

# One Step Further the ACM K-12 Final Report A Proposal for Level 1: Computer Organization for K-8

Giovanni M. Bianco  
Computer Science Serv.  
University of Verona  
Verona, Italy

giovanni.bianco@univr.it

Simonetta Tinazzi  
Scuola Media Statale  
Istituto Comprensivo "L. da Vinci"  
Bussolengo (Verona), Italy  
simonetta.tinazzi@univr.it

## Abstract

Teaching computer science to children is a major priority in most countries in the world. Nevertheless, Computer Science curricula do not seem to address the children's world, children who need specific languages, models, and presentation methods. In this paper we propose a novel approach of considering a Computer Science Education curriculum based on children's creativity and imagination. The scope is the computer organization (aka Level 1 in the ACM K-12 Final Report). Materials have been designed for children, teachers and parents and take a gender-neutral approach.

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

**General Terms:** Documentation, Human Factors, Theory.

**Keywords:** PC, Hardware, Children, Analogy, Fantasy, Play, Self-identification.

## 1. BACKGROUND

Much evidence, as reported by The ACM K-12 Final Report [16], confirms that developing Computer Science curricula for children is a major priority in most Countries. In Italy, for example, the Minister of Education has recently reformed the primary School curricula (6 to 10 years old) and one of the main priorities affects Computer Science.

Primary and secondary schools have a unique opportunity and responsibility to cover Computer Science topics but, unfortunately, CS curricula for children do not seem to take into account "their particular world" often working through an "abstract" or what is actually a reduction of classical Computer Science curricula for adults.

The ACM Report represents a model for computer science education, but not a deliverable curriculum. Additional steps are needed to formulate contents, curriculum, textbooks and laboratory materials. It is a compulsory step, when developing a CS curriculum, to consider "CS Fluency", i.e. building solid bases for CS knowledge and not limiting

the scope to "CS Literacy", i.e specific-but-limited applications [9].

From another point of view, while computer utilization continues to expand in elementary schools, the training of primary school teachers does not seem to be appropriate for CS. Teacher training in computing is certainly not a new topic: Poirot et al. [13] discussed similar arguments for colleges and high schools a couple of decades ago. It is certainly true, at least in Italy, that most of the primary school CS teachers are already working in the field, trained in a discipline other than CS and by choice (oddly by chance) are at the moment involved in teaching CS to children. This situation is similar to the U.S., as [16] reports: for teacher preparation and certification, slightly more than half of the U.S. States require CS certification to teach CS courses.

In addition, in order to design and develop a CS curriculum, two other strong aspects are of particular importance. Firstly, for a child the "Foundations of Computer Science" is the first level (aka Level 1) that they begin with [16]. It provides K-8 children with basic concepts by integrating technology principles and algorithmic thinking.

As the second point, it is well known that Computer Science has very limited success in attracting female students [14]. With reference to this point, the special issue of SIGCSE Bulletin dedicated to "Women in Computer Science" is a solid base to start from, but perhaps it is not enough because of the recruitment efforts that do not seem to focus on K-8 children, but rather on children aged from 10 to 12 [14]. It may be too late for young girls to "appreciate" CS as fun taking into consideration career opportunities. Therefore, it is of particular importance to develop a project that is gender-neutral right from the beginning, so as to appeal to both genders giving them the opportunity "to feel at ease" with Computer Science and particularly with technology [8].

Unfortunately, combining all the themes discussed so far (K-8, gender-neutral approaches, teacher training, CS fluency, computer organization) few works can be found in literature that are of much help.

One interesting example of a CS curriculum developed for children, teachers and parents has been presented in [2]: the Computer Science Unplugged.

