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Judith Gal-Ezer; Ela Zur
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REACHING OUT TO CS TEACHERS: CERTIFICATION VIA DISTANCE LEARNING

Judith Gal-Ezer and Ela Zur
The Open University of Israel
108 Ravutzki Street
Raanana, 43107, Israel
Judith,ela@cs.openu.ac.il

ABSTRACT

Teachers are the key to the successful implementation of any study program. Beyond the mastery of core professional material, teachers should have the additional ability to convey this material to others accurately and reliably, to provide perspective, and to infuse the students with interest and curiosity. This requires a rigorous, well-established teachers' certification program. Many academic institutions offer such a program for mathematics and other scientific disciplines. However, computer science is still a young discipline, and even today in many countries, it is rarely offered as an elective in high schools, nor are computer science certification programs offered in teacher training institutions. As a result, teachers who choose this discipline, have difficulty finding a study program for their own education. We at the Open University of Israel offer such a program and deliver it via distance learning. In this paper, we describe the program as it relates to the high school computer science curriculum currently implemented in Israeli high schools, and provide relevant data.

1. INTRODUCTION

We strongly believe that teachers are and always will be the cornerstone to the successful implementation of any curriculum. We think there is a difference between the background required of a practitioner or researcher in a scientific field and an educator. While the work of the researcher requires extensive knowledge and skills in the field itself, usually in the specific area of interest, the educator must have additional abilities, to convey the specific knowledge to the students, accurately and reliably; to be able to provide perspective, and to infuse the students with interest, curiosity, and enthusiasm. While some of this is a matter of personality and natural aptitude, some can be acquired by being exposed to material that goes beyond the technical core parts of the field.

That is why usually a teaching certificate is needed in order to get a

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teacher's license, in addition to the requirements of a Bachelor or sometimes a Masters degree in the discipline.

Computer Science (CS) is a relatively young discipline, and CS high school study programs are even younger. In many countries, computer science is still not taught in high schools and no CS certification program is offered. In Israel, a rigorous CS curriculum has been implemented in high schools since 1995. Still, only a few institutions offer CS certificate study programs. Also, because teachers live and teach in all parts of the country, they cannot always study at a traditional academic institution.

As a result, the Open University of Israel (OUI), a distance education institution, developed a CS teachers' certification program. The program which includes academic courses in Computer Science and in Education as well as field experience, is delivered via distance teaching, and is offered to pre-service and in-service teachers of CS. To understand the certification program, it is first necessary to describe how the OUI works.

2. THE OPEN UNIVERSITY OF ISRAEL (OUI)

The OUI is a distance education university that offers academic studies to students throughout Israel and abroad. Its study method allows its students to pursue higher education when traditional programs may not be possible.

The OUI is open to all who wish to undertake studies towards an undergraduate degree, without preconditions or admission requirements. OUI textbooks, written by preeminent specialists in Israel and abroad, are the primary component of the OUI method of study. The OUI also incorporates innovative and advanced technologies into its teaching: Internet, interactive instruction through broadband communication, multimedia, etc. In every course, students may also participate in optional tutorial sessions held at study centers throughout the country. Students submit assignments during the semester and take a final exam in every course. They determine their own pace of study based on the time at their disposal.

The OUI offers, to its 40,000 students, over 60 structured undergraduate programs of study in the Humanities, Social Sciences and Sciences, five graduate programs (which have strict admission requirements) in Business Administration, Democracy Studies, Education – Learning Technologies and Learning Systems, Biological Thought and Computer Science, as well as high school teaching certificates in several areas, and certificate studies in Computer Science.

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In order to efficiently integrate new technologies into the study system, in 1995 the OUI established the Center for Technology in Distance Education, *Shoham*. The Center deals with the development, evaluation, research and integration of integrative technology-based pedagogical solutions to meet the various needs of academic courses offered by the University, enabling it to provide higher quality and a more effective and enjoyable learning experience to its varied and dispersed student body. Recently, in order to promote theoretical and practical research in the area of instructional technologies and their integration into educational systems, the Chais Research Center for the Integration of Technology in Education was established. It provides a platform for cooperation among researchers, within and outside the Open University, in the areas of instructional technologies and their integration. It assembles theoretical knowledge on the uses of technology in teaching and learning for the benefit of the Open University and other institutions.

