith poses a barrier to understanding evolution, disregarding the problem will not solve it; on the contrary, it may deepen it. Therefore, the teacher should help the students understand that there are possible answers to their conflict (by presenting those explanations or by referring the students to them), thus providing the opportunity to receive the best scientific education, similar to their secular counterparts. As was presented above, religious teachers and scientists who had rejected evolution in the past, exposure to the possible connections between evolution and religion was the main factor leading them to accept evolution, because their exposure to the scientific knowledge had not been sufficient. Some teachers emphasised the importance of relating to the students' conceptions with cultural sensitivity and respect, and such an approach was shown to be effective in studies that gave teachers the opportunity to become familiar with their students' cultural world; and developed principles of teaching evolution in a culturally competent manner (Barnes & Brownell, 2017; Brown, 2017).

The religious scientists were more restrained than religious teachers, although most of them agreed religion should be related by the teachers. Their answers contained hesitations, mainly about the teachers' qualifications, the complexity of the issue, and students' ability to understand it. These results may support the second explanation to the gap between teachers and scientists that was revealed in the previously. Since religious scientists had more hesitations and concerns toward relating to religion in a science class, compared to the religious teachers, the source of the hesitation is probably not an anti-religious perception of scientists, but a disconnection from the challenges that appear in the class. As some of the

participating religious scientists do teach or taught evolution in the academy (as instructors to large classes or practitioners to smaller classes), the difference in their experiences may be attributed to the different characteristics between teaching in the academy to teaching in schools. For example, high school teachers get to teach wider parts of the population then those who eventually attend college / university. Another example may be the difference in educational qualification teachers are required to have (which makes them aware of learning theories, developmental stages, etc.) in contrary to academic instructors which usually are not required for such qualification (Hebert, 2001).

To summarize this part, the teachers' certainty regarding the need to relate to religion in a science class is an important start, yet the scientists' concerns that were raised here should be considered when examining solutions for how to do it in class. Now I will review the different practices that were offered to how religion should be related in a science class.

5.4. How should religion be related in a science class?

One of the findings from the religious teachers and scientists' interviews, was that all of them (except S8) acknowledge that some students may feel a conflict between evolution and their religion. Acknowledging this idea is the first practice of the ReCCEE framework (Barnes & Brownell 2017) as in order to provide a solution, teachers must acknowledge their students' might have a problem. S8 is the only participant that denied the difficulty and was surprised to hear teachers encounter opposition to evolution, as he teaches evolution in a religious university and had never encountered any opposition. Respectively, S8 was the only one among the participants that rejected the idea of relating to religion in a science class, as he didn't acknowledge there may be a conflict. This emphasizes the importance of informing teachers about the students' possible conflict, as research has shown that college instructors wrongly estimate, and usually underestimate, the number of students in their class who reject evolution (Barnes & Brownell, 2016).

When considering how to relate to religion in class, the participants' suggested nine practices based on their experiences. The first five practices were novel, while the last 4 were already offered by the ReCCEE framework (Table 21).

The first educational practice suggested by the participants was that the teacher should present the issue but should not try to convince the students - the students will decide whether to accept it or not. The teachers may be more aware of their restrictions as educators – that they can offer ideas to the students and can try to adapt the ideas to their students' culture, but the students have their free choice. This finding comes in line with recent study that found that when the instructor gave students autonomy over their decision to accept evolution, students agreed with evolution more at the end of instruction (Barnes et al., 2022)

The second practice was the adaptation to the students' culture, and it is important to note that both the first and second practices, that consider the students' point of view, were mentioned mostly by teachers, while the third practice (defining the borders between science and religion) was mentioned mostly by scientists. This finding may emphasize the concerns of each group – while the teachers are concerned with maintaining their students' free choice and making the learning accessible to them, the scientists' concern is to make sure the students understand the borders between the disciplines. Note that viewing religion as science is one of the main concerns of those who oppose relating to religion in a science class: "…If supernaturalism will be recognized as an authentic part of science… that would be the end of science education in America." (Dawkins & Coyne, 2005). Thus, emphasizing the borders and differences between science and religion may address this concern. It was previously suggested that teachers should make a clear distinction between religious and scientific knowledge, thus promoting the understanding of scientific theories and avoid attempting to change religious beliefs (Teixeira, 2019).

The fourth practice that was suggested by both teachers and scientists, was to collaborate with an expert to the issue. However, while the teachers take responsibility to deal with the issue in their class, even when they suggest collaborating with a guest lecturer – they suggest it as an expansion of what they already discussed in class. In contrary to the teachers, the scientists assign the responsibility of dealing with the issue to other experts rather than the teachers themselves, from various reasons they pointed (e.g., teachers are not qualified enough

to deal with such philosophical issues, the teachers' different culture, etc.) – which all lead to the conclusion that the issue should be related to by someone else rather than the biology teacher. Although it may be perceived as if scientists underestimate the qualification of the teachers, many teachers indicate they do lack qualifications in this issue (Siani et al., 2022, Stahi-Hitin & Yarden, 2022).

The fifth practice was to refer to the creation story, as according to many canonic Jewish commentators and rabbis (Pear, 2015; Sacks, 2011) the simplistic understanding of the creation story is a misunderstanding of the message of the creation story, which may cause the religious based opposition to evolution. This practice is very different from teaching intelligent design or creationism (Pennock, 2003), since the creation story is referred to as a religious rather than scientific source, and the participants emphasized that by relating to the creation story, they highlight the differences between science and religion. Moreover, the participants emphasize that this practice may probably fit religious schools, and not secular schools.

Practices 6-9 were suggested before in the Religious Cultural Competence in Evolution Education (ReCCEE) (Barnes & Brownell 2017). Interestingly, these practices came up inductively from this study participants' attitudes, which support the idea that the ReCCEE framework may fit also religious Jewish students. Ten of the participants emphasized the importance of presenting various approaches to the conflict, especially the compatibility (sixth practice). As the most known viewpoints are atheistic evolution and creationism, the idea to present diverse viewpoints on evolution and religion and presenting the compatibility has been shown as an important practice that increases students' acceptance of evolution (Ferguson and Lensen, 2021; Barnes et al., 2022). Moreover, I previously presented that in this study population, participants that used to reject evolution in the past indicated that they eventually accepted it after they were exposed to the compatibility between science and religion.

As religious people tend to rely on tradition, the participants suggested to mention various Jewish leaders that accept evolution, or religious scientists that can be seen as role models (seventh practice). Ferguson and Jensen (2021) found that one of the factors students mentioned as reasons for a change towards evolution acceptance was the presence of a role model. In another study, once students saw someone who reconciled evolution and religion, the conflict they felt with evolution

decreased (Holt et al., 2018). It is important to note the difference between the previously suggested practice of presenting different approaches to the conflict, from the present suggestion of mentioning that a certain religious figure accepts evolution. Some religious teachers indicated that once their students understand that they accept evolution even though they are religious, it eases the students' conflict, as the teachers are the role models for their students. As mentioning different religious figures is easy to implement, I encourage teachers to look for role models that may be appropriate for their students' culture and religion (Zimmerman, 2018).