The key concept in the work is that many topics in CS can be taught without using computers at all, from algorithms to AI, and from binary numbers to compression and cryptography. As stated by the authors: *by avoiding the use of computers altogether, the activities (i.e. games, role playing) appeal to those who lack ready access to computers, and are ideal for people who don't feel comfortable using them.*

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Remarkably, the Computer Science Unplugged book is intended specifically for those who do not have any background in CS and are frustrated when using computers because they do not feel they know much about CS. Unfortunately, the authors did not choose to include computer organization (i.e. hardware principles) in their activities.

Some hardware principles explained to children (and teachers and parents) are addressed in [1]. The author introduces "The Computer in Action" as an example of a role playing activity in which the students learn how the computer processes instructions and data by acting out the roles of the basic computer components. In a similar way as in the Computer Science Unplugged, no actual computer is needed. A student can therefore play the role of the "Math wizard", the "CPU", the "keyboarder", the "memory manager" and so on.

In this paper we introduce the approach followed at the University of Verona to prepare future primary school teachers to teach Computer Science topics [4]. The content of the course is concerned with the organization of the computer and how hardware components interact with each other. The goal of the course is to provide teachers with ideas, material and contents for K-8 children. One thing we feel is particularly important is that the material of the course has been designed to appeal to a child as well as to the parents.

The computer (PC) is a Realm. The Realm is ruled by His Majesty whose name is Si Piuh. The Mother and the Subjects help Si Piuh to govern the Realm (Fig. 1).

Imagination transports children helping them to understand and inspiring them. In fact, children need their own language based on imagination, self-identification, analogy, play, and many other features which characterize their bubbly world. The key to the success is creativity, that is one of the most important skills a child can learn [15].

Section 2 reports some of the methodological approaches we have followed to design the course on the PC hardware taking into account the fact that it is necessary to focus on K-8, teachers, fluency and gender-neutral principles. Section 3 reports feedback and the rationales behind the approach. Finally, Section 4 will conclude the paper reporting future developments.

## 2. DEVELOPING THE CURRICULUM

There are many elements that need to be considered when approaching the children's world; the following are particularly important:

**The narrative "cooling-off function":** we inform others about our experiences or beliefs, putting enough distance between ourselves and those experiences to be able to reflect on them [5].

**Children's imagination:** developing children's imagination and providing an environment to exercise, narrate and play contributes to the development of highly developed mental processes, such as abstract thinking [12].

**Peer collaboration:** when playing it is crucial to encourage peer collaboration. Peer play shows creativity and an ability to negotiate more than with parents [18].

**Experiential knowledge:** we explore the world understanding our roles in relationships with ourselves or with our peers [17].



Figure 1: His Majesty (left) and his Mother (right). In the background some servants and subjects.

Narration, fantasy, peer collaboration, imagination, self identification and exploration without risks provide children with the basic elements which enable them to move easily within "their world". Some of these elements are already present from the age of age 2 and they tend to end at early pre-adolescence [10, 11].

A case-study of the success achieved by following these principles has recently been reported. Cassel and Ryokay have lately developed a new model and machine for Fantasy play [7]. Through their language and their actions children create and explore the world in which they are playing, without any risk of failure and frustration as a result of unexpected events.

The "curriculum developing process" takes into account the elements introduced above to introduce the organization of a personal computer in the guise of a Realm where many people live and work [4].

The whole course is composed of eight modules, each one referring to features of the Realm (i.e. the PC).

**Chapter 1: In the Real of Si Piuh: the King and His loyal Subjects.** The CPU, the mother board, the graphic card, the sound card, and an introduction to the principal internal components. *A handsome, strong, powerful King, capable of leading his subjects with skill and wisdom, in an orderly, ongoing way.*

**Chapter 2: Kesh, Ram, Hard and Floppi and the relatives Ci Di and Di Vidi: the Archivists.** The concept of memory hierarchy: Cache, RAM, Hard and Floppy disks, the CD and the DVD. *What is a Realm without Its History? An enormous and endless library is necessary to store everything. An entire hierarchy of subjects deal with all the information.*

**Chapter 3: The In Put family: Secret Agents serving His Majesty.** Components that get input: the Keyboard, the Scanner and the Camera, the Mouse and the Joystick. *Every piece of information that His Majesty gets from the outside world can be of vital importance for His Realm. The In Put family exists to serve.*

**Chapter 4: The enchanted universe of the Out Put clan: messengers to the outside world.** Introducing information to the world: CRT and LCD monitors, inkjet and laser printers. *What is the Fate of an Isolated Realm? Special media need to be designed to communicate with the*

world and the noble Out Put clan will serve His Majesty in this.

