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"I Think that Teachers Do Not Teach Evolution Because It Is Complicated": Difficulties in Teaching and Learning Evolution in Israel

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Abstract

The conflict between acceptance and disapproval of evolution has led to obstacles in its teaching and learning. Other difficulties, such as both teachers' and students' alternative perceptions, student maturity in the face of learning this complicated topic, and teachers' gaps in evolution knowledge, add to the difficulties in teaching and learning evolution. The aim of this study was to grasp the difficulties in the teaching and learning of evolution perceived by curriculum writers compared to those perceived by in-service junior high school science and technology teachers and high school biology teachers in Israel. The findings revealed a wide range of perceived difficulties in the teaching and learning of evolution, mainly in the fields of religion, teacher and student knowledge, student maturity, and alternative perceptions. A questionnaire distributed among in-service Israeli teachers added strength to interviews with the curriculum writers, with both referring to some of the same difficulties. However, some difficulties were heard only in the interviews. Curriculum writers were more concerned with questions of faith that teaching evolution raises, whereas in-service teachers were concerned with their students' difficulties in understanding natural selection and mutational randomness. Teacher-training programs that focus on teachers' lack of evolution knowledge and on pedagogical skills, as well as the design of teaching materials that take into account these difficulties, are recommended for future research.

Keywords Evolution · In-depth interview · Learning difficulty · Questionnaire · Teaching difficulty

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Introduction

The theory of evolution has been accepted by almost all scientists (Dobzhansky, 1973), but is often ignored or disapproved of by the general public (Glaze & Goldston, 2019; Hawley & Sinatra, 2019; Pear, 2018). In fact, its acceptance by scientists has placed it in a central position in biology; as has been stated: "Nothing in biology makes sense except in the light of evolution" (Dobzhansky, 1973).

The disparity between acceptance and disapproval of evolution has posed obstacles to its teaching and learning. In the USA, the teaching and learning of evolution are the subject of much debate (Glaze, Goldston, & Dantzler, 2015), and today, voiced challenges to the teaching of evolution in schools are becoming increasingly common worldwide. A country's religious demographics and dominant views on the extent to which evolution should be taught in the science classroom (Hermann, 2013) influence evolution's place in the science curriculum or the time allocated to it in the syllabus. These parameters make it difficult to teach evolution, but this is only part of the picture. Other factors, such as alternative perceptions by both teachers and students, the relevance of students' maturity in learning this complicated topic, and teachers' lack of knowledge about evolution, all add to the difficulties involved in teaching and learning this topic.

In this paper, we sought to delineate the difficulties in teaching and learning evolution, a topic that has been implemented in the Israeli science and technology (ST) (Israeli Ministry of Education, 2016a) and biology (Israeli Ministry of Education, 2016b) curricula. Our main aim was to grasp the difficulties in the teaching and learning of evolution as perceived by curriculum writers of the junior high school (JHS) ST curriculum and the high school (HS) biology curriculum in comparison to those perceived by in-service JHS ST teachers and HS biology teachers in Israel. The writers of a curriculum have local and even international interests, whereas in-service teachers are usually concerned only with their own classes and do not have a wide perspective of the implications of their teaching of a certain topic on other schools and sectors. Thus, our aim was to identify the wide range of difficulties perceived by these two subpopulations and compare them, to obtain a richer, more detailed and in-depth view of the difficulties involved in the teaching and learning of evolution.

Theoretical Background

Difficulties in the Teaching of Evolution

Teaching evolution can be challenging, because in-service teachers (Hawley & Sinatra, 2019), as well as preservice teachers (Nadelson & Sinatra, 2010), have alternative conceptions of evolution. This has been found regarding natural selection (Cofré, Cuevas, & Becerra, 2017) and creationism (Nehm, Kim, & Sheppard, 2009). Teachers may serve as a source of biological evolution-related misconceptions for their students (Yates & Marek, 2014).

Teachers also lack sufficient pedagogical content knowledge (PCK) of the topic (Stasinakis & Kampourakis, 2018). This lack of PCK may include understanding the common student misconceptions about evolution, knowledge of good laboratories and activities, and awareness of evolution teaching resources to engage students and to teach about the differences between science and religion (Borgerding & Deniz, 2018). Recent papers have shown that when teachers use different pedagogical approaches, such as models

and argumentation, the understanding of evolution is facilitated (Reiss & Harms, 2019). Lack of evolution content knowledge is also common among teachers and sometimes leads to frustration with the teaching of this topic (Glaze & Goldston, 2019; Nadelson & Nadelson, 2010), but this is not the only lack that has been found. For example, prospective secondary science teachers in the USA were unaware of the nature of scientific inquiry; they failed to understand the diverse research methods used by scientists (Cofré et al., 2017). If teachers are not fully prepared, they might find it difficult to teach evolution because they themselves lack the adequate preparation for teaching it.

It seems that even when teachers are perceived as adequately prepared to teach evolution, they may still be uncomfortable with teaching its concepts. Evidence from 64 American experienced K–8 science teachers indicated that they do not feel qualified to teach the concepts of evolution (Nadelson & Nadelson, 2010). Moreover, only 28% of 926 American biology teachers introduced evidence of evolution having occurred and taught evolution as an important theme in biology (Berkman & Plutzer, 2011).

Beginning teachers often face resistance to evolution instruction and are therefore reluctant to teach it, whereas more experienced teachers are able to build trust in the community, allowing them to teach about evolution (Friedrichsen, Brown, & Schul, 2018). In a study from Turkey, a novice teacher provided non-Darwinian explanations, whereas an experienced one predominantly applied key concepts of natural selection in her causal explanations; nevertheless, cognitive biases regarding evolution were also found in the latter teacher's explanations (Yesilyurt, Oztekin, Cakiroglu, & Deniz, 2021). All of these difficulties in the teaching of evolution, combined with those in learning evolution, make the situation even more complex for both teachers and students.

