

# Investigating Greek Biology Teachers' Attitudes towards Evolution Teaching with Respect to Their Pedagogical Content Knowledge: Suggestions for Their Professional Development

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Evolution Teaching (ET) among in-service teachers in Greece was examined in an attempt to evaluate their Pedagogical Content Knowledge. Evolution teaching is a problematic issue. For this purpose, we constructed a questionnaire that was distributed to the target population and to which 181 teachers responded. We used quantitative method to determine factors that may characterize the ET milieu and which of the factors of PCK apply or not to ET. Our research finds that Biology teachers although strive to teach evolution, face specific difficulties due to lack of PCK. The research results may be useful when organizing and implementing professional development programs of teachers on ET.

*Keywords:* evolution teaching; pedagogical content knowledge (PCK); quantitative research; biology teaching

## BACKGROUND

### Teachers' issues about evolution teaching

It's not long time ago that education researchers (Cummins, Demastes, and Hafner 1994) concluded bareness about evolution: limited articles for natural

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selection, adaptation, teleology, inheritance, conceptions of time. Since then, a variety of articles have been published concerning evolution teaching (ET) (Smith 2010a; Smith 2010b).

Prospective elementary teachers lack understanding of basic concepts of evolution (Asghar, Wiles, and Alters 2007). Teachers have doubts about the accuracy of the scientific methods (Nehm and Schonfeld 2007); majors and non-majors demonstrate substandard understanding of evolution (Nehm and Reilly 2007); teachers have misconceptions about evolution theory and natural selection

(van Dijk and Reydon 2010; Blackwell, Powell, and Dukes 2003; Nehm, Kim, and Sheppard 2009) interfering their students' understanding (Jarvis, Pell, and McKeon 2003).

Other factors play important role in ET, such as religion (Boujaoude et al. 2011), pressure and stress because of conflicts (Griffith and Brem 2004), personal beliefs and teaching choices (Goldston and Kyzer 2009), conceptual ecology (Athanasiou, Katakos, and Papadopoulou 2012; Athanasiou and Papadopoulou 2012) cognitive obstacles (Thagard and Findlay 2010), or other external factors such as parents, communities (Chuang 2003).

### **Pedagogical content knowledge – PCK**

Shulman described PCK as a more specific type of content knowledge. He says: "... *the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations ...*" (Shulman 1986, 9). He claimed that teachers need strong PCK for being the best, because they have a unique way of looking at practice. Shulman's ideas still remain useful (Abell 2008).

PCK could be described as consisting of three knowledge categories: subject matter (specific part of scientific school knowledge that has to be taught), pedagogy (instructional strategies) and context (environment that teaching accomplished, classroom with rules and contracts among students and teacher). A teacher could improve his/her PCK, by enhancing any of the three parts (Gess-Newsome 2002). Context connects research with real life, teaching practice, everyday teachers' struggle in classroom (Loughran, Mulhall, and Berry 2004).

According to the integrative model of PCK, teacher knowledge can be explained by the intersection of the three above constructs: subject matter, pedagogy and context. On the other hand, transformative model of PCK, propose that PCK is a result of transformation of three components (subject matter, pedagogy, context), a new body knowledge which have the dynamic to be altered in regard of the domain that have to be taught. Integrative model propose that a teacher could improve his/her PCK, by enhancing any of the three parts. Transformative model promote synthesis and dynamic form of PCK and depends on the ability of teacher to manipulate his/her teaching strategy using the new knowledge (Gess-Newsome 2002)

### **State of the literature**

- Among teachers have been stated several conflicts that prevent evolution teaching, such as lack of understanding, personal beliefs, religion, pressure and stress, etc.
- Pedagogical Content Knowledge as a teacher's knowledge model can be analyzed and synthesized for general or specific pedagogy, providing a central idea for teaching strategies.
- Components of Pedagogical Content Knowledge are important for effective teaching, especially for problematic issues such as evolution theory.

### **Contribution of this paper to the literature**

- This paper presents an analysis of PCK components, among Greek teachers about evolution teaching, using a questionnaire.
- Low scores in several components emerge insufficient ability for evolution teaching.
- Our study reveals that training courses during professional development and undergraduates studies should be reformed including specific themes of biology education teaching and didactics.