Three teachers suggested to discuss the students' personal views on evolution and religion (eighth practice). The need to consider students' prior knowledge is one of the principles of constructivism, and is necessary to enable meaningful learning, which may lead to a deeper understanding (Jones & Brader-Araje, 2002). Some researchers claim that relating to evolution education through the lens of constructivism may cause students to accept pseudo-science explanations and deny them a proper science education (Mugaloglu, 2014; Taşkın, 2020). However, it was found that when instructors did not acknowledge students' religious beliefs, the religious students in the class felt left out. This may lead to students deciding that biology and their religious value systems are incompatible (Hermann, 2012).

Many studies discussed the importance of relating to the NOS when teaching evolution (Lombrozo et al., 2008; Nehm & Schonfeld 2007), while here, two teachers mentioned the importance of relating to the NOS prior to the introduction of evolution (ninth practice), as was also offered by Scharmann (2018). Interestingly, these two teachers hold a PhD in science teaching (T2) and Philosophy of science (T7) which may explain the importance they perceive to the teaching and learning of the NOS, generally and especially when teaching evolution.

The proper time in the teaching sequence to relate to religion was mentioned mainly by teachers. While some prefer to relate to religion prior to the teaching of evolution, some after, and some shortly before and deeply after. Thus, the teacher can choose according to her / his personal preference and the students' needs (for example, if the students' opposition is too severe that the teacher can't teach evolution, then an answer should be provided before teaching evolution).

Three participants indicated that the teachers' own identity may influence the students' acceptance of evolution – and one emphasized that the teachers' secular

worldview may be an obstacle toward the acceptance of religious affiliated students. In Israel, the teachers' sector and students' sector are not always similar (especially in national state schools with a traditional population), therefore teachers should be aware to this challenge. Studies have suggested that students' rejection of evolution and their feelings of exclusion in the biology classroom are, in part, the result of cultural differences between mostly secular instructors and mostly religious students (Barnes & Brownell, 2016; Hermann, 2012; Southerland & Scharmann, 2013). This idea is also supported by my finding in which secular teachers in traditional schools tend to experience higher opposition to evolution than religious and traditional teachers in traditional schools. It was found that Christian instructors perceived that their own religious backgrounds have guided their decisions to teach evolution in a culturally competent way, that they led to a safe environment for students, that subsequently led to an increase in student acceptance of evolution and reduce student conflict between evolution and religion (Barnes & Brownell 2018).

To summarize this part, the educational practices that were offered in this part, based on the attitudes and experiences of religious teachers and scientists, may enable teachers to relate to their students' religious based opposition to evolution in a competent manner that also consider their concerns that were raised here.

5.5. Implications and future directions

The findings of this research indicate the obvious need for intervention programs in the field, as religious-based opposition to evolution was mentioned as a challenge for many teachers in Israel. One of the findings of this research was the important role teachers may have in helping their students accept evolution, which emphasize the need to supply teachers with knowledge and tools that may enable them to cope with these challenges in class. In a survey of Israeli teachers, it was found that many of them see themselves as lacking knowledge about evolution vs. religion but are willing to invest time participating in seminars and PD courses to enrich their evolution knowledge (Siani & Yarden, 2020). A few studies in Israel have presented programmes in which the Jewish sources are deeply discussed in a science

class or in a teacher's PD programme (Allouch, 2010; Pear et al., 2015; Pear et al., 2020). These programmes were effective at decreasing students' opposition to evolution, but were best-suited to religious schools, where the students are familiar with the study of religious texts. In the present research the aim was to create generalized practices that will fit teachers and students from all sectors in Israel. Hence, I designed two programs that may fit teachers and students from all sectors: the first is a PD course, that discuss the practices that were found here and the way to imply them in class. The second is the introductory lesson to evolution that was also created according to these practices. Both programs were examined with a small sample of ~13 participants, but by implementing the conclusions of this research to wider populations may help improving evolution education in Israel.

Professional development course

In order to implement this study conclusions in a PD course, I summarized the practices that were offered by our unique population of religious teachers and scientists, that express the possible co-existence between evolution and religion, and agreed teachers should provide a response to the religious conflict in class. When they were asked how to relate to religion in a science class, they offered practical suggestions, together with challenges and difficulties that are part of the practices and should be considered when designing such a course. I offer 5 new educational practices that expands the Religious Cultural Competence in Evolution Education (ReCCEE) framework (Barnes & Brownell, 2017). These practices are unique as they were suggested by religious teachers and scientists, who personally faced with the presumed conflict in their daily life, therefore have interesting insights regarding how the issue should be related in class, and what are the difficulties it may create.

The practices are:

1. Presenting the issue but not trying to convince the students: Teachers should consider that their students' have a free choice and a personal belief system, and by trying to convince students that they should accept evolution (as presented in Stahi-Hitin & Yarden 2022a) teachers may achieve the opposite result and may decrease students' acceptance of evolution. This practice may also answer the concern of indoctrination that was raised by some scientists, as

the teachers will present the students with different approaches without trying to convince them.

2. The need to adapt to the students' culture may be challenging in a multicultural class, but a PD course should include searching and examining the different solutions to the conflict that each culture has, as the majority of teachers may encounter students from different sectors and cultures.
3. Defining the borders between religion and science is a very important practice, as the perception of religion as part of science is one of the main concerns of those who oppose relating to religion in a science class. This study emphasizes the importance of defining the borders between both. One of the ReCCEE practices is to relate to the NOS, but here I also claim that in the PD course teachers should also be presented basically with the nature of religion, which may enable them to distinguish between the two with their students.
4. As in many classes, the students' religious sector may be different from the teachers', this study suggests considering a collaboration with a religious expert. One of the goals in a PD course may be to find such experts, or the course instructors may offer a pool of religious leaders and scientists who will be willing to cooperate with teachers. This suggestion may also answer the ReCCEE important practice of presenting the students with role models.
5. Relating to the creation story in a science class may sound controversial, but as the main source of rejecting evolution is the literal understanding of the creation story, although according to many Jewish rabbis and commentators it should not be understood literally. Thus, teachers should be aware of the possible religious perceptions of the creation story, and they can even discuss it with their students, if they think it might be appropriate and helpful in their class.

These practices can be used as a basis for generating a PD course, following an explicit discussion with the teachers regarding their educational goals when teaching evolution. In addition, the different possible views of the relationship between science and religion should be discussed. That way, teachers will be familiar with possible approaches to the controversy, and hopefully will be prepared to address the students' challenges and difficulties (Scharmann, 2018; Southerland & Scharmann, 2013).

Exposing teachers to the conceptions of this research population can contribute to understanding a model for accepting both religion and evolution, which may be important for every teacher, because religiously affiliated students can even be found in secular schools. Implementation of these conclusions in teacher PD programs may help teachers promote their religiously affiliated students toward better learning of evolution and meaningful learning of science in general.

These practices were implemented in a teacher PD course, that was aimed to supply teachers with knowledge and pedagogical tools regarding certain topics in evolution, among them quarter of the total time of the course was dedicated to the students' religious based opposition.

At the end of the course, a high proportion of the participating teachers claimed that they had gained pedagogical tools as well as confidence and sensitivity that enabled them to better deal with their students' opposition stemming from religious beliefs. However, some of the teachers claimed that they were not willing to deal with such opposition, even though the course had given them the tools to do so, as they did not think it is their duty to deal with religion in the science classroom. Others claimed that they do not have enough knowledge to deal with religious matters, and mentioned there is still a need for a comprehensive course that will fit with the Israeli Jewish population.

