Examining and Mapping CS Teachers' Technological, Pedagogical and Content Knowledge (TPACK) in K-12 Schools

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***Abstract*—Computer Science (CS) teachers' training and profile is crucial to ensure students have access to quality Computer Science Education (CSE). The aim of this study is to examine the profile of CS teachers in Greece and map it using the technique of persona. This study examines a national sample of 1127 CS teachers who teach algorithms and programming in upper secondary education. The building of the persona is based on teachers' abilities and needs regarding the central aspects of their knowledge in respect to three key domains in the Technological, Pedagogical, and Content Knowledge (TPACK) framework. According to the results in the TPACK subscales, teachers' state that their Content Knowledge scales is sufficient and Pedagogical, Content Knowledge needs to be improved on. In addition, teachers feel that they need further training in how to incorporate technology in their teaching as well as how to teach algorithms; which are two areas that relate to Pedagogical Content Knowledge and TPACK. By mapping the knowledge, abilities and needs of CS teachers, we will be able to recognize the challenges they face during teaching and consider strategies and policies for addressing these challenges.**

Keywords- Technological Pedagogical Content Knowledge, CS in Schools, Teachers' Training, Empirical Experimentation, K-12 Education, Personas, TPACK.

I. INTRODUCTION

Interest in computing has risen over the last decade and the subject is now often found as a distinct discipline in secondary education. Those living in the United States, the United Kingdom, New Zealand, South Korea, and Greece have seen a rise in activities and media focus on this topic [1] [2]. This interest has generated a growing awareness in the efficacy of computing education in K-12 schools.

Computer Science (CS) teachers in secondary education are required to have a broad knowledge of both computing and Information Communication Technology (ICT) [3] [4] [5]. In addition, the Association for Computing Machinery (ACM) K-12 Educational Task Force [6] advocate for teacher training programs that prepare the computer science teachers with the necessary pedagogical skills to convey the information to the students at the appropriate level.

Authors of the Computer Science Teachers Association (CSTA) reporting [7] on CS teacher certification, advocate for the establishment of a Computer Science Praxis exam that will assess teacher knowledge of computer science concepts and the teachers' knowledge of pedagogy. Graham et al. [8] posited that educators have come to realize that knowledge of how to use technological tools is not enough. Educators need to understand how to construct appropriate learning activities, to ensure that the students understand the concepts being taught with technology effectively integrated into that learning process. Comments such as these have led several researchers (e.g., [9] [10]), to focus their studies on ways to integrate technological tools into teaching in a meaningful way.

Mishra and Koehler [10] built upon Shulman's work [11] to develop a framework combining three important aspects of teacher knowledge: Pedagogical Knowledge, Content Knowledge and Technological Knowledge. The Technological, Pedagogical, Content Knowledge (TPACK) framework is important for CS teachers to integrate technological tools effectively into their teaching practice. This is accomplished by using the technological tools to learn the subject matter and facilitate the learning process [10].

The purpose of this empirical investigation is to measure CS teachers' knowledge regarding the components of TPACK and to map the profile of CS teachers. For this study, the researchers have used TPACK elements within a quantitative survey on a group of Greek CS teachers. The study itself had the two following objectives.

- Measure CS teachers' self-identified knowledge regarding: technology, pedagogy and content.
- Investigate CS teachers' abilities and needs.

The findings of these two objectives contribute to the identification of the challenges CS teachers face and consider strategies and policies for addressing these challenges.

In the next section, the related work, the specific (Greek) educational context and the technique of personas are

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outlined. The third section presents the methodology employed in this empirical study. The fourth section presents the research findings. Finally, the paper concludes with the implications, discusses the results and the limitations of the research.