Among several considerations about PCK components, Magnusson, Krajcik, and Borko (2002) proposed the five components below: (i) orientations toward science teaching, (ii) knowledge and beliefs about science curriculum, (iii) knowledge and beliefs about students' understanding of specific science topics, (iv) knowledge and beliefs about assessment in science, and (v) knowledge and beliefs about instructional strategies for teaching science. These are the most used components which are based on research of Grossman (1990) and Tamir (1988). Researchers emphasize in these components or ascertain others as important to be part of PCK (Park and Oliver 2008; van Driel, Jong, and Verloop 2002; Loughran, Mulhall, and Berry 2004; van Driel, Verloop, and de Vos 1998)

PCK could be classified, according to the adoption of PCK's components (Veal and Makinster 1999), as follows: a) *General PCK*, specific pedagogy of concepts and strategies in disciplines such as, science, history, mathematics etc., b) *Domain-specific PCK*, focuses in one of the different domains or subject matters within a particular discipline (in science domains could be biology, chemistry, etc.) and c) *Topic-specific PCK*, the most specific level of pedagogy referred to all concepts, terms, strategies, analogies, misconceptions, etc., that a teacher should acquire in order to teach a specific topic of a science domain (in biology are the evolution, ecology, biotechnology, etc.).

Several studies have been performed about the domain specific PCK of biology-photosynthesis and heredity (Park and Chen 2012), human anatomy (Jüttner and Neuhaus 2011), HIV infection and AIDS (Mnguni and Abrie 2012), genetic testing (van der Zande et al. 2012), evolution theory (Marcelos and Nagem 2012; van Dijk 2009; Veal and Kubasko Jr. 2003), biotechnology (Gardner and Jones 2011), photosynthesis and plant growth (Käpylä, Heikkinen, and Asunta 2009), cell (Cohen and Yarden 2009), heritage (Giménez, Ruiz, and Listán 2008), general biology (Friedrichsen and Dana 2005).

### **Evolution teaching – Status Quo in Greece**

Acceptance of evolution theory in Greece, is in low rate (Miller, Scott, and Okamoto 2006). In the Greek educational system, secondary education consists of two levels, (gymnasium-lower and lyceum-upper), with three classes in each level. Biology is taught in classes, A, B and C for gymnasium and A, B and C for lyceum. The last class of compulsory education is C gymnasium; C of lyceum prepares students for national exams to enter the university. A chapter of evolution is taught only in C gymnasium and C lyceum. All science teachers (biologists, physicists, chemists, geologists, naturalists) can teach biology in any grade, even though some of them have never been taught during their undergraduate studies biology at all, not only evolution.

Since 1998 have been organized a national competition for the recruitment of teachers in secondary education. The syllabus of competition includes basic pedagogy and didactic, but there is no requirement for previous teaching experience, training certificate or university course on teaching and pedagogy. There isn't any training program for pre-service secondary education teachers. Only in-service teachers are obliged to attend a starting training program about didactic and pedagogy, in three training cycles of about a month in total. After this, there are no training programs for teachers, except from training meetings organized by school consultants.

### **Purpose**

This empirical study tried to investigate the status quo among secondary school teachers about the ET. The research questions of our study were:

- What is the state of secondary education teachers' about the three components of PCK?
- Is there any relation among teachers' undergraduate studies and effective teaching of evolution?
- Do teachers care about their professional development, especially for the specific subject of ET?

## **DESIGN AND METHODS**

### **Sample**

We made a quantitative research collecting data with questionnaires based on PCK, from the entire Greek territory. The sample population consisted of 181 participants. A 56.4% of them were women, while a 68.5% of the teachers had a bachelor degree in biology. A 34.8% of the teachers had an extra Master's degree and a 12.2% a PhD. More of them (26%) ranged between 49-54 years old, half of them (55.8%) had 1-10 years of teaching experience. 55.2% taught in lower (42.5% in C class) and 61.3% in upper (57.5% in C class) secondary education. 89% were teachers of public school from all over Greek territory.