Difficulties in Learning Evolution

We mentioned teachers' alternative conceptions as a difficulty encountered in the teaching of evolution; by the same token, students' alternative conceptions of evolution pose one of the obstacles to learning about it (Harms & Reiss, 2019). One of the most investigated of these conceptions is natural selection (Lucero, Delgado, & Green, 2020; Prinou, Halkia, & Skordoulis, 2008). While learning evolution, it is difficult for students to understand that the functions in biological systems are the outcome of natural processes, such as selection, and not a fulfillment of intentions or needs (Kampourakis, 2020). Yet, even though natural selection is taught at all levels and is a topic that has received much attention in different courses, research has shown that learning about it does not prepare students to do well on other topics in evolution (Ziadie & Andrews, 2018).

Natural selection is not the only problematic issue. The understanding of basic evolutionary concepts is not well established. Students have alternative conceptions regarding what is considered evolution in biology, the main mechanism of evolutionary changes, what the theory of evolution actually explains, and what the word "theory" means in science (Prinou et al., 2008). In addition, to explain evolutionary changes, students often use teleological and occasionally Lamarckian arguments (Eder, Seidl, Lange, & Graf , 2018).

In addition, in the USA, teachers admit that evolution is a difficult topic for their students to study because the time dimension is difficult to grasp (Hermann, 2013). Students have fixed ideas that conflict with scientific perspectives such as species change and long timespans. To understand these notions, which might conflict with students' prior experiences, background knowledge, and, possibly, personal beliefs, students may require a

conceptual change (Heddy & Sinatra, 2013). The difficulties in teaching and learning evolution add to the tenuous place held by evolution in science curricula worldwide, and make the teaching of it even more complex.

Why Are Educational Stakeholders Relevant?

The difficulties involved in the teaching and learning of evolution constitute a global phenomenon. When writing the diverse science curricula around the world, these difficulties might be taken into consideration by stakeholders who are involved in the planning and implementation of the new curriculum in the educational system, taking into consideration its needs and objectives (Birdthistle, Hynes, & Fleming, 2007). Stakeholders are identified as those who have researched the scientific ideas that should be taught in school science; they include science educators, scientists, and even historians and philosophers of science, as well as experts engaged in work to improve the public's understanding of science (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003).

In this study, we focused on the difficulties involved in the teaching and learning of evolution as perceived by two groups of educational stakeholders. Most stakeholders in the first group were writers of science curricula. Some were supervisors at the Ministry of Education; some, developers of science learning and teaching materials; and some, leading JHS ST and HS biology teachers. These educational stakeholders reflect the expected difficulties while writing the curriculum documents, known as the "formal" curriculum (van den Akker, 2003). The second group of stakeholders was made up of in-service JHS ST teachers and HS biology teachers who reflect the concurrent situation in the classroom, revealing the difficulties that arise while actually teaching evolution, referred to as the "operational" curriculum (van den Akker, 2003).

Aim and Research Questions

The aim of this research was to enrich our knowledge regarding difficulties in the teaching and learning of evolution via a survey of two groups of educational stakeholders. We refer to the first group, most of whom are involved in writing curricula, as "group A," who were interviewed about difficulties involved in the teaching and learning of evolution. We refer to the second group, the in-service teachers, as "group B," who were asked to fill out an open-ended and a closed-ended questionnaire. Use of participants from two groups of stakeholders was expected to provide a richer, more detailed and in-depth view of these difficulties. The research question investigated in this study was: Which difficulties in the teaching and learning of evolution do curriculum writers (group A) in comparison to in-service teachers (group B) perceive?

Methods

Research Design

In Israel, the teaching of evolution has changed in the last 5 years. In 2016, evolution was explicitly mentioned in the JHS ST curriculum and referred to as a compulsory

topic (Israeli Ministry of Education, 2016a); at the same time, evolution was accepted as a compulsory topic in the HS biology curriculum (Israeli Ministry of Education, 2016b). These curricula, and all curricula in Israel, are centrally written by teams led by the relevant chief supervisor at the Ministry of Education. The team is comprised of developers of teaching and learning materials, scientists involved in education, and experienced science teachers. All of these educational stakeholders are referred to in this article as group A.

The in-depth interview is a qualitative method that is suited to exploring issues that hold some complexity and to studying a process that occurs over time (Ritchie, 2003). The qualitative methodology used in this research was that of the "multiple case study," in which several cases are examined to discover the similarities and differences between them (Baxter & Jack, 2008). The interview conducted with group A dealt with two main topics: (i) pedagogical considerations regarding the introduction of evolution into the JHS ST and HS biology curricula and (ii) possible tensions regarding theological components related to this implementation. In this article, we focus on the difficulties in the teaching and learning of evolution that were raised by the interviewees with respect to the first topic.

The questionnaire, written after the results of the group A interviews had been analyzed, was sent to a few hundred teachers in group B. Of these, 95 teachers responded with a completed questionnaire. The aim of the questionnaire was to grasp the difficulties in teaching and learning evolution raised by in-service teachers.

Participants

Our research population was composed of two groups. Group A consisted of 21 educational stakeholders (Appendix 1) and group B consisted of 95 in-service teachers. In group A, two were scientists consulting for the Ministry of Education (A), two were developers of teaching and learning materials (B), three were chief supervisors at the Ministry of Education at the time of the interview (C), four were former chief supervisors at the Ministry of Education (D), five were leading HS biology teachers (E), and five were leading JHS ST teachers (F). The letters (A–F) and numbers (1–5) will be used to refer to these interviewees (Appendix 1).