Introductory lesson to evolution

The introductory lesson to evolution (Appendix 10) was developed with an attempt to answer the challenges that were raised in this research regarding the religious tensions surrounding evolution education. This lesson was based on the practices that were offered in this research, together with the pedagogical strategies of ReCCEE. The lesson was designed for the Jewish population of high-school students, but it can be adapted to different populations of students. The general structure and principles of the lesson can be discussed in the PD course, while every teacher can make the needed adjustments.

The introductory lesson was examined in a few classes in Israel, that showed a high interest and engagement by the students. Data was collected in one of these classes in a traditional school, demonstrated an initial low acceptance of evolution, together with a high perception of the conflict. Following the lesson, there was a

slight increase in the MATE score of acceptance and a decrease in the perception of a conflict, which may indicate the lesson did affect some of the students, in line with studies that showed that acknowledging the potential compatibility between evolution and religion can increase student acceptance of evolution and decrease the perceived conflict between evolution and religion (Barnes & Brownell, 2018; Truong et al., 2018). Examination of the lesson among more samples from different populations and sectors is needed to be able to have a firm conclusion. In addition, the teacher indicated the lesson was very successful and the students were engaged and interested, and that she will be using it again in the future.

As was mentioned above, 30% of the students in the class were Messianic Jews - This class is a unique multi-religious example, which usually is not found in Israel's classes, but it calls upon generating solutions also for such classes, as it was already mentioned that religious solutions can be found in all religions (Zimmerman, 2018).

5.6. Conclusions

This study demonstrated the challenges that Israeli teachers from different sectors are facing with when teaching evolution. It also examined possible solutions to these challenges, that are based on the idea that religion is an important part of some students' identity, and if teachers want to enhance their students' scientific understanding, they should relate to their religious beliefs, rather than disregarding or avoiding them. Sandford (2020), a science communicator, stated that '*The key to effective science communication isn't the science. It's communication'*; Sanford further emphasised three important principles in science communication: do not argue with beliefs, and listen to, and learn about what people think (Sandford, 2020). These principles may help create efficient science communication, which is very important, especially with respect to controversial issues among the general public such as evolution; perhaps they should be adopted by anyone who communicates science, especially science teachers, who are the mediators of science to future citizens.

This study adds another point of view to the global issue of evolution education among different societies and religions. The research emphasises the importance of

relating to teachers' experiences and perspectives in the academic discussion on whether to relate to students' religious faith during science class, because teachers are at the front line of the controversy. The research offers teachers the opportunity to relate to students' religious opposition with sensitivity, and in doing so, potentially promote their students' positive perspective of science, thereby enhancing evolution and science education for all.

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7. Appendices

Appendix 1 – Teachers' questionnaires

שאלון הוראת האבולוציה

מורות ומורים יקרים,

במסגרת עבודתי כמורה למדעים וביולוגיה בבי"ס ממלכתי, נתקלתי בהתנגדות מצד תלמידים כאשר לימדתי את נושא האבולוציה. ישנה תמיכה רחבה בספרות לכך שהתנגדות זו מונעת מתלמידים לקבל ולהבין כראוי את עקרונות האבולוציה, שמהווים בסיס חשוב להבנת הביולוגיה כולה.
אשמח לשמוע מנסיונכם ואת דעתכם בנושא באמצעות שאלון זה, המהווה חלק ממחקר שבו אבדוק עד כמה תופעה זו רחבה בארץ וכיצד ניתן למתן את ההתנגדות. השאלון אנונימי, ומיועד למורות ומורים שלימדו\מלמדים את הנושא בחט"ב או בתיכון.

תודה רבה על שיתוף הפעולה!
רעות סטאחי
reut.stahi@weizmann.ac.il

* חובה

המגזר אליו משתייך ביה"ס: *

- ממלכתי
- ממלכתי דתי
- חרדי
- ערבי
- נוצרי
- דרוזי
- ח. מוכר
- אחר: _____

היכן ממוקם ביה"ס? *

התשובה שלך

מלמד\ת בכיתות: *

- [ ] חטיבת ביניים
- [ ] תיכון

כיצד היית מתאר\ת את אוכלוסיית התלמידים שלך? (באופן כללי ובהתייחס לרובם) *

- [ ] דתיים
- [ ] מסורתיים
- [ ] חילוניים
- [ ] אחר:

כיצד לדעתך את\ה נתפס\ת בעיני התלמידים שלך? *

- ◯ דתי\ה
- ◯ מסורתי\ת
- ◯ חילוני\ת
- ◯ אחר:

האם לימדת את נושא האבולוציה? *

- ◯ כן
- ◯ לא
- ◯ אחר:

במידה והתשובה לשאלה הקודמת הינה שלילית, אנא נמק\י מדוע.

התשובה שלך

כשהתחלת ללמד את נושא האבולוציה, האם עלתה התנגדות מצד תלמידי הכיתה?

- ◯ כן, של תלמידים בודדים
- ◯ כן, של הרבה תלמידים
- ◯ לא עלתה התנגדות כלל
- ◯ אחר:

במידה ואכן עלתה התנגדות, כיצד היא באה לידי ביטוי?

התשובה שלך

האם בשיעור עלו אמירות דומות לאמירות הבאות?

- [ ] אני לא מאמין באבולוציה
- [ ] אני מאמין באלוהים
- [ ] אני לא מאמינה שבאנו מהקוף
- [ ] אלוהים ברא את כל החיות כמו שהם
- [ ] זה לא הגיוני שבאנו מחיות
- [ ] ציטוטים מספרים דתיים
- [ ] לא עלו אמירות בסגנון
- [ ] אחר:

האם לדעתך אמונה דתית של התלמידים עשויה למנוע מהם להבין את הנושא כראוי? *

- כן
- לא
- אולי
- אחר:

אנא נמק\י

התשובה שלך

האם יש מקום להתייחס לנושאי אמונה בשיעור מדע? *

- לא, בשיעורי מדע לומדים רק מדע
- כן, אם זה עשוי לשפר את הבנת התלמיד
- אחר:

אנא נמק\י

התשובה שלך

במידה ותסכים\י להזדהות ולענות על שאלות נוספות בעתיד - אשמח אם תכתב\י את שמך וכתובת אימייל.

התשובה שלך

Appendix 2 -MATE questionnaire

4. לפניכם רשימת היגדים. עליכם לסמן באיזו מידה אתם מסכימים עם כל אחד מההיגדים: מסכים בהחלט-(5), מסכים-(4),לא בטוח-(3),לא מסכים-(2),לא מסכים כלל-(1) *

סמן אליפסה אחת בלבד בכל שורה.