Before finalizing the 41 questions of the questionnaire, a pilot study was implemented. Participants had to reply to several types of questions (multiple choices, Likert-type scales, True/False, etc.) (See in Tables 1, 2, 3, for questions about PCK components). The questionnaire was divided into six sections: one with multiple choices and True/False questions about demographic characteristics and teachers' experience, one with multiple choices and True/False questions about their undergraduate university studies, one with Likert scale questions about teachers' familiarity with evolution ideas, one with Likert scale, True/False and multiple choices questions about teachers' practice in evolution teaching, one with True/False and multiple choices questions about teachers' knowledge for natural selection and evolution theory and final Likert-scale questions about teachers' knowledge for nature of science, evolution theory and natural selection.

### **Procedure of data collection**

Participants were recruited through an email sent to almost all secondary schools in Greece (nearly 3500 schools). Teachers who taught biology were asked to participate voluntarily. We used LimeSurvey (<http://www.limesurvey.org/>), an online questionnaire platform that enables the organization and collection of questionnaires responses.

### **Data Analysis**

With SPSS statistical software we analyzed the responses. The Likert-type scales we used were 5-degrees and characterization of any degree depended on the type of query. In the cases we had to do some correlation we used the Pearson's correlation. Reverse scoring was introduced in some cases, whenever it was necessary.

## **FINDINGS**

As it was mentioned (Papadopoulou, Stasinakis, and Athanasiou 2011; Stasinakis and Athanasiou 2012), results with Qualitative Research have been presented previously. To sum up, our findings indicated a shortage of proper teaching skills in the teaching of evolution among Greek-biology teachers, due to a lack in both, an acquaintance with general teaching strategies, in one hand, and a familiarity with the particular concepts related to evolution that they must transmit to their students. This is combined with the fact that some of them communicate the very

**Table 1.** Undergraduate Courses (0=minimum, 1=maximum) attended by teachers during basic degree, their participation in Professional Development (PD) (0=minimum, 1=maximum) programs in last three years, and Instructional Strategies they follow in their teaching (N=181, Mean  $\pm$  SE)

| Undergraduate Course   | Mean $\pm$ SE    | PD Course             | Mean $\pm$ SE    | Instructional strategy                       | Mean $\pm$ SE    |
|------------------------|------------------|-----------------------|------------------|--|------------------|
| General Didactics      | 0.18 $\pm$ 0.028 | Didactics of Science  | 0.28 $\pm$ 0.034 | Taking account of students' AI *             | 3.49 $\pm$ 0.077 |
| Didactics of Biology   | 0.07 $\pm$ 0.019 | Didactics of Biology  | 0.26 $\pm$ 0.033 | Using everyday examples                      | 3.79 $\pm$ 0.076 |
| Philosophy and NOS     | 0.13 $\pm$ 0.025 | Evolution Teaching    | 0.19 $\pm$ 0.029 | Implement constructivism                     | 2.87 $\pm$ 0.068 |
| History of Science     | 0.09 $\pm$ 0.021 | Issues of Evolution   | 0.19 $\pm$ 0.029 | Do experiments                               | 1.28 $\pm$ 0.048 |
| Community and Science  | 0.01 $\pm$ 0.006 | Philosophy of Biology | 0.02 $\pm$ 0.011 | Using ICT                                    | 2.94 $\pm$ 0.102 |
| Didactics of Science   | 0.14 $\pm$ 0.026 | History of Biology    | 0.01 $\pm$ 0.006 | Use of Evolution as the Unifying Theory      | 2.75 $\pm$ 0.091 |
| Use of ICT in Teaching | 0.09 $\pm$ 0.021 | None of these         | 0.52 $\pm$ 0.037 | Use lesson plans                             | 3.08 $\pm$ 0.088 |
| Pedagogy               | 0.24 $\pm$ 0.032 |                       |                  | Aims of my teaching, according to curriculum | 3.09 $\pm$ 0.077 |
| Special Needs          | 0.03 $\pm$ 0.013 |                       |                  | Implement inquiry based learning             | 2.99 $\pm$ 0.078 |
| Educational Research   | 0.02 $\pm$ 0.011 |                       |                  | Provoke cognitive conflict                   | 3.05 $\pm$ 0.081 |
| None of these          | 0.48 $\pm$ 0.037 |                       |                  |  |                  |

Note: \*Alternative Ideas.

same alternative ideas on evolution that one anticipates only from students to have. Others encounter uneasiness to teach the particular subject due to their religious beliefs, a situation that is reflected on the effectiveness of their teaching, even when they try not to communicate this controversy to their students. All these barriers underline the necessity to enhance the teaching of evolution theory in Biology departments of universities in a less "scholarly" way and improve in-service and future-teachers' training in PCK in general and as concerning evolution teaching.