3. WEB-BASED TEACHING IN THE COMPUTER SCIENCE DEPARTMENT

Courses offered by the OUI are fundamentally different from courses offered at other Universities. The customary image of a course - a classroom with a teacher on the podium facing a group of students - applies only partially to the OUI. Learning at the OUI is primarily a self-study process based on written materials, not on sitting and listening to lectures. As mentioned, the OUI makes use of web-based technologies to enhance its distance teaching, which provide a wealth of learning materials and continuous contact with faculty and other students in the course. These technologies do not replace the written study materials that constitute the core of the course, but expand and enrich them. The incorporation of web-based teaching methods is fully adapted to the written study material.

The CS Department offers a central home page that serves as a main entry point for students. It includes general information regarding the CS department, such as a description of the undergraduate and graduate CS programs, a list of faculty members and advisors, and links to course websites. Each course website represents an interactive learning environment and contains the following pedagogical and administrative elements:

- ***Interactive learning*** - One-to-one and group interaction among students, tutors and the course coordinator, through an asynchronous discussion group where students post questions and comments. Students often respond to each other's questions and discussions take place. The

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teaching staff motivates, monitors and contributes to these discussions. In addition to the asynchronous forum, it is also possible to communicate through chat technology integrated into the course website.

- ***Supplementary learning materials*** - Including digital versions of course materials such as tutorial lecture notes, exercises, and sample exams as well as links to additional materials and data sources on the internet.
- ***Bulletin board*** - Used mostly by the course coordinator to announce schedule changes, important notices and special events.
- ***Personal activity schedule*** - Gives the student a monthly view in the form of a calendar that shows all activities related to the course, such as what material needs to be covered every week, submission dates of assignments, and dates of tutorial sessions and exams.
- ***Personal notebook*** - Allows the student to personalize the website by grouping pointers to selected items and activities, such as an important comment in the discussion group, or a particularly helpful example or exercise solution.
- ***List of students*** - Includes e-mail addresses of students who wish to be in contact with other students in the course, enabling contact among students who live throughout the country.
- ***Teaching staff*** - Includes office hours and e-mails of the course coordinator and the tutors.
- ***Web-based assignment submission system*** - A fully integrated system used by students, tutors and course coordinators for submitting and grading assignments online (rather than by mail in the traditional system). The course coordinator can enter the system at any time and monitor the status of assignment submission and grading.
- ***Administration*** - On-line administrative services such as registration, notification of grades, etc.

In the following sections, we will describe the teachers' certificate program offered by the Computer Science department of the OUI. This program is closely connected to the Israeli high school CS curriculum [3].

4. THE HIGH SCHOOL CS CURRICULUM

There has been considerable activity surrounding CS curricula on all levels (See references). Particularly notable is the high-school curriculum designed by the special ACM task force [13], and the new K-12 curriculum [19].

The K-12 Curriculum is a new curriculum that is currently being

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made available. The framework, put together and published in 2003, suggests four levels of curriculum: *Level I (K-8)* Foundations of Computer Science; *Level II* (9 or 10) Computer Science in the Modern World; *Level III (10 or 11)* Computer Science as Analysis and Design; *Level IV (11 or 12)* Topics in Computer Science. The goal was to create a curriculum that could be widely disseminated and delivered, and accessible to every high school student in the US. Its motto is that every Computer Science student should understand the nature of the field and the place of Computer Science in the modern world. Students need to understand that Computer Science interleaves theoretical principles and application skills. They need to be capable of algorithmic thinking and of solving problems in other subjects and areas of their lives.

Israel's high school CS curricula was designed between 1990 and 1993 and first implemented in 1995. Its scope is 450 hours, taught over three years, and represents an extensive high-school-level study of the subject. Appointed by the body directly responsible for educational policy and its implementation, the Ministry of Education, the Committee that designed the curriculum was also heavily involved in supervising the many additional activities required to turn a skeleton curriculum into a widely-used working program.

A detailed description of the program is given in [2, 6]. Some of the principles that guided the work of the program designers are:

- ***Computer Science is a full-fledged scientific field*** and should be taught on a par with Physics, Chemistry and Biology.
- ***The program should concentrate on the key concepts and foundations of*** **the** ***field,*** emphasizing the notion of an algorithmic problem and its solution. The program should focus on enduring concepts of computer science not on changing technology.
- ***Two different programs are needed, one for the 3-unit and one for the 5-unit program,*** the first for those who have only a general interest in computer science, and the second for those who want to become more involved in this scientific discipline.
- ***Each of the programs should have both required units and electives,*** to achieve variance and flexibility.
- ***The zipper principle:*** Conceptual and experimental issues should be interwoven throughout the program.
- ***Two different programming paradigms should be taught*** to provide different ways of algorithmic thinking or different ways of solving problems.