To reach the educational stakeholders, we sent emails to 13 educational stakeholders who had been associated with the design of the ST curriculum and the biology curriculum in Israel, according to the official web page of the Pedagogical Secretariat at the Ministry of Education. We asked if they were willing to participate in an interview regarding implementation of evolution into the curricula. All of them were willing, although two of them admitted that they had not been involved in the 2016 curricula. We interviewed the 11 educational stakeholders who were involved (letters A–D) for approximately an hour and a half each, during the first half of 2018.

All of the interviewees granted permission to record the interview and to use it anonymously for research purposes. The interviewees who were working at the Israeli Ministry of Education at the time of the interview asked to read their interview before we published it. We sent them the sentences from their interview for approval and two sentences were not published because they might be interpreted as going against Ministry of Education policy.

The 10 other group A educational stakeholders (letters E and F) were interviewed in 2 focus groups for an hour and a half in mid-2018. Each group consisted of 5 teachers with at least 10 years of teaching experience. These teachers came from a variety of places and sectors throughout Israel. They were part of a professional learning community of leading teachers, meaning that they led a community of 20–25 teachers who met on a monthly basis. These 10 leading teachers therefore reflected the situation among at least 200 teachers.

Group B consisted of 95 in-service teachers who filled out a questionnaire. The questionnaire was uploaded in mid-2019 to the Israeli JHS ST teachers' website for 2 weeks and, at the same time, was emailed to 50 in-service HS biology teachers who were on the distribution list of the National Center for High-School Biology Teachers. Of the teachers who filled out the questionnaire, 50 were teaching evolution in JHS, 25 in HS, 8 at both levels, and 12 of them were not teaching evolution but were ST or biology teachers. Of these 95 teachers, 61 taught at Jewish secular schools, 21 at Jewish religious schools, 6 at Jewish ultra-orthodox schools, 4 at Arabic schools, and 3 in other sectors.

Israel is a multicultural country. According to the Israeli Central Bureau of Statistics (2018), 75% of the population are Jews, 20% Arabs (Muslims and Christians), and 5% others. Among the Jews, 45% define their way of life as secular, 41% as traditional or religious, and 14% as ultra-orthodox. Our research participants represented all parts of Israeli society, though the percentage of Arab teachers was lower than their percentage in Israeli society (~20%). Teachers in Israel usually teach at schools in the sector to which they belong: Jewish religious teachers teach at religious schools and Muslim teachers teach at Muslim schools, except for 2.3% who teach in the Jewish secular sector (Central Bureau of Statistics, 2018).

It should be noted that there was no overlap between the participating teachers of group A and group B. The goal of including a group of teachers additional to the leading teachers of group A was to enrich our knowledge of the difficulties in the teaching and learning of evolution as perceived by another group of in-service teachers via questionnaires.

Analysis of the Interview

The analysis of the interviews was conducted in stages. All of the interviews were tape-recorded, and then precisely transcribed. The aim of this procedure was to hear the interviewees' voices (Kvale, 1994), as required by the qualitative grounded theory approach, and to avoid starting our analysis with preexisting categories. Once we listened to and transcribed the interviews, we continued with a comprehensive coding process to create the categories (Devers & Frankel, 2000).

First, the first author conducted a "thematic analysis" (Boyatis, 1998; Dey, 1999) to obtain the main themes emerging from the interviews. Then, the first author obtained the codes from the thematic analysis for four interviews by "grounded theory" analysis (Basit, 2003; Corbin & Strauss, 2008). This process was performed twice by the first author at 2-week intervals to ensure intracoder reliability; 90% of the codes remained the same, but some of the categories were changed. The next stage consisted of a reflective process. The co-author of this paper, as well as two additional science education experts, validated the codes (Creswell & Miller, 2000). A dialogue took place between the researchers to agree on how the data should be categorized (Graneheim & Lundman, 2004). Elaborations that led to

any disagreements were discussed until 100% agreement on the elaborated categories was reached. The rest of the interviews were then categorized by the first author, and revised by the co-author according to the final agreed-upon categorization. During the coding process, if there were themes that matched several categories, we counted them as relating to all of those categories.

Interview Validation and Reliability

During the data collection, we attempted to be as sensitive as possible to reducing any bias due to prior expectations or experience, and to take part in analysis reflexivity. In addition, personal biases were clarified at the beginning of the research to improve the reliability of the findings (Mays & Pope, 2000). Since researchers interpret qualitative data subjectively, content validation was performed with the assistance of four science education experts, all with broad experience in qualitative analysis, so as to capture the widest possible view while defining the final codes (Elo & Kyngäs, 2008). Moreover, the researchers discussed the categorization until they agreed upon it (Graneheim & Lundman, 2004). This procedure was performed twice, to ensure precision of the categorization.

Data Analysis and Validity of the Questionnaire

To validate the questionnaire, it was examined by three experts in science education: two of them were also HS teachers and one a teacher-training expert. This validation assessed the suitability of the questions to the study's goals, the relevance of the questionnaire to the research questions, and the questions' phrasing. As Glynn, Taasoobshirazi, and Brickman (2009) suggest, we promoted candid responses by assuring the teachers that their identities would remain confidential, after explaining that their responses would help science education researchers better understand and improve evolution teaching.

The questionnaire included four sections (Appendix 2) and was constructed after the analysis of the interviews. For example, group A stakeholders spoke about the relevance of the students' age (Table 3), and we consequently asked the group B teachers question 4 (Appendix 2). Group A spoke about students who lack an understanding of evolutionary processes (Table 3) and we asked questions 5 and 6. We conducted a thematic analysis (Boyatis, 1998) to obtain the main themes arising from the open-ended answers. The third section (question 7) included alternative perceptions obtained from the in-depth interviews (Table 3), asking the teachers to refer to them using the following Likert-type scale: 1—no alternative perceptions, 5—very significant alternative perceptions. The fourth section (questions 8–11) included "yes/no" questions and multiple-choice answers to explain the choice in the "yes/no" questions. These questions referred to the teachers' lack of knowledge in the field of evolution, a topic raised in the interviews (Table 1).