Moreover, all of interviewed teachers expressed their wish for training programs for teachers about evolution, so to make clear that evolution teaching is a unifying idea and can be taught throughout all biology units. Teachers expressed several difficulties of school reality (such as apathy of the students, or missing hours for teaching, or inappropriate teaching material), but they were convinced that if they plan their lessons according to the curriculum and choose teaching strategies adapted to their classes, all these could be overwhelmed. All teachers showed a positive attitude about evolution teaching, and this is an important base in training them adequately.

**Table 2.** Teachers' statements about their evolution teaching in school context. (N=179, Mean  $\pm$  SE)

| School context  | Mean $\pm$ SE    |
|---|------------------|
| Almost never have enough time to talk about evolution, because of time pressure   | 3.36 $\pm$ 0.093 |
| There is an weaknesses in the ET because of the order of chapters in textbooks  | 2.59 $\pm$ 0.095 |
| Until recently there was no reason to teach evolution in lower school, as students are not taught at the upper secondary school | 4.23 $\pm$ 0.079 |
| It is impossible to teach evolution to students as their cognitive background is inadequate                                     | 4.17 $\pm$ 0.068 |
| I choose to teach other chapters than Evolution, since I consider them more important   | 4.12 $\pm$ 0.069 |
| ET restricted to specific chapters of lower and upper secondary school grades   | 2.97 $\pm$ 0.089 |
| I do not care about the teaching of evolution, because I think is boring  | 4.69 $\pm$ 0.040 |
| Relating evolution to everyday life is impossible, as it refers to past events  | 4.44 $\pm$ 0.054 |
| During my teaching I mainly imitate the way I was taught in my school years   | 3.92 $\pm$ 0.070 |
| One of the objectives of ET should be the change of students' religious believes  | 4.21 $\pm$ 0.067 |
| When I teach Evolution I mainly use the material contained in the textbook  | 3.08 $\pm$ 0.083 |
| My teaching experience is enough, so to make me able to teach evolution and the mechanism of natural selection                  | 3.35 $\pm$ 0.082 |

As for the present Quantitative Research, Table 1 shows the subjects related to didactics in participants' curricula during their undergraduate studies. It is clearly shown that in Greek universities, 48% of science students do not attend any course relevant to education and 24% about general pedagogy. When teachers were asked if they had taken any university course(s) that included the theme of evolution, only 69.1% gave a positive answer and 30.9% answered "No". We found statistically significant relationship between evolution teaching in classroom and evolution coursework in university undergraduate studies ( $p = 0.003$ ). No statistically significant relationship ( $p = 0.520$ ) was found between evolution teaching in classroom and the number of semesters that a teacher attended in university courses on evolution theory. We questioned participants for any Professional Development (PD) program they have participated during the last three years. Most of them, as it is shown in Table 1, did not participate in any relevant to evolution training program (mean = 0.52).

Competence expresses the confidence of a teacher, together with his/her willingness to teach a subject. So, we asked them to record adequacy they feel, when teaching five specific teaching subjects that are part of syllabus in Greek secondary education. Their stated degree of competence was (N=181, Mean  $\pm$  SE, 1=minimum, 3=maximum): biology 2.47  $\pm$  0.052, geology 1.41  $\pm$  0.05, geography 1.75  $\pm$  0.051, physics 1.67  $\pm$  0.058, chemistry 2.04  $\pm$  0.052. We found statistically significant relationship between evolution teaching in classroom and competence that teachers feel about teaching biology ( $p = 0.000$ ) and between teaching experience and adequacy to teach biology ( $p = 0.005$ ). We, also, investigated the teaching strategies they choose to teach evolution, by a 5-degree Likert-type scale with this range: 1=Not at all, 2=A little, 3=Quite, 4=Very, 5=Extremely, as recorded in Table 1. Cronbach  $\alpha$  of internal consistency for this set of items (teaching strategies), were calculated at 0.801.