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- ***A well-equipped and well-maintained computer laboratory is mandatory*** to support laboratory sessions and individual "screen time" for each student.
- ***New course material must be written for all parts of the program,*** by different teams in different academic institutions. The teams must have computer scientists on board, as well as high school teachers and researchers in computer science education.
- ***Teachers certified to teach computer science must have adequate formal computer science education,*** i.e., at least an undergraduate degree in computer science.

This final principle motivated the preparation of a "crash" program for those teachers who were already teaching CS but did not have the required formal education. These teachers could take about ten CS courses that represent the core of Computer Science, and receive a formal certificate from the Open University. This special program was not designed to substitute for a teachers' certification program, which we prepared at the OUI and is described in the next section.

5. THE TEACHERS CERTIFICATE STUDY PROGRAM

No curriculum can be implemented without the cooperation of the teachers; they are the cornerstone of every educational program. Many works have been published in the professional literature and presented at conferences relating to teachers' in-service training, teachers' certification programs, and the like [See 2, 7, 8, 11, 12, 14, 15, 16, 17, and more.]. National and international associations have been established, the best known being CSTA - the Computer Science Teachers' Association - an organization that supports and promotes the teaching of computer science and other computing disciplines, and provides opportunities for K-12 teachers and students to better understand the computing disciplines and to more successfully prepare themselves to teach and learn (for details, see: http://csta.acm.org/).

The CS teacher certification program developed at the Open University is geared for students with an undergraduate degree in Computer Science. Applicants with a degree in a related field of study are required to take qualifying courses in Computer Science and/or Mathematics before beginning the program. An academic advisor (the second author of this paper) for the teaching certificate in Computer Science determines which courses each student needs to take.

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The program has three components:

1. Academic credits in Computer Science, including the course *Algorithmics: The Foundations of Computer Science*, which provides a bird's-eye-view of the discipline, and the seminar: *Topics in Computer Science Education*. Students who have taken these courses as part of their Bachelor's degree studies are required to take other courses in Computer Science.

2. Academic courses in Education, including *Critical Thinking: Statistical and Intuitive Considerations*, *Curriculum Design: Development, and Implementation,* and either *Educational Psychology* or *Individualized Instruction*.

3. Methodology and field experience. Every student must participate in the workshop, *Methodology of Computer Science Teaching*, and successfully complete the field experience during which they have to observe a number of classroom lessons and practice teaching at least two lessons in a designated school.

The program may differ from one student to another, since some of the mandatory courses may have already been part of the student's undergraduate studies, in which case other courses from the CS and Education department are substituted. Also, some of the teachers who take the program are already high school teachers. For them, a specially-tailored field experience has to be designed. That is why the OUI *Study Programs Approval Committee* and the academic advisor for the Teaching Certificate in Computer Science have to approve each student's study program.

6. COURSE DESCRIPTIONS

In this section, we briefly describe the courses included in the certification program.

Computer Science Courses

Algorithmics: The Foundations of Computer Science

The course is based on a translation of *The Science of Computing: Exploring the Nature and Power of Algorithms*, by D. Harel (Addison-Wesley, 1989), and updates based on a later version of the book by D. Harel and Y. Feldman [10].

The course provides a bird's-eye-view of the discipline, surveying basic topics in computer science. It focuses on the fundamentals of machine-executable processes and on the concept of the algorithm - the procedure which generates these processes (rather than the structure of the computer, its physical use, or specific programming languages). The

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following questions are raised: What kinds of problems can be solved using the computer, and how? Which problems cannot be solved using the computer, and why? The course helps to organize the material studied in the various computer science courses and surveys current and future research in the field.

Topics in Computer Science Education

A description of this course is given in Gal-Ezer and Harel [2]. The course is based on a reader of articles edited by the first author of this paper. In addition to an overview, there are several topics that we believe educators should study and become familiar with, and we discuss each of them separately in the course. The topics are: History of CS, that of the theory as well as that of the machines themselves; the question of the nature of the field and its relationship with other disciplines; the details of various CS curricula and study programs on both high school and college/university levels; a variety of issues concerning problems of teaching programming; and the use of tools and aids in teaching computer science. The reader is constantly updated, with obsolete articles replaced with new ones. This is usually done through the course website, by providing links to new articles.

