Thinking Parallel: The Process of Learning Concurrency

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During the past two years, Prof. Ben-Ari and I have developed a course in concurrent and distributed computing (CDC). The course is designed for high school students who study advanced computer science (CS) in the twelve grade. CDC is characterized by *communications* between processes and by *non-deterministic* behavior, which are not issues in a sequential programming. In particular, non-determinism makes a correctness proof extremely complex and it is far from routine to develop a correct concurrent algorithm.

The goals of the course are *derived from* the goals of the CS curriculum that are in turn *derived from* the goals of science teaching which were expressed in a directive of the Ministry of Education:

- **Students will understand their world better**. Both the natural and the technological world are essentially parallel. By studying CDC, students will be able to understand and explain these systems, and to reason about their possible failures.
- **Students will be challenged**. Solving problems in CDC is certainly a challenging activity, as noted above.
- **Students will acquire research skills**. Students develop critical thinking and discussion skills because developing a correct algorithm in CDC requires reasoning rather than hacking.

I have been teaching this course on CDC for the past two years. Last year, I conducted preliminary research and evaluation in order to better understand the learning process, and to help me improve the course. I focused on the students' difficulties, classifying them in order to find out:

- **why** they run into these difficulties,
- **how** they get over them, and
- **what** a student goes through until he finishes an assignment.

I found out that the answers to these questions are to be found in the students' conceptions, such as the way they interpret correctness or the communications model, as well as in the students' methods: for example, the diagrams they draw and the scenarios they use to test the programs. In particular, I was led to examine the reciprocal influence between conceptions and methods. I noticed a process of evolution: as conceptions evolved, new methods were adapted or invented, which in turn aided in understanding the concepts. By the end of the course, students appear to

have understood the models of CDC, and have evolved from centralized thinking towards the ability to develop and analyze parallel algorithms.

My future research will be devoted to establishing this conjectured relationship between students' difficulties and their conceptions and methods, and to applying the lessons learned to improve the course.