Statistical Analysis

Two statistical methods were applied, using SAS software. Firstly, for comparing the frequencies of the members of the two groups, we used the chi-square test. Since the

Table 1 Difficulties in the teaching of evolution obtained from group A interviews

Category	No. of teachers that mentioned the category ($n=21$)	No. of times mentioned ($n=51$)
a. Teachers lack evolution knowledge	8	13
b. Evolution is not mentioned in the teaching materials	5	8
c. Evolution is not emphasized in the curricula	11	17
d. Little time is allocated for evolution	4	5
e. There are no questions regarding evolution in external exams	5	8

members could mention more than one category, the chi-square test was corrected (Vlach & Plašil, 2006). For comparing the mean of the times a category was mentioned by members of the two groups, the Mann-Whitney-Wilcoxon (MWW) non-parameter test was used.

Teacher Training in Israel

ST and biology teachers in Israel acquire their scientific knowledge during a 3-year science teacher preparation program given at either colleges, where they acquire a B.Ed. degree, or universities, where they acquire a B.Sc. degree. In addition, 1-year science or biology Postgraduate Certificate in Education (PGCE) programs are offered by approximately 20 colleges and universities throughout the country. To teach in 11th and 12th grades, teachers are required to have a M.Sc. or M.A. degree. After preservice training, the student teachers start a 1-year practicum (Israeli Ministry of Education, 2020). The in-service ST and biology training is also centrally managed by the Israeli Ministry of Education. Teacher-training courses aim to promote teaching through the acquisition of knowledge and broadening of horizons, and reward teachers with a salary raise of up to 30% along the years.

Results

This section is divided according to our analysis of the group A interviews (Tables 1 and 3) and the analysis of the group B questionnaire (Tables 2, 4, 5). From both groups, we collected information regarding "Difficulties in the teaching of evolution" (Tables 1 and 2) and about "Difficulties in the learning of evolution" (Tables 3, 4, and 5). Table 6 compares the difficulties in the learning of evolution as reflected in the interviews of group A and in the open-ended questions of group B.

Difficulties in Teaching Evolution

During the interview, the group A curriculum writers raised problems regarding "Difficulties in the teaching of evolution" that fell into the five categories summarized in Table 1. The middle column of the table refers to the number of interviewees, out of the 21, who mentioned each category during the interview. The right column refers to

Table 2 Difficulties in the teaching of evolution due to teachers' lack of knowledge as expressed in the closed-ended question on the group B questionnaire

Teachers lack knowledge about	Percent of times the item was chosen (%)	Number of teachers who chose the item[a]
a. Evolution vs. religion	33.3	27
b. Human evolution	22.22	18
c. The theory of evolution	17.28	14
d. The influence of man on evolution	12.35	10
e. The origin of diversity	6.17	5
f. Diversity as a source for natural selection	4.94	4
g. The influence of natural selection on diversity	3.70	3

[a] Of the 95 teachers, 41 of those who answered they did not lack evolution knowledge did not choose any difficulties and 6 of those who answered they lack evolution knowledge did not choose any difficulties

the number of times each of the categories was mentioned. Since there were interviewees who mentioned some of the categories more than once during their interview, the total number of statements is 51. The first category, mentioned by 8 of the group A interviewees 13 times "Teachers lack evolution knowledge," emphasizes the fact that the teaching of evolution is difficult because the teachers themselves lack the needed knowledge: *Teachers do not have the knowledge and confidence, and it will be difficult for the teacher to teach evolution. I would definitely do advanced training for teachers.* (D2). This quote shows the keen concern of educational stakeholders about the fact that teachers do not have enough knowledge in the field of evolution.

The second category, "Evolution is not mentioned in the teaching materials," was also perceived by 5 interviewees, mentioned 8 times, as making the teaching difficult: *"No life sciences book in junior high school even mentions the word evolution. The theory is not mentioned, variety and adaptation are not mentioned, as if they do not exist. It's like talking about molecules without talking about atoms"* (D3). This quote indicates that learning materials on evolution are not available to the teachers, and that they cannot easily find a chapter in a school textbook concerning evolution; this might

Table 3 Difficulties in the learning of evolution obtained from group A interviews

Category	No. of teachers that mentioned the category ($n=21$)	No. of times mentioned ($n=52$)
a. Student age	5	10
b. Students lack an understanding of evolutionary processes	4	5
c. Students have alternative perceptions:		
i. Evolution contradicts faith	12	21
ii. The time dimension	4	7
iii. The common ancestor	4	4
iv. Lamarckism vs. Darwinism	1	1
v. Natural selection	2	4

Table 4 Difficulties in the learning of evolution as expressed in the Likert-type items regarding alternative perceptions on the group B questionnaire ($n = 95$)

Students' alternative perceptions	Percentage of teachers[a]	Frequency of teachers[b]
a. Lamarckism vs. Darwinism	84.21	80
b. The time dimension	83.16	79
c. The common ancestor	81.05	77
d. Evolution contradicts faith	80	76
e. Natural selection	71.58	68

[a] Percentage of teachers that chose 3, 4, or 5 on the Likert scale (1—no alternative perceptions, 5—very significant alternative perceptions)

[b] Frequency of teachers that chose 3, 4, or 5 on the Likert scale (1—no alternative perceptions, 5—very significant alternative perceptions)

lead to not teaching the topic. This problem concerns, and even burdens, the stakeholders, because they understand the consequences of a lack of available teaching materials for the teaching of evolution.