Students are required to participate in tutorials, submit a seminar paper and present it orally. The methodology of the course was designed to combine several academic skills to which we believe teachers in their pre-service studies must be exposed. These skills include:

Self-study of advanced material - Is achieved through required reading of professional papers, some assigned by the instructor, and others that the students have to find by searching the library databases.

Preparing and delivering a lecture to fellow students - Each student is assigned one of the course topics and is required to prepare a half-hour long presentation to be delivered in class. Usually the presentation is based on one of the articles in the reader. This also serves as preparation for the presentation of the final seminar paper.

Submit a seminar paper - The seminar paper is much larger than any other exercise assigned throughout their certification studies. It requires academic research abilities and writing skills.

Seminar paper presentation - The students are required to present their seminar work to the course staff. They must defend their work and demonstrate knowledge on all the topics covered in the course.

Possible seminar paper topics are: Historical development of programming languages; Computer Science curricula in high school and colleges/universities in different countries; the relationship of the field with

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other disciplines; the first programming language and its influence; problems in teaching programming; misconceptions in Computer Science; problems in teaching recursion and pedagogical ways to prevent them; problems in teaching efficiency and pedagogical ways to prevent them; teaching different paradigms; problems in teaching the CS1 course; tools and aids in teaching Turing machines; gender issues in CS programs, and more.

A supervisor is assigned to each student. Often the course coordinator serves as the seminar supervisor. The supervisor guides the student in all stages of writing a seminar paper. Due to distance teaching at the OUI, most of the supervision is via the course website, discussion groups and e-mail. The course website includes links to supplementary learning materials such as links to articles relevant to the seminar paper and links to seminar papers written by graduates of the course.

Education Courses

Critical Thinking: Statistical and Intuitive Considerations

The authors Amos Tversky and Varda Liberman [20] designed the course based on Prof. Tversky's works. It discusses issues that appear in daily articles and recommendations concerning such questions as: does a low-cholesterol diet increase life expectancy? Is there such a thing as a born athlete? Can handwriting predict professional success? Is positive reinforcement more effective than negative reinforcement? The course is designed to provide students with basic tools for critical thinking which will help them become intelligent information consumers.

The course presents concepts in statistics and relevant methodological considerations along with psychological mechanisms which human beings tend to use to intuitively evaluate information. The course focuses on issues in which intuitive impressions which do not coincide with statistical considerations often result in systematic biases such as gambler's fallacy, over-confidence, spurious correlation, and non-regressive prediction.

Curriculum Design, Development, and Implementation

The course surveys the theoretical background underlying curriculum planning, describes the complex processes involved in curriculum planning, and examines the implementation, application and assessment of new curricula through specific examples. The topics covered are: Determining curricular objectives; Classifying the objectives; Curriculum planning and development; Communication, educational technology and curricula; Educational television; The psychological basis of curricula; Teaching strategies and curricula; Assessment; Curriculum evaluation by the consumer.

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Educational Psychology

The course provides knowledge and understanding of processes involved in education and learning. Topics covered are: The area of psychology, and specifically the field of educational psychology, major issues in the field, methods of data collection, consumers; motivational factors - internal factors which affect learning, such as motivation for achievement, curiosity, self-image, etc.; cognitive factors - the influence of cognitive factors on learning, theories relating to cognitive development, intelligence, memory, creativity, etc.; social factors - social aspects of the classroom and their influence on learning; learning - major, long-standing theories of learning: behavioral theories and their application in teaching; cognitive-phenomenological theories; major learning processes which facilitate learning in school; the school and the teacher - the teacher's role and rationale for entering the profession, ways of dealing with discipline problems and violence, and various teaching methods.

Individualized Instruction

The course enables students to shape an overall educational approach which advocates the individualization of teaching-learning processes, presents its philosophical and psychological aspects and examines various ways of developing curricula, operation, educational management, diagnosis and assessment. The course focuses on an analysis of the educational philosophy and practical operation of an individualized instruction project in the framework of the Center for Educational Technology.