We decoded their opinions for statements about ET, in their specific context of their classroom. We used a 5-degree Likert-type scale with this range: 1=Disagree a lot, 2=Disagree, 3=No opinion, 4=Agree, 5=Agree very much, as recorded in Table 2. Cronbach  $\alpha$  of internal consistency for this set of items, were calculated at 0.717. We found statistically significant relationship between the choices of ET with some of the statements below.

- "Almost never I have enough time to talk about evolution, because of time pressure" ( $p = 0.000$ ).
- "I choose to teach other chapters than evolution, since I consider them more important" ( $p = 0.002$ ).

**Table 3.** Teachers’ statements about NOS (Nature of Science), Evolution and Natural Selection (N=143, Mean ± SE)

| Teachers’ statements  | Mean ± SE    |
|---|--------------|
| All characteristics of organisms evolved through natural selection  | 2.28 ± 0.084 |
| It is statistically unlikely that life arose by accident  | 3.55 ± 0.093 |
| I believe the teaching of the biblical option of life-history has a place in the ET   | 3.63 ± 0.101 |
| Contemporary organisms are the result of evolutionary processes that have taken place over millions of years                        | 4.54 ± 0.050 |
| The theory of evolution is based on speculation and not on sound scientific observations and tests                                  | 4.44 ± 0.059 |
| Life on Earth is less than 20,000 years   | 4.57 ± 0.053 |
| The organisms living today have basically the same form that always they had  | 4.60 ± 0.051 |
| Over billions of years all animals and plants on Earth (including humans) evolved from a common ancestor (i.e. one-celled organism) | 4.21 ± 0.075 |
| Scientists are usually restricted to investigating phenomena, which are directly observable by the senses                           | 4.08 ± 0.079 |
| The term "theory" is used to describe a natural law that has not been proven  | 3.45 ± 0.094 |
| The theory of evolution is a scientific explanation that can be disproved   | 2.39 ± 0.104 |
| The theory of evolution applies to all organisms other than humans  | 4.60 ± 0.056 |
| The action of natural selection is a random process   | 3.31 ± 0.112 |
| The theory of evolution is a biological concept fundamental in understanding basic processes of living beings                       | 4.44 ± 0.058 |
| The theory of evolution refers to past events and has no practical significance in now-days   | 4.59 ± 0.050 |
| Evolution is an weak scientific explanation, because it is just a theory  | 4.37 ± 0.063 |

**Table 4.** Correlations among individual PCK items [Explanation: first number is “Pearson Correlation”, second number is “Sig. (2-tailed)”]