The third category, "Evolution is not emphasized in the curricula," was mentioned by 11 of the interviewees, 17 times: *"In previous curricula the principles of evolutionary processes were only the core ideas. I call it half-pregnancy, because if it is only in the main ideas and it has no expression within the study topics, then you have done half the work."* (D3)

"Little time is allocated for evolution," the fourth category, was mentioned by 4 interviewees, 5 times: *"There is no time to teach everything. If I teach evolution thoroughly, then I won't have time to teach the cell. Unfortunately, nothing can be taught comprehensively, but we can give general principles…. So anyone who expects the curriculum to show all of evolution, this is not going to happen, but it is not because it is evolution."* (C3)It seems that the time assigned for teaching evolution, like other topics in the curriculum, is not sufficient to delve more deeply into the topic. Is it enough for students to understand evolution in the appropriate context? We cannot really know. The relatively short time assigned for teaching evolution adds to the minor place occupied by this topic in the curriculum and to the degree to which it is addressed in the national exams. This last claim is the fifth category "There are no questions regarding evolution in external exams" mentioned by 5 of the interviewees, 8 times.

Table 5 Difficulties in the learning of evolution as expressed in the "yes/no" questions on the group B questionnaire

Teachers' perceptions of students' ability to learn evolution	Teachers who answered "yes" (%)	No. of teachers ($n=95$)
a. Significance of the age at which students learn evolution	61.05	58
b. The evolutionary explanations are difficult to understand	87.37	83
c. Students lack the basic biology knowledge needed to understand the topic of evolution	41.05	39

Table 6 Comparison of percentage, mean, and Mann-Whitney-Wilcoxon test regarding difficulties in learning of evolution as expressed in the group A interviews and in the open-ended questions of the group B questionnaire

Category	Percentage of group A members who mentioned the category ($n=21$)	Percentage of group B members who mentioned the category ($n=95$)	Mean (Std Dev) of times the category was mentioned by each member of group A	Mean (Std Dev) of times the category was mentioned by each member of group B	MWW test (Z, normal approximation)
a. Difficulty in understanding natural selection and mutational randomness	9.5	43.2	0.19 (0.68)	0.495 (0.617)	−2.681**
b. Students lack prior biological knowledge so as to understand evolution	19	35.8	0.238 (0.539)	0.4 (0.572)	N.S.
c. Students are not mature enough to learn evolution	23.8	34.7	0.476 (1.078)	0.368 (0.527)	N.S.
d. Evolution raises questions of faith	57.1	23.2	1 (1.225)	0.295 (0.599)	3.360***
e. Difficulty in understanding the time dimension	19	14.7	0.333 (0.796)	0.147 (0.356)	N.S.
f. Difficulty in understanding the origin of species	19	6.3	0.19 (0.68)	0.063 (0.245)	N.S.
g. Students have alternative perceptions					
regardingLamarckism vs. Darwinism4.85.30.048 (0.218)0.053 (0.224)N.S.*N.S.* not significant					

**> 0.001$p < 0.01$; ***$p < 0.001$

One of the former chief supervisors at the Ministry of Education claimed: *"If there was a question in the matriculation exams, they would teach evolution. In the eighth grade, if it shows up on the national exams, then they will teach it. It's not pleasant to say that this is the way to enforce things. We shouldn't enforce a plan through external exams. But that's what happens."* (D4).

Similarly, group A leading teachers expressed the lack of reference in the external tests: *"Evolution does not appear in the national exam. The national exam greatly affects teaching. Topics that appear in the national exam are taught in the classrooms"* (F3). These quotes show us that the time allocated to a certain topic in the curriculum, its place in the curriculum, and its appearance in the national exams all influence the teaching of that topic; if it is not placed centrally in the curriculum, it will be more difficult to teach, and the tendency may be to not teach the topic at all. More examples of quotations referring to the categories in Table 1 are presented in Appendix 3.

Results from the questionnaires filled out by the in-service teachers (group B) and those from the interviews (group A) showed that difficulties in the teaching of evolution stem primarily from teachers' lack of knowledge. The teachers were asked

(Appendix 2, question 8): "Do you, as a teacher, feel that you lack knowledge in the field of evolution?" Of the 95 teachers who filled out the questionnaire, 57.9% answered "yes." Even though 42.1% answered "no" to this question, when they were asked in question 10 if they would like to add knowledge in the field of evolution, 74.7% answered that they would. This finding strengthens and expands on the difficulty in teaching evolution that we heard about in the interviews, stemming from teachers' lack of knowledge about evolution. From the questionnaire answers, we understood that teachers do want to add to their knowledge of evolution and are willing to put time and effort into it; 75% of them answered that they would like to spend time participating in seminars and teacher-training courses.

The next question that we asked was (Appendix 2, question 9): "If yes, which of these terms is unclear or not sufficiently known to you (you can choose more than one)?" The three most prominent categories chosen by the teachers were "Evolution vs. religion," "Human evolution," and "The theory of evolution" (Table 2). Some of the teachers chose more than one item as unclear to them. Of all of the chosen items, we calculated the percentage of times that each item was chosen by the teachers and the number of teachers who chose each item.

Difficulties Concerning the Learning of Evolution

Another group of categories that emerged from the interviews related to "Difficulties in the learning of evolution," presented in Table 3. We traced three categories in this section: "Student age," "Students lack an understanding of evolutionary processes,"and "Students have alternative perceptions." The middle column refers to the number of interviewees, out of the 21, who mentioned each category during the interview. The right column refers to the number of times each of the categories was mentioned, giving 52 statements in total, since there were interviewees who mentioned some of the categories more than once during their interview.