Methodology

The Methodology of Computer Science Teaching Workshop

This workshop aims to impart a didactic approach to computer science teaching, while focusing on the following topics: basic topics in computer science, problem-solving methods, misconceptions, teaching and learning strategies, and more.

The workshop combines videotaped lectures, self-study of academic material, group work and exercises, and includes several mandatory 4-hour tutorial sessions. The material is presented through varied examples combined with writing in pseudo-code and in a programming language. Students submit a final paper.

Topics discussed are: the computer science curriculum - principles and objectives; curriculum planning and implementation; fundamental topics in computer science - the concept of algorithms, writing in pseudo-code, basic computation model, programming algorithms; algorithm correctness; algorithm complexity; recursion; various programming

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paradigms. Problem-solving heuristics - abstraction; decomposing a problem into sub-problems, top-down design, bottom-up design, gradual refinement; generalization, analogy, etc. Misconceptions in the following areas: variables, input statements, output statements, conditional execution, repetition, procedures, functions, arrays, etc. Teaching and learning strategies: teaching/learning methods - motivating toward concepts/ideas, case studies, demonstrations, games, projects, self-explanation, etc.; teaching in a heterogeneous classroom: pupil grouping in the classroom - group work, individual work, face to face teaching; the structure of a lesson - combining class work, lab and practice at home; writing lesson plans; assessment - writing and grading tests and exercises.

As mentioned, the main element of the OUI study method is usually the written textbook, however, this workshop deals with didactics, and we think it is very important for pre-service teachers to observe a teacher in action; thus, we decided to base the workshop on videotaped lectures given to a student audience by Dr. David Ginat, an expert in computer science education. The students are given CDs and can watch the lectures time and again.

Students are required to attend several face-to-face sessions each lasting about four hours. At these sessions, students practice the topics viewed on the videotape. Topics are presented through varied examples in pseudo-code and programming languages. The students prepare a mini-lesson based on a topic they choose, and present it. The other students and the instructor provide feedback.

At the end of the course, students submit a final assignment, which includes a detailed outline of one lesson for a specific topic from the high school CS curriculum.

Field Experience

Students begin their field experience only after the approval of the Study Programs Approval Committee and the academic advisor for the Teaching Certificate in Computer Science who also determines the detailed field experience program. The field experience takes place in a high school near where the student lives. Since our students are located all over the country, we try to find suitable high schools in their geographical areas. The practical training is administered by a teaching coordinator who assigns each student to a teacher in a high school.

Every pre-service student observes two classroom lessons for a period of 14-weeks, and is required to teach at least two classes. The teaching coordinator and the academic advisor provide feedback to the student.

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During their field experience, students need to do the following: prepare exercises, prepare lab assignments, check homework, grade examinations, participate in teachers' meetings, participate in parent-teacher meetings, help students who have difficulties in understanding the lessons, etc.

In-service teachers who take this program have somewhat fewer requirements, but they still need to take part in most elements of the field experience.

7. ENROLLMENTS, GRADUATES, GEOGRAPHICAL AND INSTITUTIONAL DISTRIBUTION

In this section, we present data related to students who took the Computer Science Teachers' Certification at the OUI between 1997 and 2006. During this period, 60 students participated in the program, of whom 35 completed the program requirements and received the Teachers' Certification (58%). About 18 students (30%) are currently at different stages of their studies and 7 students (12%) are beginning their studies. Figure 1 presents the number of students who took the program each year.

