Special Characteristics of Computer Science; Effects on Teaching and Learning : Views of Teachers

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Abstract

In this study the views of the teachers of Computer Science about the special characteristics of this subject and their effect on its teaching and learning are investigated. From the analysis and interpretation of data these teachers recognized the multidimensional character of Computer Science and that it has an effect on its teaching and learning. Whereas the reported approaches in the traditional classroom setting emphasized the model of 'transmission of knowledge', there was a radical transformation of approach towards more modern approaches transformed radically in the computer lab setting. As teachers reported, the computer acted as a catalyst in transforming the whole learning context, including the subject matter, the pupils and the teacher. Teachers recognized Computer Science as rapidly and continually changing discipline and as a subject with great cognitive opaqueness for the pupils. Hence teachers expressed the need to be educated in any new developments in this subject as well as in topics related to its teaching and learning including educational software and the Internet as tools for learning. As a result they proposed the development of a program of on-going further education for teachers. Teachers also expressed the need for school counselors for Computer Science as well as the modification of the curricula towards problem solving and programming.

1. Introduction

Computer Science is simultaneously a mathematical, scientific and engineering discipline, that has inherent cultural, social, legal and ethical issues that affect life socially and financially [2], [3]. Computer Science also has a significant impact on the teaching and learning of all educational subjects as has been acknowledged by many researchers [17], [5], [10]. As Computer Science can be viewed from this multi-dimensional perspective the educational approaches to its teaching and learning emancipate its different dimensions [2], [12]. Computer Science emphasizes three processes: theory, abstraction and design [2].

The 'theory' process is used in developing and understanding the underlying mathematical principles which apply to this discipline. The elements of this process are definitions and axioms as well as theorems, proofs and the interpretation of results. This 'theory' process can be interpreted in the teaching and learning of Computer Science as the acceptance of deductive logic in the process of the construction of meanings through a variety of examples coming from different contexts. The 'abstraction' process is rooted in the experimental sciences and is based on the design of an experiment data collection proceeding to the analysis of the results and to modeling and coming to hypothesis formation and prediction. Interpreting this 'abstraction' process in Computer Science Education we accept the constructivism approach to the construction of knowledge [20], [9], [1], [7]. This approach emphasizes the role of inductive logic in the construction of knowledge regarding

this discipline, starting from the collection and the study of the relevant data and concrete situations to form hypotheses and models. The 'design' process is rooted in engineering and is used in the development of the specific system or device to solve a given problem. This process has the following parts : definition of requirements, formulation of specifications, design and implementation and finally testing and analysis of the behavior of the artifact. The 'design' process in the teaching and learning of Computer Science emphasizes the central role of the development of pupils' ability to apply their knowledge to specific constrained real problems and to produce fast, efficient and cost effective solutions [2].

Critical thinking is very crucial for the construction of solutions in problem solving situations [15], [14], [11]. Critical thinking also, is closely related to the development of the pupils' ability to make decisions, choose between different solutions and make predictions. Pupils also, should have additional experience in developing their critical thinking as for example in working as part of a team to complete extensive projects [8], [19]. These projects involve the processes of design, implementation and evaluation as well as oral and written presentation. Through all these processes, pupils have to develop their oral and written communication skills. The limitations of time and the development of the responsibility of each member of a team have to be stressed by the teacher as crucial in the completion of project work in this discipline. Pupils' work in the computer laboratory gives them the opportunity to develop problem solving abilities and analytical skills and to gain essential experience in a number of topics such as: hardware, programming and the use of specific software.

The high level of abstraction that is involved in most of the topics related to the discipline of Computer Science causes great difficulties in its teaching and learning. For this reason different methodologies based on the development of inductive and deductive reasoning could be used as well as the computer itself as a cognitive tool in the teaching and learning of Computer Science. Making the power of the computer productive in teaching Computer Science is essential in the process of decreasing the great cognitive opaqueness of a majority of related topics. For example: topics related to computer architecture, computer networks and telecommunications etc. Educational software in the form of multimedia or simulations as well as multi-representational software are appropriate in the teaching and learning of Computer Science. In particular, the use of multi-representational software that consists of representational systems with floating transparency are appropriate in helping pupils move from the representations that are appropriate for their cognitive development to more abstract ones [6]. The Internet also can be used as a tool for learning Computer Science, giving pupils the opportunity to access a vast amount of relative knowledge and to use tools or environments placed faraway. All the above computer tools that can be used effectively in Computer Science Education can also play a crucial role in the teaching and learning of any subject. At this point it can be seen that the design and the evaluation of learning environments based on computer-tools is an integral part of Computer Science Education.