	1	2	3	4	5
האורגניזמים הקיימים כיום הם תוצאה של תהליכים אבולוציונים שהתרחשו במשך מליוני שנים.	◯	◯	◯	◯	◯
לא ניתן לבחון את נכונותה של תיאוריית האבולוציה בצורה מדעית.	◯	◯	◯	◯	◯
בני האדם המודרנים כיום הם תוצאה של תהליכים אבולוציוניים שהתרחשו במשך מליוני שנים.	◯	◯	◯	◯	◯
תיאוריית האבולוציה מבוססת על הנחות שלא נבדקו, ולא על תצפית ובחינה מדעית.	◯	◯	◯	◯	◯
רוב המדענים מקבלים את תיאוריית האבולוציה כתיאורייה מדעית תקפה.	◯	◯	◯	◯	◯
הנתונים הקיימים כיום אינם מוכיחים חד משמעית אם האבולוציה מתרחשת באמת.	◯	◯	◯	◯	◯
גיל כדור הארץ הוא פחות מ-20 אלף שנים.	◯	◯	◯	◯	◯
יש כמות משמעותית של נתונים התומכים בתיאוריית האבולוציה.	◯	◯	◯	◯	◯
האורגניזמים קיימים היום באותה הצורה הבסיסית, "פחות או יותר", שבה היו תמיד.	◯	◯	◯	◯	◯
האבולוציה אינה תיאוריה שתקפה מדעית.	◯	◯	◯	◯	◯
גיל כדור הארץ הוא לפחות 4 מיליארד שנה.	◯	◯	◯	◯	◯
תיאוריית האבולוציה הנוכחית היא תוצאה של מחקרים ושיטות מחקר מדעיים מבוססים.	◯	◯	◯	◯	◯
תיאוריית האבולוציה מאפשרת תחזיות לגבי מאפיינים של עולם הטבע שניתנות לבחינה מדעית.	◯	◯	◯	◯	◯
תיאוריית האבולוציה לא יכולה להיות נכונה משום שהיא סותרת את תיאור הבריאה בכתבי הקודש.	◯	◯	◯	◯	◯
בני האדם כיום דומים בצורתם הבסיסית לבני אדם שהיו מאז ומעולם.	◯	◯	◯	◯	◯
תיאוריית האבולוציה נתמכת על ידי נתונים עובדתיים, היסטוריים ומעבדתיים.	◯	◯	◯	◯	◯
אנשים רבים בקהילה המדעית (חוקרים) מטילים ספק בהתרחשות אבולוציה.	◯	◯	◯	◯	◯
תיאוריית האבולוציה נותנת משמעות למאפיינים והתנהגויות השונות שאנו רואים אצל אורגניזמים שונים.	◯	◯	◯	◯	◯
למעט מספר יוצאים מהכלל, היצורים החיים הופיעו על פני כדור הארץ בערך באותו זמן.	◯	◯	◯	◯	◯
האבולוציה היא תיאורייה שתקפה מדעית.	◯	◯	◯	◯	◯

Appendix 3 -Evolution questions from the matriculation exams:

2017 Question 16:

טז. איזו מן המוטציות האלה תשפיע יותר על האבולוציה של מין מסוים?

1. מוטציה שאינה משנה את הכשירות של הפרט, ומתרחשת בתא רבייה (גמטה).
2. מוטציה שאינה משנה את הכשירות של הפרט, ומתרחשת בתא גוף.
3. מוטציה המעלה את הכשירות של הפרט, ומתרחשת בתא רבייה (גמטה).
4. מוטציה המעלה את הכשירות של הפרט, ומתרחשת בתא גוף.

2017 Question 18:

יח. איזה מבין המשפטים שלפניך נכון בנוגע לתהליך של ברֵרה טבעית באוכלוסייה מסוימת?

1. פרטים מסוימים משנים את עצמם, ומעבירים לצאצאיהם את התכונות שרכשו.
2. הפרטים מסתגלים במשך חייהם לשינויים בסביבה, ולכן כולם שורדים.
3. רק תכונות המקנות יתרון הישרדותי עוברות בתורשה.
4. יש שונות גנטית בין הפרטים, ורק חלקם שורדים לאחר שינויים בסביבה.

2018 Question 7

7. אצל ארנבונים חומים יכולה להתרחש מוטציה הגורמת להופעת ארנבונים לבנים. האם צפוי שקצב התרחשות המוטציה יהיה דומה באוכלוסיית ארנבונים חומים החיה באזור מושלג ובאוכלוסייה כזאת החיה באזור מדברי?

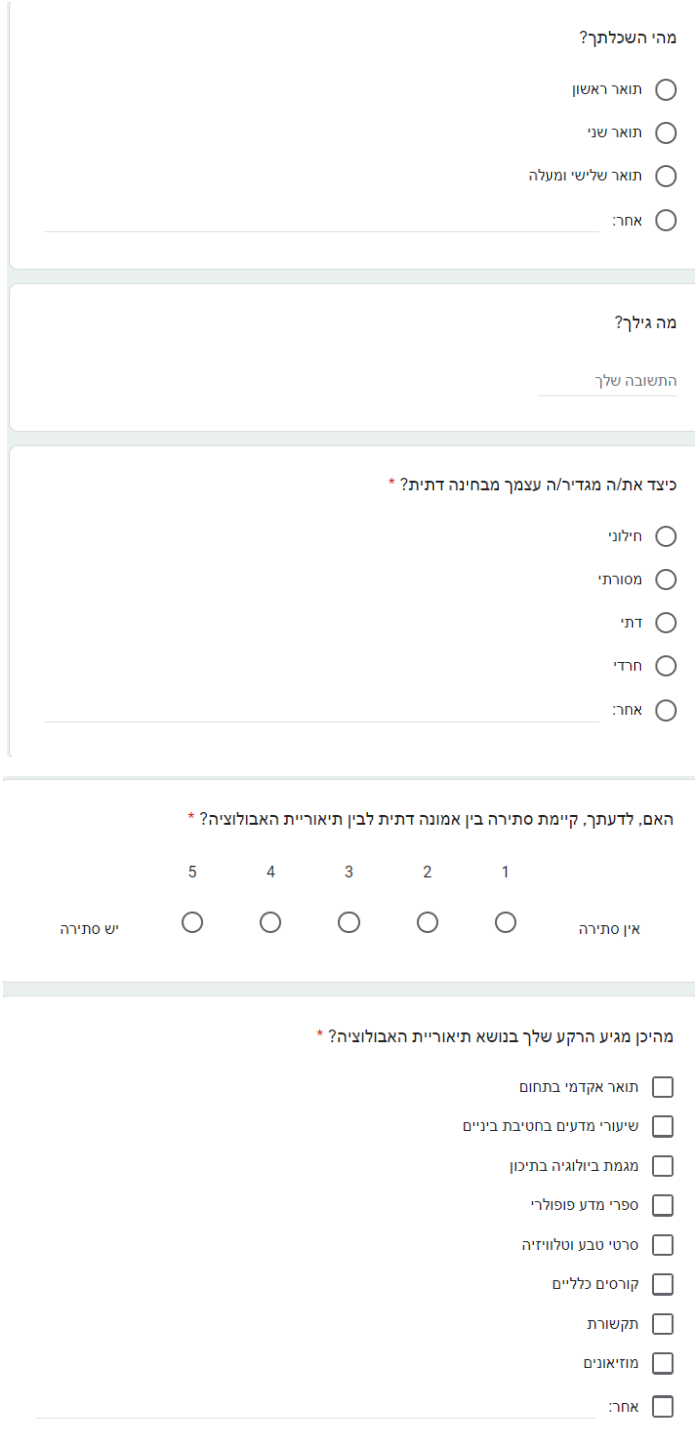
א. לא. קצב התרחשות המוטציה יהיה גבוה יותר באזור מושלג, משום שפרווה לבנה היא התאמה לתנאי שלג.