|  | Undergraduate courses | Participation in training programs | Degree of adequacy | Instructional strategies | Teaching practice - Context | Knowledge Subscale: Evolution | Knowledge Subscale: Natural Selection | Knowledge Subscale: Nature of Science |                 |
|--|-----------------------|------------------------------------|--------------------|--------------------------|-----------------------------|-------------------------------|---------------------------------------|---------------------------------------|-----------------|
| <b>Undergraduate courses</b>                 | 1                     | -0.126 (0.092)                     | 0.128 (0.086)      | -0.041 (0.584)           | -0.221** (0.003)            | -0.098 (0.245)                | -0.202* (0.015)                       | 0.085 (0.310)                         | -0.026 (0.757)  |
| <b>Participation in training programs</b>    | -0.126 (0.092)        | 1                                  | 0.042 (0.574)      | 0.210** (0.005)          | 0.276** (0.000)             | 0.196* (0.019)                | 0.162 (0.052)                         | 0.087 (0.298)                         | 0.171* (0.039)  |
| <b>Degree of adequacy</b>                    | 0.128 (0.086)         | 0.042 (0.574)                      | 1                  | 0.351** (0.000)          | 0.154* (0.040)              | 0.060 (0.475)                 | 0.066 (0.431)                         | -0.068 (0.418)                        | 0.081 (0.335)   |
| <b>Instructional strategies</b>              | -0.041 (0.584)        | 0.210** (0.005)                    | 0.351** (0.000)    | 1                        | 0.375** (0.000)             | 0.130 (0.123)                 | 0.220** (0.008)                       | -0.140 (0.095)                        | 0.102 (0.223)   |
| <b>Teaching practice - Context</b>           | -0.221** (0.003)      | 0.276** (0.000)                    | 0.154* (0.040)     | 0.375** (0.000)          | 1                           | 0.361** (0.000)               | 0.373** (0.000)                       | -0.74 (0.380)                         | 0.345** (0.000) |
| <b>Knowledge Subscale: Evolution</b>         | -0.098 (0.245)        | 0.196* (0.019)                     | 0.060 (0.475)      | 0.130 (0.123)            | 0.361** (0.000)             | 1                             | 0.800** (0.000)                       | 0.424** (0.000)                       | 0.881** (0.000) |
| <b>Knowledge Subscale: Natural Selection</b> | -0.202* (0.015)       | 0.162 (0.052)                      | 0.066 (0.431)      | 0.220** (0.008)          | 0.373** (0.000)             | 0.800** (0.000)               | 1                                     | 0.059 (0.480)                         | 0.537** (0.000) |
| <b>Knowledge Subscale: Nature of Science</b> | 0.085 (0.310)         | 0.087 (0.298)                      | -0.068 (0.418)     | -0.140 (0.095)           | -0.74 (0.380)               | 0.424** (0.000)               | 0.059 (0.480)                         | 1                                     | 0.222* (0.007)  |
| <b>Knowledge Subscale: Nature of Science</b> | -0.026 (0.757)        | 0.171* (0.039)                     | 0.081 (0.335)      | 0.102 (0.223)            | 0.345** (0.000)             | 0.881** (0.000)               | 0.537** (0.000)                       | 0.222* (0.007)                        | 1               |

Note: \* Correlation is significant at the 0.05 level (2-tailed), \*\* Correlation is significant at the 0.01 level (2-tailed).

- “I do not care about the teaching of evolution, because I think is boring” ( $p = 0.006$ ).

Also, we decoded their knowledge about evolution theory, their opinions for statements about NOS (Nature of Science), evolution and natural selection. We used a 5-degree Likert-type scale with this range: 1=Disagree a lot, 2=Disagree, 3=No opinion, 4= Agree, 5=Agree very much, as recorded in Table 3.

Cronbach  $\alpha$  of internal consistency for this set of items, were calculated at 0.745. We found statistically significant relationship between ET and teaching practice ( $p = 0.001$ ). In Table 4 all correlation results among individual PCK items are shown.

We found that adequacy is positively correlated with teaching strategies ( $r=0.351$ ,  $p<0.01$ ) and practice in specific school context ( $r=0.154$ ,  $p<0.05$ ). We also found that 82.4% of the teachers taught evolution and 17.6% not. In more cases, teachers do did not teach evolution because of inappropriate programming.

## DISCUSSION

Most of the secondary education teachers seemed to lack understanding of concepts in evolution and instructional strategies (Papadopoulou, Stasinakis, and Athanasiou 2011; Stasinakis and Athanasiou 2012). This is due to their undergraduate studies, which were focused on sophisticated scientific concepts, and the fact that most of them had not attended any PD (Professional Development) course or training program on ET. Research in Greek prospective educators found that teaching in undergraduate studies is able to improve understanding and acceptance of evolution (Athanasiou, Katakos, and Papadopoulou 2012).

There are no considerable differences among teachers of different fields in their ET skills. We agree with other researchers (Prinou, Halkia, and Skordoulis 2005; Nehm and Schonfeld 2007) that biologists do not have better performance than non-biologists in teaching basic aspects of evolution theory. Teachers use textbooks for reading, making them determinant for students' scientific literacy students and teachers' knowledge.

Teachers who studied evolution in undergraduate level prefer to teach evolution in their class, although we did not find any correlations between number of semesters they studied evolution and ET in class. Future teachers reduce their misunderstandings about evolution, when they have the opportunity to talk about them in university. These findings are in agreement with those of Nadelson and Nadelson (2010), who found that teachers need PD on teaching evolution, not in general, but in a specific and focused on teaching content. Primary education teachers who had not attended any biology courses during their academic studies, they showed lower self-esteem about teaching biology subjects (Mavrikaki and Athanasiou 2011).