II. THEORETICAL BACKGROUND AND RELATED WORK

A. TPACK Framework and its Use in CS

Since the development of Mishra and Koehler's TPACK framework in 2006 it has become a popular lens for studying teacher knowledge and has been used in many recent teacher studies (e.g. [12] [13] [14]). The TPACK framework (Figure 1) is introduced by a three part Venn diagram to draw attention to how the technological, pedagogical, and content knowledge can be separated and how the intersections connect the different knowledge areas. The center of the Venn diagram where the three knowledge components converge, is the complete TPACK as it represents the Technological, Pedagogical, and Content Knowledge as a cohesive whole, working and interacting together (Figure 1). In other words, the teacher is able to understand and negotiating the complex relationships between the three knowledge areas.

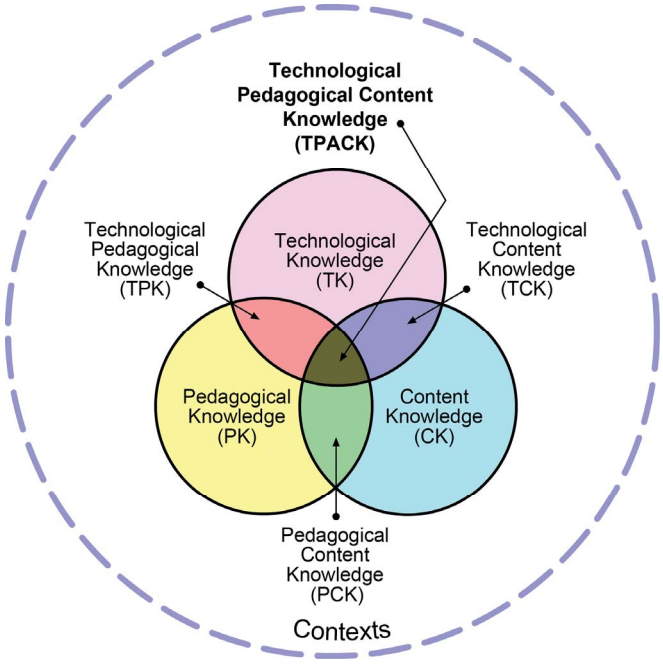

Figure 1. The TPACK framework (Reproduced by permission of the tpack.org © 2012)

The TPACK framework is made up of seven different knowledge components. There are the three unitary components of knowledge (Content, Pedagogy and Technology), three dyadic components of knowledge (Pedagogical Content, Technological Content, Technological Pedagogical) and one overarching triad (Technological Pedagogical Content Knowledge). In 2010 Jimoyiannis [15] adapted the Pedagogical Content Knowledge (PCK) intersection to elucidate what that looks like for CS teachers. This list includes:

- Content knowledge, for subject matter.
- Knowledge and perceptions of the goals, objectives, means and strategies of teaching CS at every level (knowledge of the curriculum).
- Knowledge of methods of understanding, perception, difficulties and misunderstandings encountered by students in specific units of CS curriculum.
- Knowledge of appropriate models of knowledge, available educational means and effective teaching strategies for each unit.
- Knowledge and perceptions about how to evaluate the scientific literature on CS and teaching approaches for CS.

This provides the reader with a good example of how the knowledge strands can be woven together in a meaningful way.

The TPACK of in-service and pre-service teachers has been measured in both qualitative and quantitative studies revealing very prominent insights in many fields (e.g., mathematics [9] [13] [16]). However, although TPACK and PCK attributes of CS teachers is considered important [17] [18] [19], few empirical studies have been conducted in this area. Therefore, the purpose of this paper is to measure the TPACK abilities of secondary CS teachers and use this information to determine the abilities and needs of those teachers. This will help inform those who design CS teacher training programs.

B. Computing Education in Greece

In Greece, the teaching of Computing and ICT in secondary education is conducted by teachers holding an initial degree in Computer Science, Computer Engineering, or Applied Informatics. Secondary Education in Greece is divided into two cycles: compulsory lower secondary and non-compulsory upper secondary education. Compulsory lower secondary education is provided in Gymnasium (Middle School), while non-compulsory upper secondary education is taught in one of two types of Lyceums (High Schools): the General Lyceum and Vocational Lyceum.