2. The context of the study

This study aims to illuminate the views of teachers of Computer Science about the different characteristics of this discipline and their effect on its teaching and learning. The importance of the investigation of the teachers views about teaching and learning Computer Science has been reported [13]. Twenty seven teachers participated in this study. These

teachers come from different types of schools (Gymnasium, Lyceum, Technical Lyceum, Night Lyceum and Night Technical Lyceum) and different geographic regions. All these teachers had 5-12 years of teaching experience in this subject. They also come from different scientific backgrounds such as Mathematics, Science, Computer Science and Computer Engineering. They participated in a program for teacher education in specific topics regarding Computer Science. During this program they were asked to reflect on their teaching experience on the subject of Computer Science and write their opinions about its special characteristics and how these affect their teaching practices. The data resources consist of all these papers written by the teachers during this study.

3. Results

Teachers who participated in this study viewed Computer Science as a discipline with different characteristics from other subjects that pupils were taught in schools. These characteristics included the multiple dimensions of the subject as well as its rapid and continuous change and development. Moreover, teachers recognized that this subject is very abstract and complicated as well as being closely related to the computer as a tool.

The multiple dimensions of Computer Science. Teachers reported that they are unable to be competent enough to employ the necessary knowledge to teach all subjects that constitute Computer Science. They also recognized that different teaching approaches have to be used for each subject. As a result these teachers proposed the necessity of the development of a program of on-going further education for teachers. Through this program Computer Science teachers would have the opportunity to be educated in any development regarding this discipline as well as investigating its essential, fundamental and non temporal parts. Moreover, this program would provide opportunities to teachers to study modern learning theories as well as to experience new teaching practices in Computer Science. Teachers formed categories of the subjects that constituted the discipline of Computer Science in secondary education, and then they described their teaching approaches regarding the subjects that fall in each category. In particular, they formed three categories, characterized by them as 'theoretical', 'applications' and 'general purpose software'. In their view, Algorithms, programming languages and Operation Systems fall into the 'theoretical' category, while Data Bases and Multimedia were viewed as 'applications'. As regards 'general purpose software' these teachers viewed the Access data base, the Windows operating system as well as the microsoft Excel spread sheets as essential elements.

Teaching approaches. Different teaching approaches corresponding to each of the above formed categories were reported by the teachers. These teaching approaches are presented and discussed bellow:

a) Teaching Algorithms and Operation Systems. The teaching approach that was reported here emphasizes the model of the transmission of knowledge. Teachers described this approach as a sequence of steps. As a first step, the teacher presents verbally the subject matter in terms of theoretical rules and examples. The media that are used are oral presentation, chalk and the blackboard. During this time the pupils are encouraged to express their opinions and difficulties in the teaching topic or to ask any questions. In the next step the teacher gives other examples to the pupils for consolidation. Most times these teaching approaches were realized without any pupil / computer interaction.

b) Teaching programming languages. Here, as well, teachers started to teach by presenting the syntactical rules of each specific command, then they presented small programs and finally they dealt with larger ones. These larger programs were taught in relation to the problems they solved and to the related specific algorithms. These problems usually did not relate to the pupils everyday life, so that no special meanings could be constructed by the pupils. In every case the pupils were asked to run the presented programs in the computers.
c) Teaching Data Bases and Multimedia. Here the teaching approach was different. Teachers reported that they started to teach by presenting verbally an application using chalk and the blackboard. They also discussed the pupils' opinions about this specific application. In the next phase, projects were assigned to the pupils to be accomplished in groups. When these projects had been completed by the pupils they were presented to the whole class. This presentation was followed by a whole class discussion and questioning by the pupils as well as by the teacher. While project work is strongly suggested as an appropriate teaching approach by the literature, teachers who participated in this study expressed their insecurity about project work. In particular, they expressed that they didn't have the appropriate knowledge to form and to manage interdisciplinary projects as well as projects that included research and data collection from different fields. Teachers also expressed anxiety about how to manage a number of groups working together. More specifically they expressed that they felt uncomfortable listening to all the noise coming from the discussions of the pupils during their group work. In addition they felt overwhelmed when they had to walk around a number of groups and to answer all the pupils' questions.
d) Teaching general purpose software. In these subjects the teaching approach started with an instructional part. In particular, pupils learnt on line the basic features and uses of each specific piece of software following their teacher's instructions step by step. After this phase, pupils had to work in groups to accomplish project work. The completion of the projects was followed by an oral presentation to the whole class and whole-class discussion followed in the same way that has been described in the previous approach ©.

