A Survey of Computer Science Teacher Preparation Programs in Israel Tells Us: Computer Science Deserves a Designated High School Teacher Preparation!

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ABSTRACT
This paper focuses on the development and implementation of computer science (CS) teacher preparation programs, which are among the educational and pedagogical challenges faced by those involved in the current development of CS. It presents a survey that reflects the accumulative knowledge gained in Israel over the past twenty years with respect to CS teacher preparation. We explored nine institutes (six universities and three teacher education colleges) that offer CS teacher preparation programs. The survey indicates that while the programs vary in their implementation details, they are all motivated by the unique characteristics of CS, which play a central role in their design. We suggest that this observation further emphasizes the obvious: CS deserves designated CS teacher preparation programs. We therefore hope that this survey will contribute to the community of CS educators in general and to practitioners involved in developing CS teacher preparation programs in particular.

Categories and Subject Descriptors
K.3.2 [**Computers and Education**]: Computer and Information Science Education – *Computer science education*, *Curriculum*.

General Terms
Management, Performance, Human Factors.

Keywords
Computer science education, computer science teacher preparation, Methods of Teaching Computer Science course, practicum in computer science.

1. INTRODUCTION
The dynamic development of computer science (CS) poses a variety of pedagogical and educational challenges, including those that address high school CS teacher preparation, which are the focus of this paper. The importance of this topic emerges from the observation that though the international community of CS educators addresses it extensively, specific CS teacher preparation frameworks do not exist in most countries [1,4,8].

The Israeli high school CS curriculum [9] is considered one of the most advanced in the world [21,23,27]. Thus, there is an interest in the factors that foster its success, and particularly in CS teacher preparation programs, which play a critical role in the implementation of the curriculum. This interest motivated us to explore the current situation in Israel with respect to the structure and content of teacher preparation programs.

The survey presented in this paper is based on data collected from heads of CS teacher preparation programs and from instructors of the Methods of Teaching Computer Science (MTCS) course, which is one of the main components of many of these programs. The study addresses the rationale and implementation of the programs and highlights similarities as well as at differences between them. One of the main observations that emerged from the survey is that *the characteristics of the field of CS have a significant impact on the design of the surveyed CS teacher preparation programs*. We also found that most of the programs have a similar structure with relatively small variations in their implementation. In this paper, however, we focus mainly on the common aspects of the programs.

Most of the material presented here does not address a specific high school CS curriculum and, therefore, we suggest that it can be applied to a variety of CS curricula implemented in different countries. Specifically, based on the accumulative knowledge and experience we present, we suggest that each institution can tailor its CS teacher preparation program to fit its specific prospective CS teacher population.

2. SURVEY BACKGROUND

2.1 CS Teacher Preparation in the World
The rapid changes and development in the field of CS pose a huge challenge for designers of high school CS curricula and, consequently, for teacher preparation programs as well [6,15,17,23,26]. This fact is amplified due to the fact that in most countries no CS teacher preparation programs are offered [1,4,8], and further, no requirements for CS teaching certificates are defined. For example, according to a survey published in the USA in 2007 by the CSTA, only 53% of the 45 states that completed

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the survey declared that they have at least some defined requirements for a CS teaching license [3]. Two partial explanations of this are the fact that different states offer different CS high school curricula [21,27,28] and that no international or national standards exist for CS teacher preparation programs. Accordingly, in places where CS teacher preparation programs do exist, they usually address general principles of teaching science rather than focusing specifically on teaching CS. This lack of designated CS teacher preparation programs can, subsequently, explain why CS is taught in many high schools by mathematics teachers or teachers of other scientific disciplines [5,29].

Thus, the CS education community has expressed its awareness of the need for special teacher CS preparation programs by establishing the Computer Science Teachers Association (CSTA) [27,29], and supporting its various activities. A special CSTA task force report states, for example, that "Teachers must acquire both a mastery of the subject matter and the pedagogical skills that will allow them to present the material to students at appropriate levels." [27, p. 18]. This report also recommends defining standards for a CS teaching license, a fact that will eventually determine the contents to be included in CS teacher preparation programs.

Another CSTA report deals with ways to improve the teaching of CS in the high school, declaring that "It is also clear that teachers are the corner stone of successful curriculum implementation." [24, p. 40]. The report addresses the need to deal with the development of both pre-service and in-service CS teachers, and mentions the role of a professional CS teacher organization in the ongoing support and professional development of CS teachers. One attempt to support in-service CS teachers was reported by Carnegie Mellon University, which conducts a summer workshop for high school CS teachers with the objective of enriching their teaching materials [2].