**Chapter 5: The Amazing Transport in the Realm.** Connecting internal components: the ISA and the EISA buses, the PCI bus, the "graphic" bus AGP, the AT interface. *Every subject needs to receive orders to enable him to do his job. Who can provide these? No trouble: special buses have been designed to transport everything inside the Realm.*

**Chapter 6: Links with the Outside Colonies: the armored Buses.** Connecting external devices: the SCSI bus family, the serial buses USB and FireWire, serial and parallel ports. *How Outside Colonies can share Information with the Realm? The world can be dangerous and frightening. Special armored buses have been designed. Nothing can damage them!*

**Chapter 7: Net and Mo Dem: royal ambassadors.** Talking with other PCs: Net and Modem, the Ethernet and Token Ring networks, the connection protocols V.xx, K56, ADSL. *Special rules and protocols are needed to talk to other Realms in the world. His Majesty give this duty to Net and Mo Dem, royal ambassadors.*

**Chapter 8: All together! The Masters are Present.** ASCII and UNICODE codes, the BIOS, the operating system. *What is the language spoken in the Realm? ASCII is its name and it really is a pretty strange language.*

In the following part, the course will be analyzed bearing the four elements introduced at the beginning of the Section in mind .

## 2.1 Cooling-off: the narrative body

Teachers can "tell stories" (and children can listen to them) about hardware topics. Where children are concerned, Narration is considered to be one of the most important ways of conveying content.

*This book introduces the Subjects and tells ordinary stories of a great and efficient Realm. It is a hard-working Realm, where His Majesty, his Mother and the ambassadors live, where we can find workers, archivists, writers and artists, a Realm where tales tell of families and clans, secret codes and old rites. It is a Realm where even the poorest and the smallest Subjects have their own dignity. A Realm where the external world frightens and at the same time enriches this one. In this world Masters look after their Subjects continuously, motivating them to do their work thoroughly. But, what is the name of the Realm? Step by step you'll work it out...*

The PC (i.e. the Realm) is ruled by the CPU, i.e. His Majesty. The name of the king is Si Piuh, which is the Italian pronunciation of CPU. Synchronizing all the activities inside the PC is very hard. By analogy, leading the Realm is not as easy as one may think.

However, the king does have all that he needs to organize the work with skill and wisdom. His Masters (i.e. the software programs) act as his guides. He trusts his Masters and interacts with his Subjects so as to carry out the orders he receives from the Masters themselves.

By analogy, in fact, the CPU can be regarded as the most important component of a PC, fast, strong and powerful.

*A handsome, strong powerful King, capable of leading his Subjects with skill and wisdom, in an orderly, ongoing way.*

*He is a King who is capable of inspiring the strongest servants but, at the same time, capable of being patient with the*

*weakest and the smallest ones, for each Subject is important to the Realm.*

## 2.2 Children's imagination: translating reality into fiction

Each hardware component is *translated* into a Gnome with specific features and behavior patterns.

Some features of "The Mother" are outlined here. The CPU is attached to the mother board. All the hardware components need the mother board to give them the support they need and to enable them to talk each other and to the CPU.

In the Realm, the Mother supports Si Piuh in all his work. She is the only one who can talk to her Son and to the other people of the Realm.

*She receives commands from her Son, delivers them to the Subjects, and waits patiently for an answer from them.*

The King would sometimes like to work faster and faster. However, he cannot understand all his Mother's worries: she takes orders, delivers them, waits, and runs...through the winding streets of the Realm.