"Student age" was raised by 5 of the interviewees 10 times, related to the issue that evolution is a difficult topic to study because it involves material that might not suit the students' cognitive stage: *"Evolution is not understandable at any age, but it is worthwhile teaching concepts in evolution according to the child's understanding."* (A2). According to these quotes, the student's age is a decisive factor in his or her ability to learn and understand evolution, since a certain maturity is needed to study this specific topic.

The second category that we heard regarding difficulties in learning evolution: "Students lack an understanding of evolutionary processes" was expressed by 4 of the group A interviewees 5 times: *"If the children do not understand what diversity is within a group, they cannot talk about evolution. They can't talk about natural selection…It turns out that the perception of variance is counterintuitive. Another thing that is hard to understand is that if there are successful individuals, I know that a certain set of features is successful, so why do I vitiate it every time? This is something that is hard to understand."* (B1).

This quote shows the difficulty involved in understanding basic evolution terms, leading to a problem understanding the more complex processes, and introducing the last category in Table 3: "Students have alternative perceptions," which is divided into

five subcategories: "The time dimension," "Evolution contradicts faith," "The common ancestor," "Lamarckism vs. Darwinism," and "Natural selection."

The most prominent alternative perception was "Evolution contradicts faith," raised by 12 of the interviewees 21 times. One representative example: *"It's probably something they heard at home, they heard this misconception that evolution contradicts faith and they bring it to the classroom"* (E3). "The time dimension" was an alternative perception reflected by 4 of the interviewees, 7 times: *"One of the toughest cognitive failures is the depth of time. Two thousand years we understand, ten thousand is the limit, beyond that we do not understand. Can't process it"* (B1). "The common ancestor" was referred to by 4 of the interviewees, such as the following:

> *It is very difficult for people to understand what a common ancestor is. That we evolved from the monkey. No, we and Monkey had a common ancestor. So teachers also have trouble with this. It is a misconception. The common ancestor may have been a monkey, but he is not the monkey you see today.* (B1)

"Lamarckism vs. Darwinism" was brought up by only 1 interviewee: *"So you can teach Darwinism and evolution and in the end, when the student answers the test he will become clearly Lamarcksist. At the end the child returns to what is convenient for him"* (E2).

Finally, "Natural selection" was brought up by 2 of the interviewees: *"If students do not understand the differences within a group they cannot talk about evolution. They cannot talk about natural selection, so do not talk about diversity within a group…Now it turns out that the perception of diversity is contrary to our intuition"* (B1). More examples of quotations referring to the categories in Table 3 are presented in Appendix 4.

The five alternative perceptions that were raised by the interviewees as contributing to the difficulties in learning evolution were also prominent in the group B responses to a closed-ended question in the questionnaire relating to difficulties concerning the learning of evolution (Table 4). The in-service teachers were asked (Appendix 2, question 7): "In the field of evolution, students have alternative perceptions. To what extent do you think your students have these alternative perceptions?" (Likert-type scale 1—no alternative perceptions, 5—very significant alternative perceptions). The middle column in Table 4 shows the percentage of in-service teachers who chose 3–5 on the Likert scale with respect to their students' alternative perceptions of "Lamarckism vs. Darwinism," "The time dimension," "The common ancestor," "Evolution contradicts faith," and "Natural selection." Eighty percent and more of the teachers ranked the first four alternative perceptions as 3–5, declaring that their students had significant alternative perceptions. The right column shows the frequency of teachers who chose these alternative perceptions as referring to their students. We checked for differences in the in-service teachers' opinions regarding these alternative perceptions of their students among those teaching in different religious sectors (Jewish religious, Jewish non-religious, Arabic, Jewish ultra-religious). We found no significant difference, meaning that these teachers' opinions do not relate to the religious sector to which they or their school belongs. In contrast, there was a significant difference between HS teachers and JHS teachers for two of the alternative perceptions: "The common ancestor" ($p = 0.0019$) and "Evolution contradicts faith" ($p = 0.0194$). For both concepts, according to their teachers, JHS students had more alternative perceptions than HS students.

As opposed to group A (Table 3), in group B (Table 4), "Lamarckism vs. Darwinism" was chosen by the highest percentage of teachers as a very common alternative perception. "Evolution contradicts faith," which was the most prominent alternative perception among group A, was less prominent in the choice of the group B in-service teachers. "The time dimension" was quite common in both groups. It should be mentioned that group A mentioned these alternative perceptions during the interview while group B was asked to relate to these alternative perceptions explicitly.

In addition, we asked the in-service teachers three "yes/no" questions (Appendix 2, Section 2): A high percentage of teachers answered "yes" to all three questions (Table 5), especially the question pertaining to evolutionary explanations being difficult to understand. Thus, the in-service teachers think that learning evolution is a difficult task. For these three questions, there was no significant difference between the teachers' answers according to school religious sector.

Each of these questions was followed by an open-ended reasoning for their answer to that question. The in-service teachers' open-ended answers to all three questions were divided into categories, obtained by thematic analysis, which are summarized in Table 6.

Interestingly, some of the difficulties in the learning of evolution that emerged in the open-ended answers to the questionnaire were similar to those expressed in the interviews. We summarized the common categories of both research groups' open-ended answers in Table 6 and compared the percentage of group A members who mentioned each category to the percentage of group B members who mentioned the similar category. Comparison of the percentage of members mentioning each category showed a significant difference, $\chi^2 = 26.66$, $p = 0.0086$ (DF = 12). To analyze which of the categories contributed to this significant difference, we analyzed the means of the number of times each category was mentioned by each member of group A and B and compared them by MWW test. The analysis showed that the means of two categories "Difficulty in understanding natural selection and mutational randomness" and "Evolution raises questions of faith" were significantly different between the two research populations. The higher mean of group B (0.495 ± 0.617) in the category relating to difficulties in understanding natural selection and mutational randomness shows that in-service teachers see this as a weighty difficulty in learning evolution much more than the group A members (0.19 ± 0.68). It seems that those who actually teach the topic of evolution in classes and face the students' learning difficulties, in class or in exams, see this topic as difficult in particular, more than curriculum writers.