The 1st grade of the General Lyceum, represents an orientation year with a general education program. The 2nd and 3rd grades offer three curricular directions: Theoretical, Scientific, and Technological. Students who follow the technological direction take a specific course named Applications Development in a Programming Environment (hereinafter the CS course), that involves the development of algorithms and programming. This course has been taught for more than ten years (since 1999). It focuses on the algorithmic approach and on the development of problem-solving skills in a programming environment. This subject is assigned to CS teachers and their examination at the national level is considered in selecting students for admission in higher education programs.

The overall aim of the 3rd Lyceum CS courses is to develop analytical and synthetic thinking, acquire methodological skills and be able to solve problems within a

programming environment. This course was not designed to educate programmers and for this reason it is not designed to teach students sophisticated programming techniques. The course focuses on approaches and techniques of problem solving with emphasis on structured thinking. Many basic algorithmic and programming concepts, such as conditions, expressions, and logical reasoning, are fundamentals of general knowledge and skills to be acquired in general education [20] [21].

The curriculum states that this subject must be taught (at least partially) in a computer lab. The Hellenic Ministry of Education has certified specific educational software to support the lab work, especially for the Lyceum CS course. The educational software has been designed, 1) to support teaching, 2) to complement the subject's needs and IT use and 3) to assist students to understand the material. The certified software includes an activity space, a flow chart developer and a programming environment in accordance with the textbook.

C. The Use of Personas

Personas technique creates fictitious characters called personas; this technique portraits the target character on whom capabilities and efforts should focus. Persona is an archetype of actual characters (e.g., users, students, teachers) with well-defined attributes and it was first introduced in HCI community by Cooper [22]. Persona is a powerful and multi-purpose analysis technique that can help designers, educators and software engineers to identify the functionalities and capabilities of the target audience, by taking into account their needs and goals [23]. These imaginary characters are defined with data retrieved from initial investigation of the target character.

Researchers argue that people more easily remember people profiles than technical reports. Furthermore, personas act as a mechanism to enhance attention and help in the organization of data [24] carried out during the design phase of a product, curriculum, or policy.

Building the Persona of CS teachers will assist the improvement of the CS subject in various ways. For example, the curriculum designer might wonder, “Are CS teachers able to use sophisticated technological tools?” or “Do CS teachers need regular training?” The data collected from building the Personas will provide a responses to these questions as they will help us identify the challenges and needs CS teachers face and provide appropriate training(e.g., with certifications program).

III. METHODOLOGY

A. Context

This empirical study was conducted in the context of the Greek educational system with a specific focus on CS teachers in upper secondary education (with students from 16 to 18 years old). At a minimum, the CS teachers of Greece hold an undergraduate degree in Computer Science, Computer Engineering, Informatics or Applied Informatics. Their teaching responsibilities are to teach CS and technology as described in detail above. As such, our sample consisted of experienced CS teachers and they were asked for their knowledge and experience regarding the attributes we were investigating.

B. Sampling

The final sample of respondents were comprised of 1127 CS teachers (65.83% of the Greek CS teachers of the upper secondary education) who have taught the main CS course of the high school, which named *Applications Development in a Programming Environment*. From the total teachers, 66.4% were male and 96% were under 50 years old. The majority of teachers (61%) had, an undergraduate degree, while 35% had, a postgraduate degree, and the remainder had a doctoral degree.

C. Measures

The questionnaire consisted of 25 questions about TPACK and was based on the survey instrument developed by Schmidt et al. [16]. All questions were related to the three key domains in the TPACK framework (technology, pedagogy, content and the combination of these areas). The 25 questions in the questionnaire were divided into questions about Content Knowledge (CK) (4 questions), Technological Knowledge (TK) (3 questions), Pedagogical Knowledge (PK) (4 questions), Pedagogical Content Knowledge (PCK) (2 questions), Technological Content Knowledge (TCK) (3 questions), Technological Pedagogical Knowledge (TPK) (4 questions) and Technological Pedagogical Content Knowledge (TPACK) (3 questions). The responses were each scored using a 5-point Likert scale where 1 stands for ‘strongly disagree’, and 5 stands for ‘strongly agree’. For each subscale the participant's responses were averaged. The questionnaire included ten questions that provided demographic data. The participants completed the questionnaire in the middle of the school year, having covered the appropriate material for all of the basic algorithmic components (sequential structure, conditional structure and loops). The respondents came from the 13 regions of Greece. The sample was representative of the population of educators of Computer Science by region.