ב. כן. כי גם ארנבונים לבנים וגם ארנבונים חומים יכולים לשרוד בשני האזורים.

ג. כן. התרחשות מוטציה היא אירוע אקראי שאינו תלוי באקלים השורר בבית הגידול.

ד. לא. קצב התרחשות המוטציה יהיה גבוה יותר באזור מדברי, משום שפרווה לבנה קולטת פחות חום.

Appendix 4 – Pre interview questionnaire



*This questionnaire also included the MATE questionnaire that appears in Appendix 2.

אבולוציה ודת (למורים וחוקרים)

- ספרי על עצמך – השכלה, תפקידים
- איך הגעת לעסוק בנושא האבולוציה? למה דווקא אבולוציה?
- האם הנושא העסיק אותך בעבר?
- איפה למדת תיכון\חטיבה? האם למדת אבולוציה? איך לימדו אותך?
- איך לימדו תנך? (קריאה מפורשת, פרשנויות, אילו פרשנויות?)
- האם אי פעם חשת התנגדות פנימית לנושא? קונפליקט?
- אם כן - האם תוכלי לתאר מה השפיע עליך? היתה נקודת מפנה \ בהדרגה?
- מה המסר שקיבלת מהמשפחה לגבי המדע?
- מה מאפשר לחיות עם שני הדברים במקביל? מחבר בין הדברים או מפריד?
- מה דעתך על הגישות השונות לפתרון הקונפליקט?
- האם וכיצד ניתן ליישב בין עקרון האקראיות באבולוציה לבין תפיסת ההשגחה הדתית?
- מה עמדתך בנושא אבולוציה של האדם?
- האם כיום, אתה נתקל בהתנגדויות מהסביבה הקרובה?
- האם מנסה לשכנע אותם?

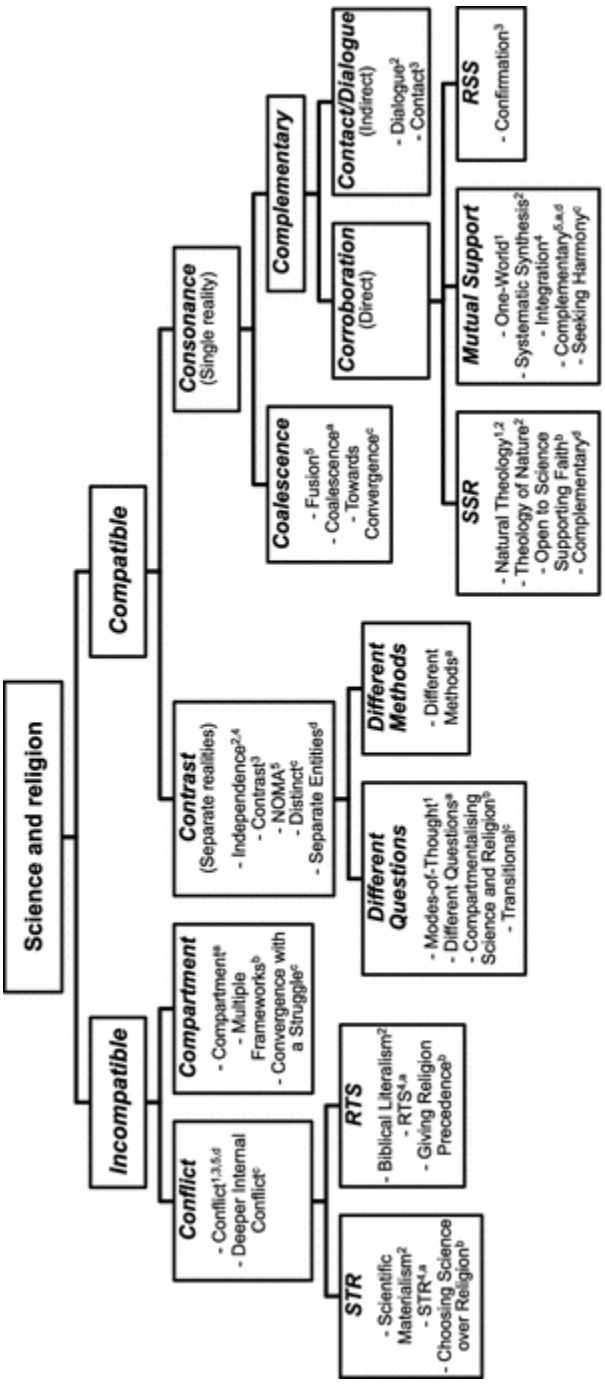
הוראת אבולוציה - למורה

- כמה שנים מלמדת? איפה? למה בחרה ללמד ביולוגיה?
- האם חשוב ללמד אבולוציה, ומדוע?
- איך את מלמדת אבולוציה? (רצף, מספר שעות?)
- האם נתקלת בהתנגדויות? יכולה לתאר סיטואציה? נוצר ויכוח בכיתה?
- על מה מבוססת ההתנגדות של התלמידים, לדעתך? אפשר להתמודד עם הפער?
- איך את מתמודדת עם ההתנגדות בכיתה? מה יכול לעזור ללמד את הנושא?
- האם נתקלת בהתנגדויות מצד ביה"ס – הנהלה, מורים אחרים, הורים?
- האם יש מקום להתייחס לנושאי אמונה בשיעורי מדע?
- האם משלבת מקורות שאינם מדעיים גם בנושאים אחרים?
- האם תעלי את הנושא בעצמך גם אם זה לא עולה מהשטח?
- האם תלמיד יכול להבין מבלי לקבל?
- האם חשוב שתלמידים יקבלו אבולוציה? האם מנסה לשכנע, גם אם מתנגדים?
- האם יש לך בנושא ערכים מסוימים שחשוב לך להעביר לתלמידים?
- מה היית עושה במידה וזו היתה אוכלוסייה אחרת של תלמידים? (חילונים\ דתיים)

הוראת אבולוציה – לחוקר (\מרצה)

- האם חשוב ללמד אבולוציה, ומדוע?
- האם חשוב שתלמידים יקבלו אבולוציה?
- האם לימדת\מלמד את הנושא? באיזו מסגרת?
- האם יש מקום להתייחס לנושאי אמונה בשיעורי מדע?