The difficulty regarding questions of evolution and faith was more present among curriculum writers (1 ± 1.225) than in-service teachers (0.295 ± 0.599), showing that the former are more concerned about this issue than the latter. Maybe this is due to the fact that curriculum writers are more exposed to the science education literature and to global developments regarding tensions of evolution and faith than in-service teachers, and are more aware of the need to deal with them in classes.

Discussion

The aim of this study was to grasp the difficulties in the teaching and learning of evolution as perceived by curriculum writers (group A) in comparison to in-service teachers (group B). To trace the difficulties, we conducted in-depth interviews with the curriculum writers and sent a questionnaire to in-service JHS ST and HS biology teachers. The results of both of

these tools gave a complex yet coherent picture of the difficulties involved in teaching and learning evolution. A wide range of difficulties were raised by both research populations. The difficulties were mainly in the field of religion, teacher and student knowledge, student maturity, and students' alternative perceptions. The questionnaire results supported those of the interviews, referring to most of the difficulties raised in the latter, whereas some difficulties were only raised in the interviews. Thus, we acquired a wide range of difficulties raised by these two subpopulations, providing a richer, detailed and in-depth view of the difficulties in teaching and learning evolution.

Difficulties in Teaching Evolution

A central emerging theme regarding difficulties in teaching evolution in both the interviews and the questionnaires was teachers' lack of evolution knowledge. This theme has been reported in other parts of the world as well (Kim & Nehm, 2011). For example, in Indiana, USA, HS biology teachers were uncomfortable with evolution because they did not feel that they had a sufficient understanding of evolutionary principles and the scientific validity of the supporting evidence to teach this topic (Rutledge & Mitchell, 2002). In Israel as well, even though science teacher training is currently done thoroughly, teachers admit they lack the appropriate knowledge to teach evolution. This might be a result of the fact that when the experienced teachers studied in universities and colleges, there was no "Evolution" course in most of the Israeli institutes and the topic was only a marginal part of other courses. Nowadays, the situation is different in most institutes. Lack of knowledge is an obstacle to teaching evolution and can thus be presented as a difficulty in evolution teaching; however, the situation is reversible. Following teachers' courses, one could see statistically significant gains in teacher knowledge of evolution and the nature of science, and a significant decrease in misconceptions about evolution and natural selection (Nehm & Schonfeld, 2007).

It should be mentioned that teachers have also previously reported biological topics other than evolution as difficult to teach; JHS teachers have indicated difficulties in understanding biology concepts, nonavailability of teaching aids, and more (Chavan, 2016). Yet, biology teachers generally indicate little difficulty in teaching most of the topics in biology (Ogunkola & Samuel, 2011). This analysis shows us that evolution might be a unique topic in which a great deal is known about the lack of teachers' knowledge on the subject.

In contrast to a lack of knowledge about evolution, which was raised as a difficulty by both research populations in this research, a few themes regarding difficulties in teaching evolution were prominent among the curriculum writers, but were not mentioned by the in-service teachers. One such theme was that not only is evolution not emphasized in the curricula, it occupies a very marginal, noncentral place there, preventing it from being taught by some teachers. Emphasis in the curriculum is a universal issue because, in many countries, evolution has never been an integral part of science or biology curricula. In some states in the USA, legislation prevents teaching it (Hall & Woika, 2018). Thus, the curriculum is certainly a domain that stakeholders the world over have to deal with, and in this research, we assume that the curriculum writers refer to it because some of them were in charge of the implementation of evolution into the curricula. In-service teachers did not refer to it, probably because they are less concerned with issues that are not directly related to their students.

Surprisingly, another theme that was not mentioned as a difficulty in teaching evolution by the in-service teachers was the absence of any mention of evolution in the teaching materials. The curriculum writers referred to this as a difficulty for teachers. This difficulty in teaching evolution is an international one. The lack of any reference to evolution in biology textbooks has been noted in many world regions (Aleixandre, 1994). These cases show that the educational stakeholders have examples in other countries to rely on. Currently, in Israel, there is no official textbook dealing with evolution as part of the core curriculum. The ecology book that most teachers use (Amir, 2007) mentions evolution a few times, but there is no chapter dealing with the topic thoroughly. Some teachers, who teach evolution more comprehensively than in that textbook, use PowerPoint presentations or other teaching materials that they find on-line. Thus, the fact that in-service teachers did not refer to this issue may mean that it bothers them less. We cannot be sure why; they might have found satisfactory alternatives, they might be using outdated teaching materials, or maybe they avoid teaching the topic and they do not feel that teaching materials are lacking.

Difficulties in Learning Evolution

When dealing with difficulties in learning evolution, a central product of the research was that the alternative perceptions mentioned by in-service teachers as most prominent among their students were similar to those that the curriculum writers mentioned. These alternative perceptions included the concept that evolution contradicts faith, the time dimension, the common ancestor, and Lamarckism vs. Darwinism. Much research has been published regarding alternative perceptions in the field of evolution among students (Kampourakis, 2020). However, prior research revealed that not only students, but also teachers, possess alternative perceptions relating to evolution (Nehm et al., 2009; Yates & Marek, 2014) and these are often indistinguishable.