School counselors for Computer Science. Teachers expressed their need to consult an expert when they needed, so they proposed the recruitment of a specialist as a school counselor for Computer Science in secondary education. In particular they expressed the need to be advised about any new development regarding the discipline of Computer Science in secondary education as well as in modern learning theories and teaching practices.

The Computer Science Curricula. Teachers stressed the need for the modification of the existent curricula in the discipline of Computer Science towards a lab-oriented approach in all grades of secondary education. As teachers proposed, especially for Lyceum level education, the curricula should shift from the teaching of every topic related to the discipline of Computer Science to an approach that emphasizes problem solving processes using algorithmic and programming approaches. The need for the training of pupils in the use of basic and fundamental computer tools in Lyceum education was also reported.

Teachers views about rapid and continuous change and development of Computer Science. Teachers acknowledged the rapid and continuous change and development of

Computer Science and stressed the need for on-going education in the modern development of this discipline. They also underlined the need to be educated in the fundamental and non temporal issues in each subject of Computer Science. They also emphasized the need to change their teaching plans and activities in order to fit in with the changes relating to software and hardware issues. Moreover, teachers recognized the need for a continuing attempt at compatibility between new knowledge and the available hardware and software technology. In addition they emphasized the use of modern technologies in teaching and learning Computer Science such as the use of educational software and the use of the Internet.

Teachers views about Computer Science as a non transparent discipline. Teachers stressed pupils' difficulties in understanding fundamental issues in Computer Science as it involves knowledge emerging as a result of a sequence of abstractions. So, teachers expressed their difficulties in forcing pupils to move from the simple recall of information towards the development of critical thinking. Emphasizing this point they recognize the need for the use of special learning environments in the teaching and learning of Computer Science such as multiple representational educational software, simulations and other educational tools.

Teachers views about the discipline and the tool. Teachers recognized the powerful effect of the computer in the whole learning context. More specifically teachers stressed that the computer can act as a challenge to many changes in the whole classroom cultural environment In particular they recognized that the understanding and the interest of their students increased when they interacted with computers in the computer laboratory. Teachers also appreciated that the pupils shared their attention and time in many directions such as interacting with the computer, attending to the teachers' actions, and interacting with the other pupils working in the same group. So the general cultural environment of the classroom changed towards a more student - centered environment. In this computer- enriched environment, the authoritarian role of the teachers is decreased and the role of the teacher as facilitator of the learning process becomes more appropriate. Moreover, the fact that the number of computers in each laboratory is limited, forces the pupils to work in group developing their cooperative skills. The nature of the discipline of Computer Science also encourages the teachers, to try project work with their students. Moreover, as these teachers reported, the interest of their students increased when they worked in the environment of the computer laboratory whereas they were reluctant to learn topics about Computer Science in the traditional classroom setting. The fact that the teaching of Computer Science is strongly dependant on computers themselves, illuminates some fundamental limitations in the learning situations. So, the proper maintenance of the computers during all the time of teaching, is vital in the teaching and learning process. Teachers expressed that they have difficulties in accepting effectively a double role; that of teacher and also of technician. So they proposed the recruitment of a person as a technician in each school in order to give technical support for any problem that might arise in the computer laboratory.