Our literature review revealed that descriptions of CS teacher preparation programs in the international literature are rare, and if such descriptions exist, they are, in most cases, obsolete [7,14,19,20]. Recently, awareness of the topic has increased and several publications have been published on the topic. For example, Kolczyk (2008) deals with the teaching of basic concepts in algorithms in Poland [16] and Grugurina (2008) addresses CS teacher preparation in Groningen University in Holland [11]. And yet, no detailed descriptions of teacher preparation programs that could serve as a model for other places are to be found.

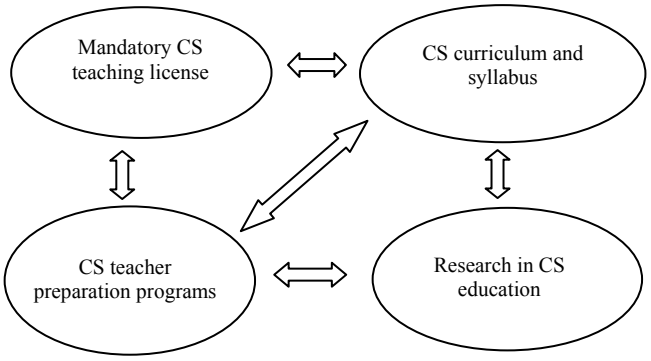
2.2 CS Teacher Preparation in Israel

Israel has a national-wide high school CS curriculum; thus, all CS high school students study according to the same curriculum. A general model for CS high school education in Israel is presented in [13] (see Figure 1). The model consists of interrelationships between four key components:

- A well-defined **CS curriculum**, including written text books and teaching guides;
- A requirement of a mandatory formal **CS teaching license**;
- **Teacher preparation programs**, including at least a bachelors degree in CS and a CS teaching certificate;
- **Research** in CS education.

We propose that each of these components, as well as the relationships among them, contribute to the infrastructure of the Israeli high school CS curriculum, and together make it one of the leading high school CS curricula in the world.

Figure 1: A model for a high school CS education program



The survey presented in this paper focuses on the third component of the model – CS teacher preparation programs. Teacher preparation programs in Israel have two main frameworks:

a) *Teaching certificate* studies offered to graduate students who already have a bachelor's degree in CS.
b) *Bachelor of Education* (B.Ed.) studies that include disciplinary studies along with broad educational studies, which also provide a teaching certificate.

In both cases, the teacher preparation studies are based on four tires: (1) disciplinary studies; (2) general pedagogical studies (such as psychology and general teaching skills); (3) studies related to the didactics of the teaching of the discipline; and (4) practice teaching the discipline in school classes. The present survey focuses on the third and fourth tires – *the didactics and practice teaching of the discipline*, in our case, the teaching of CS.

According to our literature review, much of the literature on CS teacher preparation is based on the Israeli experience. For example, a series of papers published in *Inroads – The SIGCSE magazine* [12,18] describe the MTCS course at the Technion – Israel Institute of Technology and the CS practicum performed in high schools. Several other papers describe the integration of a tutoring model into the Technion's MTCS course [22] and another series of papers present a teacher preparation program offered by the Israeli Open University [10, 30]. The above-mentioned papers describe mainly teacher preparation programs offered by the Technion and the Israeli Open University; the survey presented in this paper widens the perspective and examines several additional Israeli universities and colleges that offer CS teacher preparation programs.

3. SURVEY DESCRIPTION

3.1 Survey Objectives

The survey objectives are to identify the rationale, core studies, and implementation model of Israeli CS teacher preparation programs.

3.2 Survey Participants

The survey was conducted in nine Israeli academic institutions that offer CS teacher preparation programs: five universities (the Technion – Israel Institute of Technology, The Open University of Israel, the Weizmann Institute, Tel-Aviv University, and Ben-Gurion University); one general college (the Jerusalem College of

Technology[1], with its subdivisions into Machon Lev and Machon Tal[2]), and three academic colleges of education (Beit Berl, Oranim, and Al-Qasemi College of Education[3]).

The participants from each institution included the heads of the CS teacher preparation programs and the instructors of the MTCS course. In total, data was collected from 14 participants (in some institutions the same person serves in both roles).

Among the heads of the CS teacher preparation programs, seven have been serving in this position between 8 to 17 years and seven are also the instructors in the MTCS Course.