Another noticeable theme regarding difficulties in learning evolution that we heard from both research populations was the relevance of the students' age. The influence of age in determining understanding and acceptance of evolution is controversial. Some studies found that even young children aged 5–6 years do not basically oppose the idea of within-species variation (Emmons & Kelemen, 2015), whereas others found age to be a factor associated with learners' acceptance of evolution alongside their religious beliefs (Mpeta, de Villiers, & Fraser, 2015). Other authors recommended that evolution not be taught at the JHS level, because older students may be better equipped cognitively to understand topics in evolution (McVaugh et al., 2011). Most of these outcomes support the findings of this research that age is a relevant issue when speaking about understanding the main concepts of evolution, and that young students might encounter difficulty grasping the main concepts of the topic.

An additional theme that emerged from both research populations is that students lack an understanding of evolutionary processes. A high percentage of in-service teachers argued that evolution explanations are difficult to understand. This claim expands the list of difficulties in learning evolution beyond the generally attributed theological ones (Siani & Yarden, 2020). This lack of understanding is a widespread phenomenon involving a misunderstanding of the nature of science, and personal difficulties in understanding due to evolution's seemingly abstract nature (McVaugh et al., 2011). In addition, teachers indicate that their students generally possess a low understanding of evolution (Peker, Comert, & Kence, 2010).

Another interesting finding is that the curriculum writers spoke more about the controversy between evolution and faith than did the in-service teachers. Thus, in-service teachers, who meet students daily, face their students' learning difficulties in class or in exams, difficulties which are less related to the controversy of evolution and religion (Hawley & Sinatra, 2019). Student difficulties relate to the complexity of the evolution subject matter, especially natural selection and mutational randomness. The curriculum writers are probably more involved in this worldwide controversy than in-service teachers, and we might conclude from this difference that controversy of evolution and religion should be spoken about with teachers and should be raised to their awareness so they will deal with it in their classes. These findings are in line with previous ones (Siani & Yarden, 2020) in which implementation of evolution into the ST and biology curricula was less controversial than expected, which might mean that in-service teachers barely deal with the controversial part of evolution in classes.

In conclusion, looking into the difficulties involved in teaching and learning evolution according to the two research populations of stakeholders, we see that both populations raised similar problems of students' alternative conceptions and lack of teacher knowledge. However, a closer look at the results raises some points that distinguish the two groups of educational stakeholders. The considerations of those concerned with national implications of the teaching and learning of evolution also involve how the topic is, or is not, emphasized in the curricula, the availability of teaching materials, and the controversy of evolution and faith, whereas in-service teachers are less concerned with these issues.

Limitations

A noticeable limitation of our study is the small number of participating interviewees. Had the number of interviewees been larger, we would have heard more opinions relating to difficulties in teaching and learning evolution. Nevertheless, in Israel, the curricula are centrally written and are obligatory for all sectors; as such, they do not involve many stakeholders. We did interview the curriculum writers of the Ministry of Education who were associated with the ST and biology curricula when the topic of evolution was introduced. We aimed to overcome this limitation by adding another research tool, i.e. the questionnaire sent to the in-service teachers, thereby expanding our scope so as to enrich and deepen our understanding of the difficulties involved in teaching and learning evolution perceived by the two research populations.

Another limitation of our study is that we did not interview students; this could have added the perspective of learning difficulties from the students' angle. We did not want to add the students' angle because this could have biased our results or shifted the focus to other aspects that were not raised by the educational stakeholders.

Recommendations and Further Research

This study has some implications, at the practical level of teaching and learning biology in HS and JHS, and at the science education research level. On a practical level, institutes in charge of teacher training have a duty to organize teacher-training programs in evolution. These programs might reduce the teachers' doubts about whether they should deal with this topic at all, and the extent to which they should focus on it in their classes.

Taking into account the findings of this research, we are currently conducting a 30-h teacher-training program that focuses on knowledge and pedagogical skills in topics that the teachers mentioned lacking knowledge about: evolution vs. religion, human evolution, and evolution theory. Our hope is that once the teachers have enough knowledge and skills to teach evolution, the number of alternative perceptions—both theirs and their students'—will decrease, and they will teach evolution without trepidation. Glaze and Goldston (2019) placed the heavy responsibility of overcoming obstacles to teaching and learning evolution on the shoulders of professors in teacher education, who are often the only ones who interact with science teachers about pedagogical aspects of teaching controversial topics.

In addition, the difficulties in teaching and learning evolution create a platform for designing teaching materials that take these difficulties into account. We have designed a few student-centered online activities in evolution (Siani & Yarden, 2021), and we are currently designing more such activities. The need for these activities arose from this research, because educational stakeholders claimed that evolution is not mentioned in the teaching materials. The activities are also an opportunity for science education research since they are constructed on a platform that enables us to follow students' alternative perceptions, their difficulties, and their evolution understanding at the beginning of the activities and after them.

The findings of this research may serve other countries, especially multicultural ones, which are making changes in science or biology curricula, or planning training courses for their teachers. In light of the findings, teacher training might include—in addition to knowledge regarding the theory of evolution—a session on the attitude of various religions in that country to evolution. This could help teachers deal with the students' alternative conceptions and controversy of religion and evolution in these countries, where some of the students come from religious homes (Barnes & Brownell, 2017). The importance of this recommendation increases in light of the finding that in-service teachers are less concerned about the issue of evolution and faith controversy in their classes.

Another recommendation with global relevance is that when adding evolution to the curricula, the fact that evolutionary explanations are difficult to understand should be taken into consideration. Difficulties in understanding the time dimension, natural selection, Lamarckism vs. Darwinism, and questions of evolution and faith are main issues to address. Referring to these difficulties explicitly in class, and facing the fact that they are obstacles to fully understanding evolution, might improve students' understanding of these topics.

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