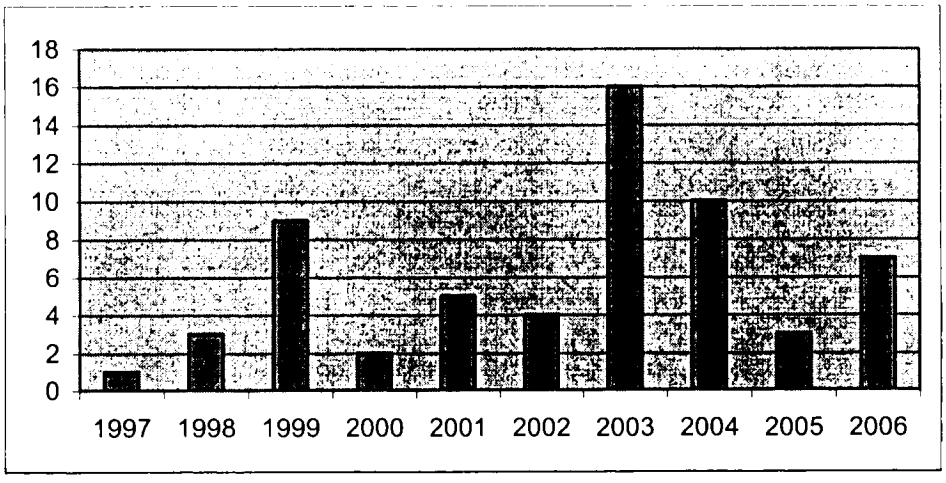

Figure 1 – Number of students, by year

As Figure 1 indicates, in 2003 more students began the program than in other years. Our explanation for this phenomenon is that many CS graduates who were unable to find jobs in the high-tech industry decided to to become high school Computer Science teachers.

Figure 2 presents the geographical distribution of students between 1997 and 2006.

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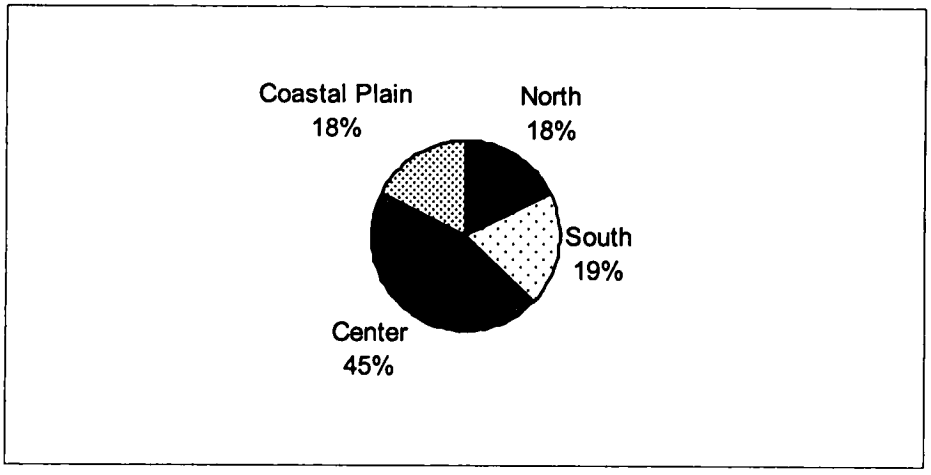

Figure 2 - Geographical distribution of students

As Figure 2 shows, more than 50% of the students live in distant areas of the country (not in the center). The OUI's distance education enables students all over the country to participate in this program.

Figure 3 presents the types of universities and colleges from which the students graduated before joining the program.

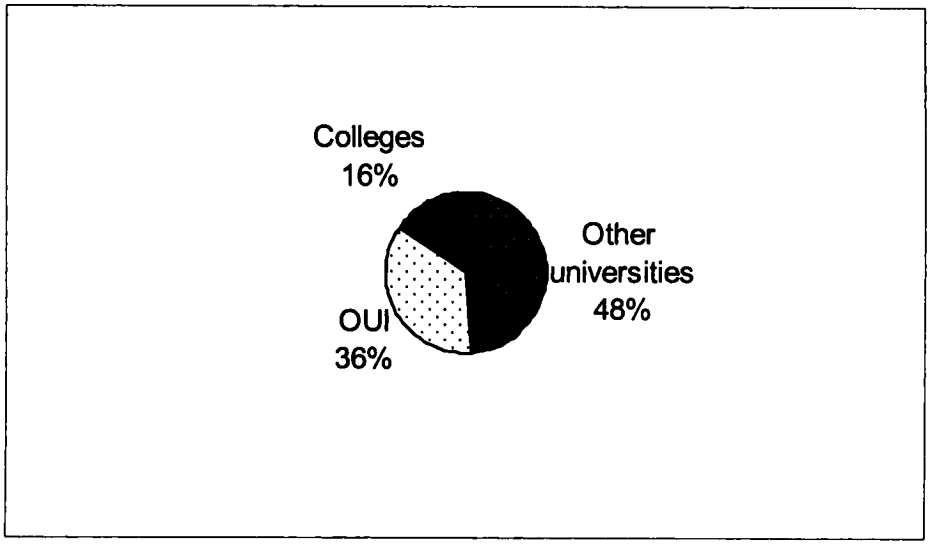

Figure 3 - Distribution of universities and colleges

When we asked the students who graduated from other universities why they chose to enroll at the OUI, most of them said that the main reason for this was that the distance study method enabled them to enroll in the program and begin their studies towards a teachers' certificate without leaving their home or their work.