Figure 2: The Mother and the ISA Bus.

Once again, a solution to this problem can be found within the Realm.

*The idea is not so bad and one solution can be found: if many orders are sent and received at the same time, hopefully all the Mother's worries could be lessened. But, how many exactly? Sixteen, thirty two, sixty four or many more?*

## 2.3 Peer collaboration: building relationships

Every behaviour in the Realm strongly resembles its corresponding behaviour in the PC. A child can therefore understand hardware relationships by considering an easily identifiable Gnome through self-identification and peer play.

With a bit of imagination, in our Realm, there are exactly the same relationships one can find in any PC: gates to the outside world, artists that produce paintings and sounds, Masters who guide the whole process, libraries to store information, buses to transport information, ambassadors who know communication protocols, servants and as many other Subjects as one can imagine.

A PC cannot work without the hardware components that help the CPU. The graphic card, the sound card, the network adaptor and the modem can easily be represented as people living in the Realm.

As time goes by, Si Piu and his Mother make a tremendous effort to do their jobs. In such a big, special Realm thousands of talents can be relied on. If you look carefully, you can find many Servants: Vi Giei the master of all the painters, Di Essepi the master of all the musicians, Net and Mo Dem the ambassadors to the outside world.

Each servant has her/his own features that are strongly related to the features found in the corresponding hardware component.

For example, the teacher can give the following information about the relationships between the Mother and the ISA Bus (Fig. 2).

Many kinds of Buses have been created so far. They all have Different colours, sizes and levels of power. The ISA Bus was the first. What an engineering result for those times! Room was made for the driver and 16 independent wheels! At every stop the Mother waits patiently, sure that the driver will come. With her pages of instructions received from her Son, she gets on and rides to the next stop.

Just for a little comprehension, the number of wheels is related to The number of bits in the real world.

## 2.4 Experiential knowledge: discovering the role

We are only aware of the external effects of many computer components: image visualization, sound production, printing, booting. Unfortunately, their hidden work often remains unclear. How do they work to provide such external results?

For example some sentences describing the Painter Vi Giei (which stands for the VGA card) follow (Fig. 3).



Figure 3: The master of all the painters: gnome Vi Giei.

A Painter of innate talent, she is very precise, efficient and tidy. Nothing escapes her. When Si Piu gives her an

order, she promptly carries it out, such as drawing elegant lines and sublime characters. Then with masterly skill, she sketches, colours and just as quickly wipes them out again.

There are many hidden jobs that are unclear to non-prophans as well, such as, for example, the Bios function (Fig. 4).

There is a secret place within the Realm. A place the King cannot enter. Here, wise priests protect a mysterious coffer. What's its content? It is said that it contains the most precious treasure of all: an ancient book written by the greatest of all the Masters: OSS himself. It is the sacred book of Bios, an enlightened text, that only a wise priest can read and understand.

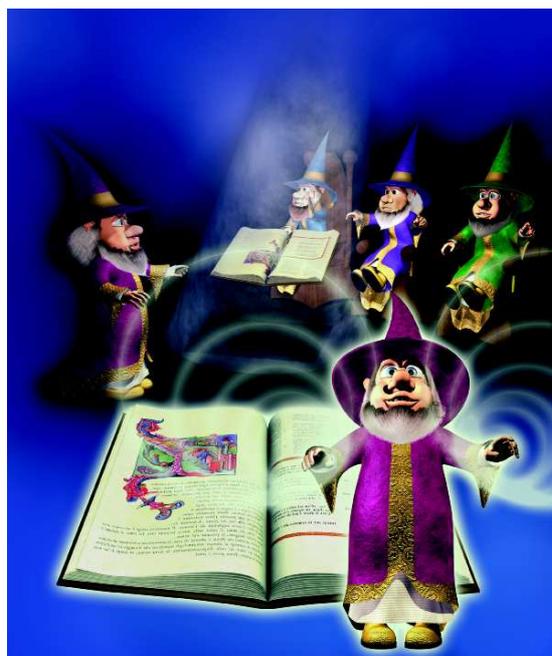


Figure 4: Sage gnome priests protect a mysterious coffer: the book of Bios.