4. Discussion

Teachers recognized that the discipline of Computer Science has a multidimensional nature that affects its teaching and learning. Even though their views towards the epistemological nature of this discipline appeared limited, these views could be characterized

as superficial and as deriving only from the school-book knowledge about Computer Science as a discipline. This is not unexpected because these teachers as well as the students in the corresponding University departments don't have any education about epistemological issues regarding Computer Science. Teachers classified the subjects of Computer Science as they were classified by the school curricula without any reference to the basic processes that are implied in these subjects.

The reported teaching practices especially in teaching Algorithms and Operating Systems emphasized the model of the 'transmission of knowledge' [18] by the teacher. According to this model the whole classroom environment is teacher – centered and the teacher's role focuses exclusively on a good presentation of the subject mater ignoring pupils' thinking processes. From this perspective the learning process is viewed as the pupils' gradual movement from simple concepts to more complex ones while problem solving holistic approaches are neglected. Moreover the emphasis is put only on the learning outcomes while the learning processes are ignored. The above approach was also reported in the teaching of programming. The reported teaching approaches emphasized the syntactic rules of the programming languages and not problem solving activities. The pupils' gradual movement from simple concepts to more complex ones was also reported as the current working learning path in these teachers' classrooms.

In teaching Data Bases, Multimedia and general purpose software the teaching approaches were a little different. Pupils' learning usually took place in the computer laboratory and projects were assigned to the pupils to complete in groups. In the computer lab teaching setting, the organization of the class as well as the whole cultural environment of the classroom is changed [16]. Pupils engaged in a variety of interactions with the computers, the teachers and their peers. Moreover, the teachers couldn't remain as authority figures relying on their knowledge about the subject matter but as facilitators of the learning process. In this context the learning process involved cooperation, project work and the use of tools. Teachers signified difficulties in designing inter - disciplinary projects and in managing team work effectively in this lab setting probably because they still adhered to the 'transmission of knowledge' model of learning. In spite of these difficulties, the computer lab setting in relation to the nature of this discipline signaled essential changes in the whole classroom context of Computer Science Education. These changes are compatible with constructivist approaches of learning that acknowledge the active, subjective and constructive character of the knowledge [20] as well as with sociocultural approaches that emphasize the role of tools and communication [21].

The rapid change of the discipline of Computer Science imposes the need to emphasize the fundamental and non temporal issues in its learning and teaching [4]. This need is related to the clarification of these issues and the education of teachers through the establishment of a program of on-going further education for teachers. These programs could be extended to topics related to Computer Science Education as the majority of the teachers of this subject had not been educated to teach it. The high abstraction and opaqueness of the majority of the subjects of this discipline also demand the use of different approaches in its teaching and learning. Educational computer tools and environments as well as the Internet can be used to help teachers and students to overcome the difficulties deriving from the subjects' high abstraction and opaqueness. The modification of the curricula towards problem solving through programming was viewed as appropriate and proposed by the teachers.

5. Conclusions

Teachers who participated in this study recognized that the discipline of Computer Science has a multidimensional character that has an effect on its learning and teaching. The reported teachers' views were superficial as they may have derived from school-book knowledge about this subject.

The reported teaching approaches in Algorithms, Operating Systems and Programming languages were guided by the model of 'transmission of knowledge' and realized in traditional classroom settings. The teaching approaches relating to Data Bases, Multimedia and general purpose software developed towards more modern approaches which were realized in the computer lab setting. In this setting, the computer acted as a catalyst in transforming the whole learning context. In this setting the pupils engaged actively in their learning, working in teams to complete projects. The teachers' role was replaced from that of authoritarian to one of facilitator of the learning experience. In addition to the fact that these learning approaches can be further developed the data show that the existence of the computer in the classroom in relation to the nature of the subject of Computer Science can help the whole educational context to change towards one that is more constructivist and sociocultural.

Teachers expressed the need to be educated in topics related to any new developments in this subject including the use and development of educational software as well as in topics related to its teaching and learning. As a result they proposed the development of a program of on-going further education for teachers. Teachers also proposed the recruitment of school counselors for Computer Science as well as the modification of curricula towards problem solving through an algorithmic approach along with programming especially in the Lyceum. Moreover, they realized the need for the use of computer-based educational tools, environments and the Internet as tools for teaching and learning Computer Science.

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