D. Data Analysis

The first step of our analysis is the descriptive statistics of the measurement attributes and the demographics, education and experience of the respondents. In the next step we used the results of the descriptive statistics to categorize our data (e.g., demographics, teacher needs, TPACK attributes) and determine the persona of the CS teachers.

IV. RESEARCH FINDINGS

At the time of the study, the majority (76%) of the respondents had more than 3 years of experience teaching CS. The average mean for all items was 4.05. The range of response was 4, with a minimum response of 1, a maximum response of 5, and a standard deviation of 0.81. In particular, respondents expressed high CK (4.38/5) and slightly lower TK, PK and TPK (4.12-4.18/5). Also, respondents expressed positively for the intersection between content, pedagogy and

technology (TPACK) (4.03/5). However, their PCK and TCK were not at a high level (3.51-3.68/5).

The mean, the standard deviation, and the number of items for each TPACK attribute are reported in Table 1.

TABLE I. SUMMARY OF MEASUREMENT SCALES OF TPACK

TPACK attributes	Number of Items*	Mean	Std. Deviation
TK	3	4.16	0.55
CK	4	4.38	0.49
PK	4	4.12	0.53
PCK	2	3.51	0.69
TCK	3	3.68	0.80
TPK	4	4.18	0.51
TPACK	3	4.03	0.66

* Items refers to the number of questions that focus on particular TPACK components and have been adopted from [16]

In addition to gathering the descriptive statistics that measured CS teachers' TPACK, the correlations among each of the attributes were also examined using Pearson correlations. Pearson's correlation coefficient between the factors was used, which quantifies the strength of the relationship between the variables. Pearson's test suggests all the factors are related relatively strong. In particular, the correlations coefficients between the attributes varied from .235 (TCK and PCK) to .746 (PK and TK), can be seen in detailed in Table 2.

TABLE II. PEARSON'S CORRELATION COEFFICIENT BETWEEN TPACK ATTRIBUTES

	TK	CK	PK	PCK	TCK	TPK
TK						
CK	0.48					
PK	0.75	0.55				
PCK	0.43	0.31	0.38			
TCK	0.32	0.32	0.28	0.24		
TPK	0.49	0.40	0.46	0.39	0.32	
TPACK	0.51	0.41	0.47	0.33	0.35	0.72

Correlations are significant at the 0.01 level.

In order to map the knowledge, the abilities and the needs of CS teachers, we developed their persona. Using the persona technique, we created a fictional teacher, named Greek CS teacher (Figure 2). The data extracted from our study was the starting point to create that fictional teacher, where his characteristics were based on real data from the teachers who participated in our study. The character created was based on an aggregated set of characteristics from several participants in the study.

Specifically, the persona consisted of the demographics, education and experience of the teacher and his needs and level of TPACK attributes (Figure 2). An interesting finding is that 54% of the teachers who took part in the research claimed that they need training to properly teach the CS courses. In particular, 70% of the CS teachers reported that they needed to be trained in how to incorporate the course educational software in their teaching, 43% wanted to be trained in how to teach algorithms, while 37% agreed that they needed training in using the educational software of their courses.