Teachers do not have the ability to transform their scientific knowledge to examples, models, representations and concepts easily conceivable by their students. The latter comes to support the idea of PCK of Shulman (1987) that expert teachers should have the ability to transform subject matter knowledge more comprehensively to learners (van Driel, Verloop, and de Vos 1998; Zembal-Saul, Starr, and Krajcik 2002). Insufficiency was revealed when they have to teach evolution as a unifying theory: even though biologists are more convinced about the central role of evolution in biology, they are unable to teach it because they do not know how to implement this option in their teaching, just like Donnelly and Boone described before (2007).

In our study, most of the teachers do not use the curriculum, while many of them do not know its' existence. A proper use of the curriculum could provide teachers with instructional strategies, targeted objectives, and activities about ET. We also



found that the ambiguous or no use of the curriculum leads to another holdup: the necessity for prerequisite knowledge for a student to be taught evolution.

So there are some teachers who believe that the chapter of genetics should precede the evolution while others believe that the reports from paleontology can explain much of the phenomenon, and should be preceded. This kind of reasoning indicates that we need to know more than just students' misconceptions: we should also determine what students need to know in order to be taught evolution. A certain prior knowledge of students it is probably a necessary step for ET. Research shows that basic prior knowledge plays a dual role in teaching: it provides students with additional confidence in their basic understanding of biology and increases their confidence in order to struggle with their alternative conceptions (Boujaoude et al. 2011; Cornett, Yeotis, and Terwilliger 1990).

Another interesting finding is the fact that few teachers in our study use lesson plans. As a result teachers often fail to set purposes beyond cognition. Study (Abraham et al. 2012) shows that an organized teaching using lesson plan could increase acceptance and understanding of evolution. Teachers, in research of Griffith and Brem (2004), could be more effective in ET if they possessed most up-to-date information about evolution and had access to richer lesson plans for ET.

Teachers feel inadequate or insecure to teach biology and evolution theory. Therefore they are worried for "difficult" questions from their students. Inadequate teachers do not have confidence in their abilities and knowledge to teach evolution and in some cases they do not accept evolution (Griffith and Brem 2004; Akyol et al. 2012).

Moreover we found among teachers a lack of basic epistemological issues, such as the role of chance in evolution, the probabilistic complexity in evolutionary phenomena, the concept of geological time, the term 'theory' and its meaning in epistemology. No one can argue that ignorance of the NOS is responsible for not teaching evolution by Greek teachers, but this deficit complicates the situation and makes harder for them to acquire solid and clear beliefs about evolution (Kampourakis 2013).

## CONCLUSIONS & IMPLICATIONS

- Most of the secondary education teachers seemed to lack understanding of concepts in evolution and instructional strategies, due to their undergraduate studies which were focused, mostly, on sophisticated scientific concepts. A fact suggesting the imperative need for universities' science departments that prepare perspective science teachers to teach evolution, not only in a pure scientific form, (such as the role of chance in evolution, the probabilistic complexity in evolutionary phenomena, or the meaning of geological time, etc.), but in a form adapted to the needs of daily teaching of school, as well.

- The fact that no considerable differences among teachers of different fields were found in their performance in teaching basic aspects of evolution theory compared to biologists, suggests, that all science teachers are able to comprehend basic concepts about evolution, but especially these which are referred to textbooks.

- The fact that teachers who studied evolution in undergraduate level prefer to teach evolution in their class, having a better self-esteem, suggests for the need of professional development programs on teaching and learning evolution focused on a teaching content.

- Teachers were found to lack the ability to transform the scientific knowledge to examples, models, representations and concepts, easily conceivably to his/her students. The latter comes to support for the need to include PCK in future and in-service teachers training. In the same context, few teachers use lesson plans. Teachers could be more effective in evolution teaching not only if they possessed

most up-to-date information about evolution, but also, access to richer lesson plans for teaching evolution.

- The same applies to the necessity of teaching evolution as a unifying theory of biology: future and in-service teachers training should include the ability to schedule and apply the ability to transform formal forms of teaching biology according to the textbook into a revolutionary optics with evolution as the unifying theory.

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