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It is known that, throughout the world, most CS graduates join the high-tech industry, some remain in academia and only a few become CS high school teachers, and these have not always been the graduates with the best grades. We were pleased to see that the students who participated in our program graduated from the OUI or other academic institutions with relatively high grades, as shown in Figure 4.

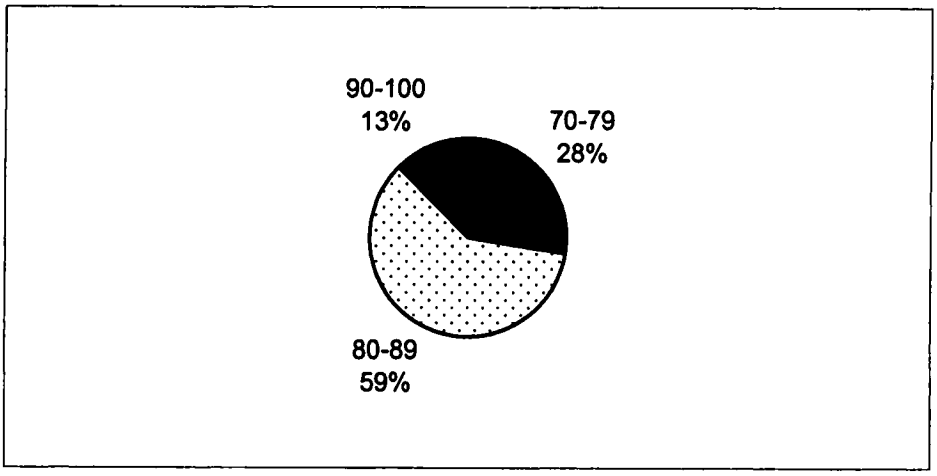

Figure 4 - Distribution of GPA for the Degree

One can see that most of the students participating in the program are very good students. Also while most of the students who graduated from the program are teaching in high schools, some work in the high-tech industry while taking the program, preparing for an alternative profession (just in case). Some will take a year or two off, and volunteer to teach in one of the high schools where they live. Although we have not supported this remark with research, many students express their satisfaction with this program.

One more thing worth mentioning is the fact that traditionally, most high school teachers are female. Indeed here too, 65% of our students are female, yet a larger than normal percentage of the students is male.

8. DISCUSSION AND FUTURE CHALLENGES

We cannot overestimate the importance of the role that teachers play in the implementation of a study program, especially a new program. In computer science, a rapidly-changing discipline, this is even more critical.

When the high school computer science curriculum was first implemented, there were few institutions which offered a CS certification program, and practicing teachers from many other disciplines took on the responsibility of teaching CS. It seemed that what was needed was a

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program which could be delivered via distance teaching, so that teachers from all over the country, especially in-service teachers, could enroll.

The OUI accepting the challenge, and offered teachers' certification in computer science by distance learning has been an important contribution to education, since teachers do not necessarily live near universities, or teach in schools that are near universities. The fact that potential teachers can also take core courses in computer science education through distance learning also helps to recruit CS teachers even from within the high-tech industry.

Today, no CS teacher can get a license without having formal CS education (Bachelor's or Master's degree), and in addition, a CS teaching certificate. The OUI program makes this available to pre-service and in-service teachers.

Teachers have to stay current with the rapidly changing technology in the CS field. There has been a paradigm shift in the high school curriculum, from procedural languages (Pascal or C) to object-oriented (OO) languages (Java or C#). The educational problems that arise when teaching OO languages in colleges or universities (Objects first? If not, then when? How to teach objects?, etc.) come up in high school as well. Teachers who are recent college graduates probably learned OO languages in the introductory courses. However, in-service teachers have to learn a new language and a new paradigm and how to convey it properly to their students. This is very challenging, and needs ongoing training. In the OUI certificate program, in-service teachers can take the introductory CS course with Java, and then take *Advanced Programming with Java* and *Advanced Programming with Java Workshop*. These courses are offered by the OUI via distance education so that students from all over the country, including in-service teachers, can participate. Staying up-to-date is an on-going challenge both for computer science teachers and for the Open University.

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