Appendix 6 - Summary of the approaches on the relationship between science and religion (Yasri et al. 2013)



Summary of the correspondence between the full set of published views on the relationship between science and religion. The terminology used in this paper to discuss the different positions is shown in *italics* the header of *each box* and the corresponding views from other work are listed below using the original category names. Citations labelled *1–6* are taken from the philosophical literature and *a–d* from the educational literature (*1* = Polkinghorne (1986), *2* = Barbour (1990), *3* = Haught (1995), *4* = Nord (1999), *5* = Alexander (2007), *a* = Yasri and Mancy (2012), *b* = Taber et al. (2011), *c* = Shipman et al. (2002) and *d* = Hokayem and BouJaoude (2008) (*STR Science Trumps Religion*, *RTS Religion Trumps Science*, *SSR Science Supports Religion*, *RSS Religion Supports Science*)

Appendix 7 - Science and Religion Self-Identification Inventory (SRSII):

מהי תפיסתך בנוגע לקשרים בין דת ומדע? *

	מסכים בהחלט	מסכים	לא בטוח	לא מסכים	לא מסכים כלל
1. חלק מההיבטים של המדע סותרים את הדת אבל אני לא מבין לגמרי את הסתירות	○	○	○	○	○
2. חלק מההיבטים של המדע סותרים את הדת. כאשר ישנן תשובות שונות לאותן שאלות, לדעתי רק המדע מספק תשובות מבוססות..	○	○	○	○	○
3. חלק מההיבטים של המדע סותרים את הדת. כאשר ישנן תשובות שונות לאותן שאלות, לדעתי רק הדת מספקת תשובות אמיתיות.	○	○	○	○	○
4. דת ומדע לא סותרים זה את זה, משום שכל אחד מהם עונה על שאלות שונות (המדע עוסק בשאלות על העולם הפיזיקלי, כאשר הדת עוסקת בשאלות אתיות, ערכים ומשמעות).	○	○	○	○	○
5. דת ומדע לא סותרים זה את זה משום שבניית הידע בכל אחד מהם שונה (הידע המדעי נבנה על ידי בחינה אמפירית של תופעות, בעוד שהידע הדתי נבנה על ידי פרשנות של כתבים דתיים).	○	○	○	○	○
6. ניתן לשלב בין דת ומדע משום שהם מספקים את אותן תשובות לאותן שאלות.	○	○	○	○	○
7. דת ומדע משלימים. שניהם שימושיים לצורך הבנת כל היבטי החיים.	○	○	○	○	○

אחר/תגובות/הערות:

התשובה שלך

מהו המשפט שמתאר בצורה הטובה ביותר את תפיסתך בנושא?

- 1. חלק מההיבטים של המדע סותרים את הדת אבל אני לא מבין לגמרי את הסתירות
- 2. חלק מההיבטים של המדע סותרים את הדת. כאשר ישנן תשובות שונות לאותן שאלות, לדעתי רק המדע מספק תשובות אמיתיות.
- 3. חלק מההיבטים של המדע סותרים את הדת. כאשר ישנן תשובות שונות לאותן שאלות, לדעתי רק הדת מספקת תשובות אמיתיות.
- 4. דת ומדע לא סותרים זה את זה, משום שתפקידם לענות על שאלות שונות (המדע עוסק בשאלות על העולם הפיזיקלי, כאשר הדת עוסקת בשאלות אתיות, ערכים ומשמעות).
- 5. דת ומדע לא סותרים זה את זה משום שבניית הידע בכל אחד מהם שונה (הידע המדעי נבנה על ידי בחינה אמפירית של תופעות, בעוד שהידע הדתי נבנה על ידי פרשנות של כתבים דתיים).
- 6. ניתן לשלב בין דת ומדע משום שהם מספקים את אותן תשובות לאותן שאלות.
- 7. דת ומדע משלימים. שניהם שימושיים לצורך הבנת כל היבטי החיים.
- אחר:

Appendix 8 - Meeting schedule of the teacher training course

The parts of the teacher training course that are dealt with in this paper are in italics.

Type of meeting	Content/scientific knowledge	Pedagogical[a]
1. Synchronous	Lecture by an expert in ecology and evolution: "The evolution of arthropods as an example of the new synthesis in evolutionary research"	*Pedagogical discussion with the teachers regarding:* *i. Challenges in teaching evolution.* *ii. Difficulties in teaching and learning evolution.* iii. Alternative conceptions of evolution among students. From the science education literature aspect.
2. Asynchronous	Teachers read articles concerning: i. Arguments against the teaching and learning of evolution (Tsanza, 2014) ii. Alternative concepts in evolution	Forum discussion: *i. What opposition to learning evolution do you hear in your classes? (Select the three most prominent from a list of 10 arguments.) How do you as a teacher deal with the students' opposition to learning evolution?* ii. What alternative concepts in evolution do you perceive in your classes? How do you as a teacher deal with them? Teachers wrote their answers and responded to other teachers.
3. Synchronous	A lecture by an expert in ancient DNA and human evolution: "Human evolution. What can you learn about it from ancient DNA?"	i. Discussion with the teachers regarding difficulties in teaching human evolution. ii. Experiencing an online activity on human evolution regarding lactose resistance: https://petel.weizmann.ac.il/biology/login/signup.php?key=T6518373X&lang=en
4. Asynchronous	Teachers watch two online lectures on human evolution	Forum discussion: i. In light of the human evolution lectures, should this topic be included in the biology curriculum? ii. How should it be taught in the classroom?
5. Synchronous	*A lecture by a biologist with expertise in theology: "Theological solutions in the field of evolution"*	*i. Exposing teachers to pedagogical tools that will aid in dealing with students' opposition stemming from religious beliefs.* *ii. Discussion with the teachers using the following leading questions:* *1. Should one engage in the religious context during the teaching of evolution, before or after it?* *2. Can the ideas for theological solutions to this conflict presented in the lecture help you when you teach evolution? Explain which ideas, and how they can help.* *3. Can the principles of culturally adapted teaching help your teaching? Which principles? How can they be applied in class?* *4. For teachers who teach mainly a secular population: Is it worth engaging in this topic even if there is no opposition from the students? Why?*
6. Asynchronous	Teachers read an article about students' opposition stemming from religious beliefs	Forum discussion: *i. Is it worth dealing with issues related to religion in a science class?* *ii. How did the 5th meeting help you deal with questions of religion and science in your class?* iii. Plan a lesson that deals with religious opposition in your class. Specify the stage when you will teach the lesson, explain why you chose the specific topic and what sources you used.
7. Synchronous	A guided tour of the National Natural History Collections at the Hebrew university in Jerusalem.	Discussion with the teachers regarding the way to use a museum tour as a tool for teaching evolution.
8. Asynchronous	Forum discussion: i. What scientific information was new to you on the tour? ii. Which of the collections did you find most interesting and relevant?	Forum discussion: In light of the lessons learned: i. Choose three ideas from the 2010 biology curriculum (Ministry of Education, 2010) in which evolution was an extended topic and explain why it is important to teach these ideas. ii. Choose one idea that you think can be omitted from the curriculum and explain why.

Appendix 9. Summarizing task of the teacher PD course

1. *Did you join the course to expand your knowledge of evolution or because of difficulties in teaching the topic in your classroom? Is there another reason? Answer in detail.*

2. Have you ever participated in an evolution course? What was the added value of this course, if there was one?

3. (a) *Specify how relevant each of the four synchronous meetings was for you. Refer to the scientific knowledge and to the pedagogical knowledge.*

(b) Which of the meetings was most significant to you?

4. Was the division of the meetings/sessions into a scientific part and a pedagogical part helpful to you? Use examples.

5. Which of the content taught in the course will you take to your classroom? Explain why.

6. Did the assignments/tasks in the course have an added value beyond what was discussed during the meetings? Which of the assignments/tasks? Explain.