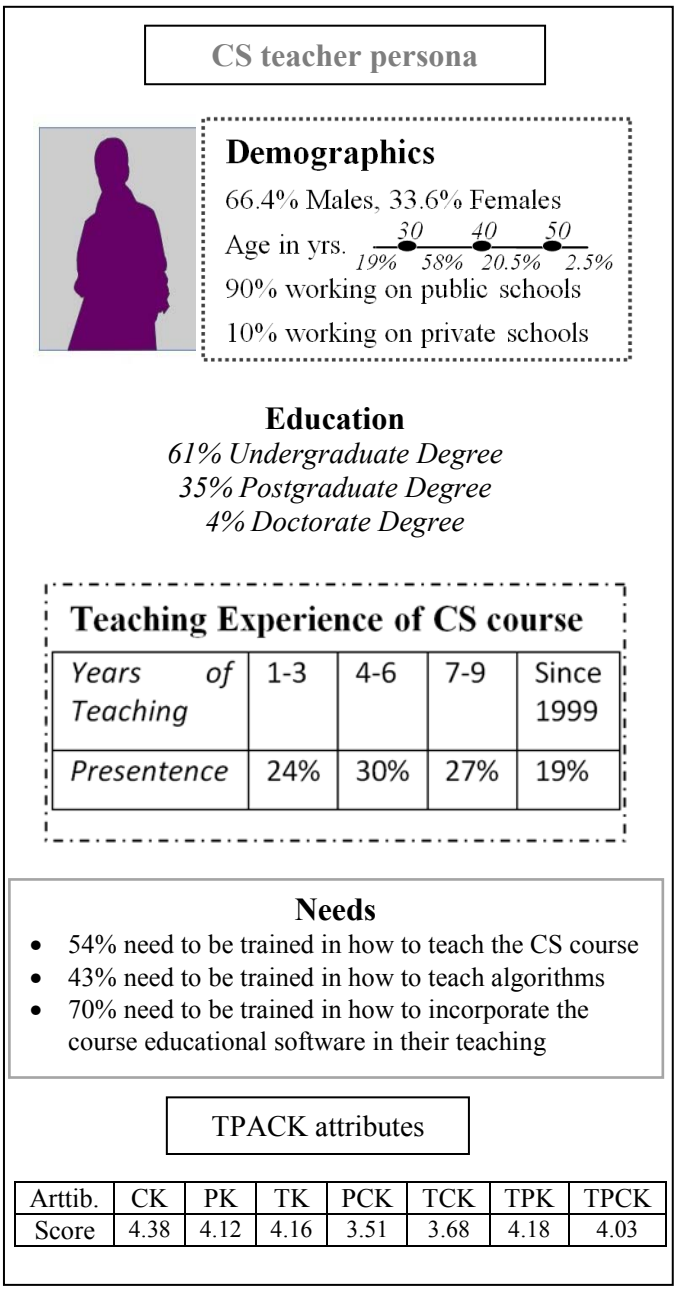

Figure 2. CS teacher Persona based on the collected data

V. DISCUSSION

Based on the empirical results, more than half of the teachers wanted training to teach the CS course; and particularly they asked for extra training in the sectors of pedagogy, technology and the integration of technology in their teaching practice. On the other hand, the other 50% of the teachers does not want further training beyond their initial degree.

In regard to TPACK, it seems that those who participated in this survey rated their knowledge of content (4.38) higher than that of the other cognitive subscales. With this high CK, it suggests that teachers felt confident in their knowledge on algorithmic and problem solving concepts; which are presented in the subject.

Technological Knowledge (TK) (4.16) was also very high. According to Mishra and Koehler [10], TK is associated with the ability to manipulate the technological tools and also the knowledge behind how to use the technology with others. This was also reflected in questions concerning the type of training teachers consider as necessary. A small percentage (37%) of the respondents reported that they needed training in educational software to support the lab work.

The Pedagogical Knowledge rating (4.12) was very close to that of the Technological Knowledge. The high average implies that CS teachers have deep knowledge of the educational process and methodology of teaching and learning and thus can achieve the aim of the subject.

According to their responses, teachers seem to have very high Technological Pedagogical Knowledge (TPK, 4.18). This shows that educators have realized that teaching and learning are altered when using specific technological tools. This knowledge includes awareness of their tools' restrictions and affordances in designing pedagogical strategies.

The average scores for TCK and PCK were lower (3.68 and 3.51 respectively) than the other domains. For TCK, it seems that teachers rate themselves at a lower level in the understanding of how technology and subject matter both aid and limit each other. Therefore, teachers seemed to need assistance to comprehend how the use of technology can pedagogically be incorporated into teaching and learning. This is also reflected in questions concerning the type of training they consider necessary, where a percentage of 70% of the respondents needed training in methods to integrate educational software in their teaching practice.