Among the ten MTCS instructors, four have been teaching the course for over 10 years, three - between 5 and 9 years, and the other three - less than 5 years. All of them have also been coordinating the high school practicum for between 3 to 17 years.

Further, eight of the participants were and are involved also in the development of the national high school CS curriculum; ten are involved in the professional development of in-service teachers; eight are strongly involved in research in CS education, and seven were or are involved in teaching high school CS.

3.3 Data Resources

Data was collected using the following tools:

1. Open questionnaire distributed to the heads of the CS teacher preparation programs and to the instructors of the MTCS courses. The questionnaire addressed the personal credo of the research participants, the pedagogical objectives of the CS teacher preparation programs and of each of its elements, the professional skills that CS teachers should acquire, and details of how these topics are actually expressed in the program.
2. Documents that describe the rationale and structure of the CS teacher preparation programs.
3. Syllabi of the MTCS courses and descriptions of the practicum.

4. SURVEY FINDINGS

In this section, we present the survey findings with respect to the structure of the programs (Section 4.1), the survey participants' rationale and vision of the characteristics of CS and how they should be expressed and reflected in the teacher preparation programs (Section 4.2), and the programs' main components (Section 4.3).

4.1 The Structure of the Programs

As in any other discipline, CS teacher preparation programs are offered in two frameworks described in Section 2.2: (a) Teaching certificate and (b) Bachelor of Education (B.Ed.).

The surveyed programs are based on the following components (1 unit is ~ 28 academic hours):

(1) CS studies - either as a major or a minor;
(2) General pedagogical studies - 20-27 units;
(3) Didactics of CS - 2-6 units;
(4) Practicum in high school classes - 2-6 units.

It is noteworthy that all of the programs include, in their general pedagogical studies, courses that relate to research methods, and in most of the programs, students practice research skills within the CS discipline. This fact further illustrates the interconnections between the four elements of the Israeli high school CS education model (Figure 1).

[1] The JCT institution combines professional studies with Jewish studies.
[2] Machon Lev is for men and Machon Tal is for women – Students learn in different courses up to the gender.
[3] Al-Qasemi College of Education teaches Arab students.

4.2 The Essence of CS – The Participants' Perspective

One of the main findings of the survey reveals the common conception of all survey participants regarding the *essence of CS* and how *it inspires the actual implementation of the CS teacher preparation programs*.

In what follows, we present, and illustrate using the survey participants' words, the main characteristics of CS which in their opinion must be understood by prospective CS teachers (PCST).

- **CS is a dynamic field that keeps changing**
  - *PCST should feel comfortable with the frequent developments in the field, which enables them updating their teaching materials.*
  - *PCST should be able to read professional papers (in CS and in CS education research).*
- **CS knowledge and its interconnections with other disciplines**
  - *PCST should have sufficient professional knowledge in order to have the self-esteem required to teach the pupils.*
  - *PCST should have broad perception of the various aspects of CS and of its interconnections with other fields.*
- **The centrality of problem-solving processes in CS**
  - *Problem-solving processes are at the heart of CS and therefore should be at the heart of its teaching.*
  - *Pupils must become familiar with different programming paradigms to provide different perspectives of problem-solving processes.*
  - *CS teachers must be aware of learners' difficulties during problem-solving processes.*

4.3 Main Components of CS Teacher Preparation Programs

The survey participants addressed the importance that the PCST should acquire both *CS knowledge* (Section 4.3.1) and *CS pedagogical knowledge* (Section 4.3.2), and further, with respect to *CS pedagogy* - the importance of *integrating theory and practice.* Table 1 indicates the frameworks within which the PCST learn each component. In what follows, we elaborate on these components as expressed by the survey participants and demonstrate them using illustrative quotes.

Components of CS teacher preparation programs	Frameworks in which the PCST acquire this knowledge	
CS	- CS courses - MTCS - Designated courses offered by science education departments	
CS Pedagogy	**Theory**	- MTCS - Other designated courses
	Practice	- Practicum - MTCS

Table 1: Components of CS teacher preparation programs – the perspective of the survey participants

4.3.1 CS Topics

We start with several illustrative quotes that show the emphasis of CS knowledge in CS teacher preparation programs:

- *PCST must grasp the connections between different topics in the field of CS.*
- *PCST must acquire a broad perspective of the discipline at a high level of abstraction.*
- *PCST must acquire extensive knowledge on topics that are not usually taught in regular CS degrees, such as the history of CS, CS scientists, and a discussion of what CS is.*

This CS knowledge is acquired in addition to courses studied as part of the CS studies, in designated courses offered by the science education departments that offer the CS teacher preparation programs. These courses focus on CS contents with special attention to aspects relevant to high school CS teaching.