7. Have you been teaching human evolution in your classes? Will the course change your approach? Why?

8. *Have you been teaching religious belief and evolution in the classroom? Has the course changed your approach? Why?*

9. What teaching materials (books/online courses, etc.) do you use to teach the subject of evolution?

10. Do you think there was unnecessary content in this course? What content, and why was it unnecessary?

11. Are there any other issues in evolution that you wanted the course to deal with? What issue and why?

12. Which of the topics presented in the course would you like to appear in new teaching materials?

13. Would you like to participate in further courses on evolution? Explain.

[a] The parts of the teacher training course that are dealt with in this paper are in italics.

שיעור פתיחה לאבולוציה

מיקום ברצף הלימודים: לפני תחילת הוראת האבולוציה (בהתאם להעדפת המורה – בתוך אקולוגיה/גנטיקה)

שכבת גיל: חטיבה עליונה

משך השיעור: 90 דקות (2 שעות אקדמיות)

התאמה מגזרית: מתאים לכל המגזרים באוכלוסיה היהודית, ניתן לבצע התאמות לדתות אחרות.

ציוד: מקרן ומחשב (השיעור מלווה במצגת), כרטיסיות משחק "מי מאמין באבולוציה"

מטרות השיעור:

א. חשיפת התפיסות הקיימות של התלמידים בנוגע לאבולוציה
ב. התלמידים ייצרו אבחנות בין מדעי ל-לא מדעי (תרבותי/דתי)
ג. התלמידים יבצעו פעילות בה יתבקשו להתאים בין אמירות של אנשים דתיים/חילונים בקשר לאבולוציה, במטרה להבהיר שאנשים דתיים לא בהכרח מתנגדים לאבולוציה
ד. התלמידים ייחשפו לראיות התומכות באבולוציה מתחומים שונים

מהלך השיעור:

במידה והמורה מעוניין לבחון האם קבלת האבולוציה בקרב תלמידיו השתנתה בעקבות הפעילות, ניתן להעביר לתלמידים את שאלון ה-MATE הממוחשב לצורך מענה עליו לפני ואחרי השיעור.

1. <u>סיעור מוחות</u>
המורה תכתוב על הלוח/תקרין במצגת את השאלה: מה עולה לכם לראש כשאתם שומעים את המילה: אבולוציה?
מומלץ להשתמש בכלי שנקרא: mentimeter (https://www.mentimeter.com/), אליו התלמידים נכנסים באמצעות הסמארטפון, מקלידים את תשובתם, שמופיעה על הלוח והמנטימטר מדגיש תשובות חוזרות בצורה הבאה:

(במידה ויש אתגרים טכנולוגים בכיתה ניתן לעשות זאת באמצעות כתיבה על הלוח כמובן).

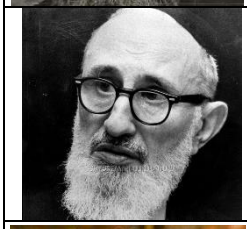
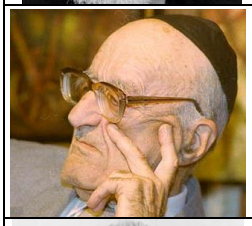
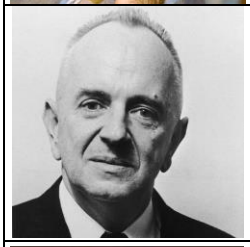
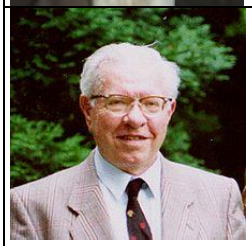
2. <u>דיון על ההבדל בין מדע לדת</u>
לאחר שכל התלמידים ענו על השאלה, המורה תשאל את התלמידים האם לדעתם כל האמירות שלהם הן מדעיות? אם לא, לאיזה תחום הן קשורות? לאחר מכן יתקיים דיון בכיתה בו האמירות יחולקו למדעיות ושאינן מדעיות. המורה תגדיר את ההבדל בין מדע לתחומי דעת אחרים (תרבות, דת) ותדגיש שלמרות שאבולוציה היא תיאוריה מדעית, יש לה השלכות והקשרים שאינם מדעיים.

בשיעור זה נלמד בעיקר על ההקשרים המדעיים של תיאוריית האבולוציה, אך לפני כן, בואו נראה כמה דוגמאות לחיבור בין השניים.
יש לציין שהחלק הזה יכול להיות מעמיק יותר/פחות בהתאם לידע של המורה בטבע המדע ובפילוסופיה של המדע, ברצון להעמיק בנושא, וביכולת התלמידים להתעמק בדיון (שתלויה בגיל).

3. <u>מי מאמין באבולוציה?</u>
הכיתה תחולק לקבוצות של 3-2 תלמידים. כל קבוצה תקבל 2 סטים של כרטיסיות: סט אחד המכיל תמונות ותיאור קצר של אנשים שונים (רבנים, מדענים וכו'), וסט המכיל אמירות של אותם אנשים בנוגע לאבולוציה. התלמידים יתבקשו להתאים בין אדם למה שאמר. פעילות זו תחשוף את ההנחות של התלמידים על מי לתפיסת עולמם אמור להתנגד לאבולוציה ומי לקבל אבולוציה. האנשים שנבחרו לפעילות זאת מציגים טווח רחב של תפיסות – מהתנגדות לקבלה, ויציגו לתלמידים את המורכבות.
ניתן לבחור אנשים שונים בהתאם לאוכלוסיית התלמידים (דת/מגזר וכו').
לאחר שהתלמידים התאימו בין הכרטיסיות, יתקיים דיון בכיתה בו התלמידים יסבירו את בחירותיהם.
לאחר מכן, המורה תציג את התשובות המפתיעות - בפעילות יש כמה רבנים ידועים שמקבלים אבולוציה – מה שיכול לעזור לתלמידים בעלי נטייה דתית להבין שדתיים לא בהכרח חייבים להתנגד לאבולוציה, ולכן עשוי להפחית מעט את ההתנגדות שלהם.
המורה תסכם את הפעילות בכל שאנשים דתיים לא בהכרח מתנגדים לאבולוציה, ותשאל את התלמידים למה לדעתם המחלוקת סביב אבולוציה מסרבת להעלם?
כדי לגבש דעה על אבולוציה, צריך להבין שזו אחת התיאוריות המבוססות ביותר במדע (רצוי להסביר כאן את המשמעות של תיאוריה במובן המדעי, ולא היום יומי).

4. <u>אבולוציה על קצה המזלג</u>
על מנת לחשוף את התלמידים למקורות הידע המגוונים שתומכים באבולוציה, המורה תציג 4 מקורות. משום שזו רק פתיחה לנושא ובהמשך ילמדו על כל המנגנונים באופן מפורט, כאן המטרה היא רק לחשוף ולעורר עניין ולכן המורה יכולה להסביר בקצרה ובתאם לרמת העניין של התלמידים: 1. מאובנים, 2. דמיון צורני בין איברי גוף של אורגניזמים בוגרים, 3. דמיון בין עוברים של בע"ח שונים, שמעיד על מוצא משותף, 4. אחוז הדמיון הגנטי הרב בין יצורים שונים.
לאחר הצגת הראיות לאבולוציה, המורה תציג סרטון קצר שמסביר על המנגנון האבלוציוני (יש הרבה סרטונים ברשת והמורה יכולה לבחור בהתאם להעדפתה, לרמת וגיל התלמידים, ולהגבלת הזמן.)
יש אפשרות לפתוח לדיון את השאלה האם השיעור סייע לתלמידים למתן את ההתנגדות שהרגישו כלפי אבולוציה, וניתן גם להעביר את שאלון קבלת האבולוציה בסוף השיעור.