## 3. DISCUSSION

The approach introduced so far is designed to make a (gender-neutral) child interested: the story itself, how people of the realm interact with each other and how they behave, entertain the child, while at the same time, giving him/her a profound understanding of computer architecture. Secondly, the course is designed for teachers who do not have any a priori CS knowledge. It is important to prepare non-technophobe teachers, showing them that CS can be fun. In the same way, parents also need help: their everyday support of their children is invaluable but parents need to "feel at ease" with CS topics. These are the rationales behind the paper.

The entire course lasted for a half-semester for a total of 32 hours. At the end of the course, students were given (86) feedback forms to evaluate the course features. These feedback forms included the following questions.

**Why did you attend the course?** Most of them (78) answered "it was compulsory", some of them (8) replied that they were "interested in the approach adopted".

For the following questions, possible answers are: Yes, definitely; Yes, perhaps; Perhaps not; Definitely not.

**Do you have a CS background?** Most of the students (76) answered "Definitely not".

**Is the course motivating?** Among all the students 36 answered "Yes, definitely", 40 replied "Yes, perhaps" and the rest were Not satisfied.

**After attending the course, has your interest in CS increased?** Most of the students (76) answered "Yes, definitely" or "Yes, perhaps".

**Are you surprised about the topics in the course?** Responses are: Yes, definitely (58); Yes, perhaps (25) and the rest were unsurprised.

**Would you recommend the course to your friends?** Answers were: Yes, definitely (73); Yes, perhaps (7) and the rest wouldn't recommend the course.

**Do you think the material of the course would be of some help To you in your activities?** Most of the students (69) answered "Yes, definitely" or "Yes, perhaps".

The feedback is extremely encouraging: future teachers have The materials and the content (pictures, novel ways of describing the hardware, ideas on how to describe hardware functioning principles) to prepare children's lessons. Students also showed profound interest in the "hidden" parts of the computer and were "involved" in the material used during the course.

It is of crucial importance that Computer Science topics be somehow thought of as being relevant to parents as well. For example, The UK has been considering the need for parents to support their children's learning at home. It is absolutely necessary to produce good guides and books, and not the ones produced so far, which seem to have been based, rather, on a dubious rationale [6].

The "rediscovery" of imagination and play is also crucial for children with special educational needs: usually, Computer Science topics for handicapped children are not considered to be of top priority, which only goes to widen even further the existing gap between them and normal children.

Children now have the opportunity to "play" (in a gender-neutral way) with CS topics. They are "naturally" (as far as their age is concerned) introduced to the real principles of CS, and thus provided with the foundations for CS Fluency.

## 4. CONCLUSION

Teaching Computer Science to children is a high priority and cannot be a done merely by reducing Computer Science books designed with different goals in mind, such as College or University Courses. Rather, young learner teaching activities must have specific ingredients: play, imagination, self-identification, narration, peer collaboration, and many other features typical of the child's world.

The course at the University of Verona has been designed to develop new teaching strategies when Computer Science topics need to be taught to children. A child can now play with these topics, finding new ways of understanding the hidden but important workings found within the box called a PC. It may be of some help both for teachers and for children to re-discover Computer Science topics, changing what is sometimes thought of as being fixed and unchangeable: teaching and learning.

Furthermore, it is crucial to begin teaching CS topics in a gender-neutral way thus avoiding the introduction of

frustrating concepts that may actually create adult technophobes [3].

Future developments will study the development (which already exists at a prototype phase) of a high quality, interactive game based on the history of the Realm. This is a necessary tool if we want to "provide a complete service" for children, parents, and teachers.

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