The last dyadic component (PCK) shows that, even if teachers of CS had both pedagogical knowledge and deep knowledge of their subject matter, they seem to be less confident in transforming and applying their Content Knowledge into their teaching practice [11]. Finally, the score in TPACK (4.03) shows that teachers were aware of the intersection between content, pedagogy, and technology. Thus, it appears that teachers enhance teaching with a dynamic equilibrium, between the three teaching components (pedagogy, content and technology).

Despite the fact that CS teachers claim to possess the above attributes, it seems that only the 62% are making use of the technological tools and the computer laboratory, while the 38% teach the subject exclusively in the classroom. Out of the 62% of teachers who use technological tools and the laboratory, 65% consider that conducting sessions in the laboratory reduces the time needed to cover the curriculum. However, they typically use technological tools to present algorithmic issues (41%) and there is less use of technology for students to practice with the available tools and relevant training scenarios (31%).

VI. CONCLUSIONS

In this empirical study, CS teachers' knowledge and needs were examined. In particular, we measured teachers' CS TPACK attributes and their needs in regard to teaching CS. The levels of TPACK attributes were relatively high amongst teachers (4.05/5 as an average value).

In particular, according to the results in the seven subscales, teachers stated that their knowledge was between the values 4.38 (CK) and 3.51 (PCK). Moreover, it seems that the teachers who taught the course wish to be trained in how to incorporate educational software in their teaching practice improve their TCK, as well as their overall TPACK. This leads us to conclude that teachers want to have the ability to determine when technology contributes and when it obstructs the teaching of CS. It seems, therefore, that teachers need support in helping them evaluate how technology affects their lesson. Teachers' high degree of independence in TPK indicates that they are capable of evaluating the consequences technology has on teaching and learning, but they are not ready to determine the way technology can improve teaching and learning. As a result, it is important for teachers to acquire the experience that will allow them to determine the technological tools that will appropriately support specific cognitive goals during the development of algorithm. It will also allow them to know how the content of their course can determine or modify the technology in use.

Finally, the findings regarding teacher preference for algorithm training indicates that even though teachers have a) pedagogical knowledge and b) very good knowledge of their subject, they claim that they are less capable of transforming and effectively applying their knowledge for teaching. Thus, it could be claimed that there is a need to incorporate more CS in and pre service training. This will enable CS teachers to identify the most common student misconceptions as well as to be able to find ways to overcome them [25] [26].

The results may prove useful in the design of future training programs for CS teachers in Greece and worldwide. According to these results, teachers are in search of a teaching framework that is far removed from the conventional classroom and which incorporates more use of the laboratory, something that is in compliance with the nature of the course, too. Despite the fact that CS teachers are those with the greatest experience in and knowledge of computer use, it seems that they wish to be trained in the incorporation of technological tools in their teaching. Furthermore, special attention must be given to the development of appropriate educational scenarios and

examples that will contribute to the improvement of student learning but also of teacher work.

As with any empirical study, there are some limitations. First, in this study the respondents are Greek CS teachers, who are part to the Greek educational system; this may limit the generalizability of the findings. However, the Greek CS undergraduate degree (which is the precondition for CS teachers) conforms with the international standards for CS teachers [5] [27]. Secondly, these data are based on a self-report methodology; other methods such as depth interviews and observations could have provided a complimentary picture of the findings through data triangulation.

These are the first efforts to develop the profile of CS teachers based on empirical data. Future studies with empirical data from different countries e.g. Europe and US with different educational systems' and CS curricula [27] [28] using wide variety of measures (i.e., observations, interviews) will allow us to better understand and map CS teachers knowledge and needs. Currently, the authors are preparing a series of interviews with experts (experienced CS teacher, CS teacher trainers, and supervisors) in order to extend academic knowledge in understanding CS teachers' knowledge.

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