כרטיסיות לפעילות: מי מאמין באבולציה?

"האבולוציה שופכת אור על דרכיו של אלוהים"	**הרב אברהם יצחק הכהן קוק** הרב הראשי האשכנזי הראשון בארץ ישראל.	
""מעולם לא הוטרדתי באורח רציני על-ידי הבעיה של תיאור בריאת העולם אשר בתורה לעומת התיאור המדעי של האבולוציה"	**הרב יוסף דוב הלוי סולובייצ'יק** רב אמריקאי, ראש ישיבה ,פילוסוף דתי.	
"אינני חושב, אני יודע שהייתה אבולוציה. כמו שאני יודע – לא מאמין – שקיימת יבשת אוסטרליה, אף שלא ראיתיה מעודי."	**פרופ' ישעיהו ליבוביץ'** מדען והוגה דעות.	
"שום דבר לא הגיוני בביולוגיה אלא לאורה של האבולוציה."	**תיאודור דובז'נסקי** גנטיקאי וביולוג אבולוציוני.	
"האבולוציה לא רק שאינה מוכחת, אלא אף בלתי אפשרית."	**פרופ' משה טרופ** חוקר ביוכימיה באוניברסיטת אריאל.	
"הסיכוי שצורות חיים מפותחות התפתחו במקרה, דומה לסיכוי שסופת טורנדו הפוגעת במחסן גרוטאות תגרום באקראי להיווצרות מטוס בואינג 747."	**סר פרד הויל** אסטרונום בריטי.	
"בסיפור על דבר הבריאה נתפרש גם כן סדר הבריאה ... המינים נבראו כל אחד בפני עצמו וכפשוטו של מקרא... ולא שנתפתחו זה מזה".	**רבי מנחם מנדל שניאורסון** הרבי מלובביץ, האדמו"ר השביעי של חסידות חב"ד	

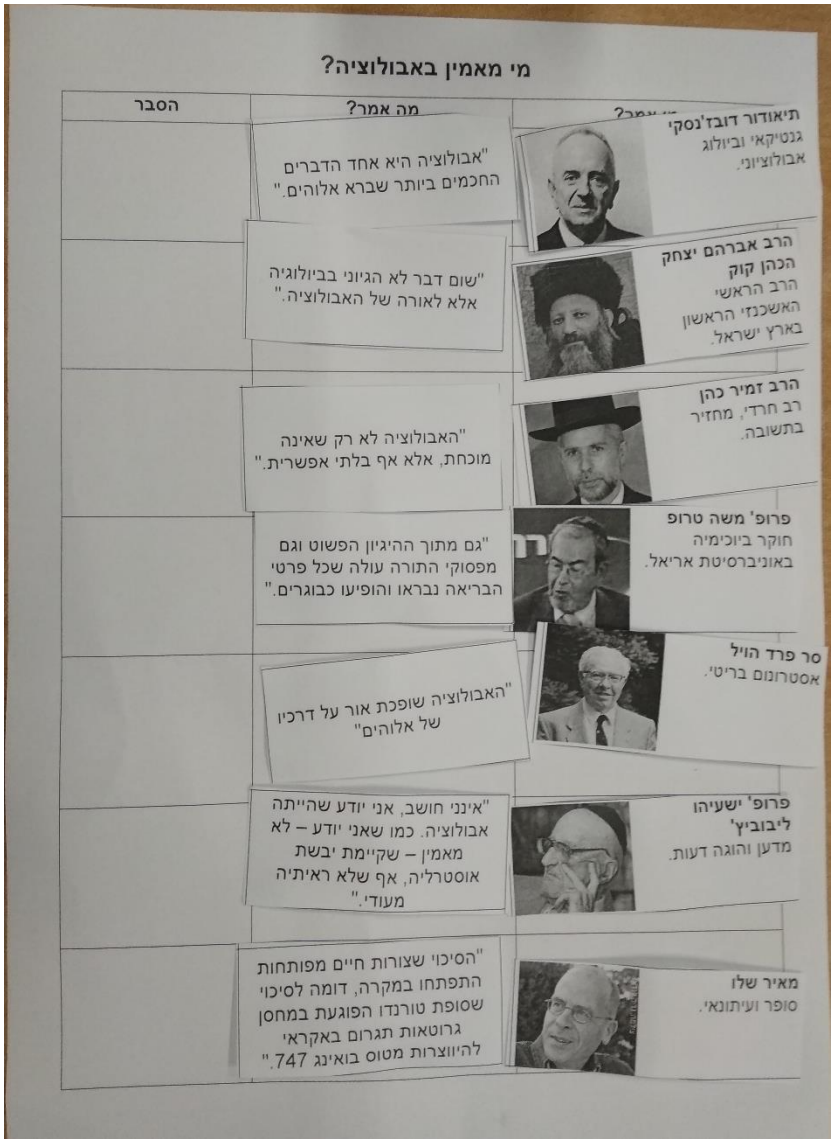
Appendix 11 – example of students' answers to the brainstorming

The students were asked what comes to their mind when they hear the word "evolution", and here two examples from two different classes are presented:

ביתה י'

ביתה ט'

Appendix 12 - Example of students' answers to the activity: “who believes in evolution?”



מי מאמין באבולוציה?

מי אמר?	מה אמר?	הסבר
תיאודור דובז'נסקי גנטיקאי וביולוג אבולוציוני.	"אבולוציה היא אחד הדברים החכמים ביותר שברא אלוהים."	
הרב אברהם יצחק הכהן קוק הרב הראשי האשכנזי הראשון בארץ ישראל.	"שום דבר לא הגיוני בביולוגיה אלא לאורה של האבולוציה."	
הרב זמיר כהן רב חרדי, מחזיר בתשובה.	"האבולוציה לא רק שאינה מוכחת, אלא אף בלתי אפשרית."	
פרופ' משה טרופ חוקר ביוכימיה באוניברסיטת אריאל.	"גם מתוך ההיגיון הפשוט וגם מפסוקי התורה עולה שכל פרטי הבריאה נבראו והופיעו כבוגרים."	
סר פרד הויל אסטרונום בריטי.	"האבולוציה שופכת אור על דרכיו של אלוהים"	
פרופ' ישעיהו ליבוביץ' מדען והוגה דעות.	"אינני חושב, אני יודע שהיתה אבולוציה. כמו שאני יודע – לא מאמין – שקיימת יבשת אוסטרליה, אף שלא ראיתי מעודי."	
מאיר שלו סופר ועיתונאי.	"הסיכוי שצורות חיים מפותחות התפתחו במקרה, דומה לסיכוי שסופת טורנדו הפוגעת במחסן גרוטאות תגרום באקראי להיווצרות מטוס בואינג 747."	