4.3.2 CS Pedagogy Topics

This component focuses on pedagogical content knowledge (PCK) [25], i.e., pedagogical knowledge that is specifically relevant for teaching CS. Such knowledge is acquired mainly in the MTCS course and the practicum. The following participants' abbreviated quotes emphasize the need to combine theoretical subjects with their implementation in the teaching of CS in general, and the need to show the PCST ways to apply outcomes of CS educational research in their own teaching in particular.

We present the survey participants' perspective on the two aspects of teaching CS, theory and practice, when asked to describe their perceptions of two main components of the CS teacher preparation program – the MTCS course and the practicum in high school CS classes.

The MTCS Course

The survey participants addressed the following topics with respect to the MTCS course. As can be seen, most of the topics relate the theory with the practice of CS teaching. We note that only illustrative quotes are presented.

CS pedagogic theory

- *PCST should acquire knowledge and tools for planning, creating and preparing lessons.*
- *The studies must be based on recent CS education literature. It is important to facilitate guided discussions based on the learned material.*
- *PCST should explore the main information resources like the ACM Digital Library and the Journal of Computer Science Education.*
- *PCST must become aware of the need for ongoing learning, ongoing reflection and ongoing professional development.*

Familiarity with the high school CS curriculum

- *PCST should become familiar with the national high school CS curriculum they intend to teach.*
- *PCST should become familiar with CS curricula used abroad.*
- *The curriculum should be broken down into main topics and each topic should be addressed from different perspectives.*

The teacher's perspective

- *A teaching toolbox should be anchored in the CS learning content: active learning, inquiry learning, peer teaching, teaching in the lab, learning by projects, animation and visualization tools, internet, games, different kinds of questions, patterns.*
- *[Students'] problems that emerge should be discussed and coping approaches should be offered.*
- *How to plan a teaching sequence and a lesson for a specific topic defined in the curriculum.*
- *PCST should acquire strategies to evaluate pupils' products: class assignments, homework, exams, projects.*
- *PCST should employ ongoing reflective thinking to improve their performance.*
- *PCST should become familiar with the main online information resources that the CS teachers can use.*

The pupil's perspective

- *PCST should increase their awareness to pupils' learning processes and difficulties.*
- *PCST should analyze students' difficulties and typical mistakes in different topics of the curriculum.*
- *PCST should adapt learning materials to meet the needs of pupils with different cognitive skills.*

The survey participants also referred to the teaching strategies applied in the MTCS course. These strategies should serve as an example for good teaching and should combine all of the above perspectives.

The practicum

The survey participants use the MTCS course as an opportunity to prepare the prospective CS teachers for their practicum in high school CS classes, as is described in what follows:

- *The practicum provides an opportunity to apply, for the first time, the theoretical knowledge the PCST are exposed to in the* [MTCS] *course. The students prepare and teach mini-lessons to their peers in the course and get their feedback.*
- *A tutoring project is integrated in which each PCST tutors another university student who is taking an introductory CS course.*

The objectives of the actual practicum that takes place in high school classes, as perceived by the survey participants, address benefits beyond the acquisition of actual teaching experience. As is illustrated in what follows, the participants also address the benefits gained from observing the mentor-teacher teaching and from the actual opportunity of becoming familiar with the school system, from a teacher's perspective.

First teaching experience

- *PCST gain some basic experience in the preparation of CS lessons.*
- *PCST gain some basic and initial experience in teaching CS.*

Observing the mentor-teacher

- *PCST observe the teaching of lessons in the computer lab and in the traditional class.*
- *PCST observe different aspects of school teaching, such as pupils' behavior, teacher-pupil discourse, class atmosphere*
- *PCST benefit from the guidance and supervision of an expert.*

Becoming familiar with the school system

- *PCST are first introduced to high school pupils.*
- *PCST participate in the different activities that their mentor-teachers are involved.*

5. Discussion

The accumulative experience gained in Israel during the past two decades with respect to CS teacher preparation delivers a very clear message: *Since CS has unique characteristics,* ***designated*** *CS teacher preparation programs should be offered*. This

message has two main implications: (1) only teachers with formal CS background should teach CS in the high school; and (2) a general science-teaching certificate is not sufficient for teaching CS. We intend to follow up this survey by interviewing the survey participants and examining additional details of the actual application these programs (e.g., hours allocated to each aspect of the above findings).

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