Teaching Programming and Language Concepts Using LEGOs® (Case Study 4)

An Engaging Way to Introduce Computing

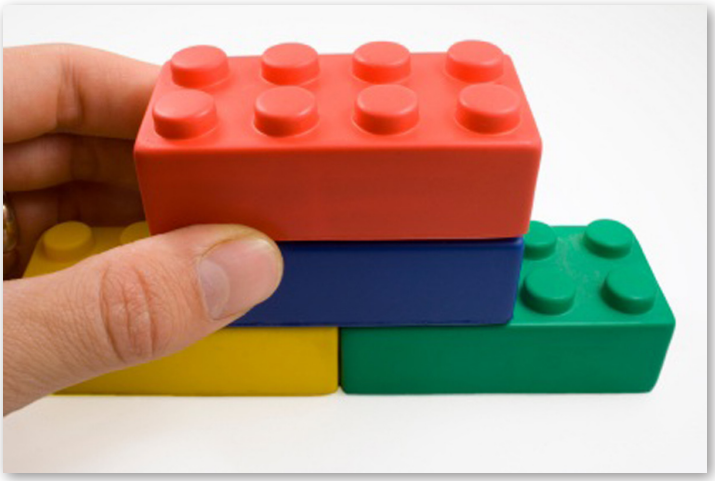
K-12 Education | Undergraduate

Teaching Programming and Language Concepts Using LEGOs® is an innovative method for using LEGO® bricks to teach programming and other computing concepts to middle and high school students as well as to undergraduate freshmen in introductory computer science classes. In this assignment, individual LEGO® bricks are used to express a special-purpose programming language, integrating tactile and kinesthetic elements into the learning experience and helping to make abstract concepts more concrete.

The method has two main learning outcomes:

- *Language Specification* – The goal of the assignment is to be able to build LEGO® creations on a standard grid base plate. To build a creation brick by brick, it is necessary to specify the type of brick, its color, and its location on the base plate. The combination of colors and positions indicates a specific action. Students learn to develop and state a set of sequenced instructions, a critical skill for programming.
- *Bridge to Other Abstract Concepts* – This teaching method has been used to teach a variety of topics to different audiences, including freshman CS majors, K-12 students, and K-12 teachers. In each group the use of the language provides opportunities to discuss more abstract concepts, including CPU Simulation, Writing and Testing Programs, and Extending the Programming Language.

Informal assessment of these exercises has been positive. Participants enjoy working with LEGOs® as a means of exploring programming and processing concepts. In one case, 100% of the freshmen taking an introductory computer science course were engaged in the exercise: an unprecedented event, according to the instructor. In fact, 75% of participants volunteered positive comments about the LEGO® exercise in end-of-semester course evaluations. Currently, the exploration of partnerships with assessment specialists to help develop quantitative aptitude progress methods is underway.



The use of LEGOs® may "level the playing field." Students both with and without computer programming experience struggle with the assignment. When told that they have learned a central concept of computer programming, inexperienced students feel both successful and confident, in spite of not using the computer to "program." Because the LEGO® approach does not directly involve technology that can be seen as intimidating to students, this approach shows promise for increasing participation of diverse audiences.

Implementing this program is strikingly simple because it only requires LEGO® pieces and a basic understanding of how LEGOs® fit together. A base plate and different-shaped LEGO® blocks are easily acquired and a single base plate is sufficient for each participating student or team. Clear language specifications for each type and combination of LEGOs® should be established prior to the onset of the exercise to avoid confusion later; however, a knowledgeable instructor or moderator can quite easily provide some instruction and guidance for each exercise to each participating group.

RESOURCES

Computer Science Teachers Association Resource Site: http://csta.acm.org/Resources/Resources.html
Cynthia Hood and Dennis Hood, "*Teaching Programming and Language Concepts Using LEGOs®*." Proceedings of the 10th Annual SIGCSE Conference on Innovation and Technology in Computer Science Education, 2005. Available from the ACM Digital Library.
The Educator's Reference Desk Lesson Plans in Computer Science: http://www.eduref.org/cgi-bin/lessons.cgi/Computer_Science
For free offline activities for teaching computing concepts, try "Computer Science Unplugged," located at: http://unplugged.com

NCWIT offers practices for increasing and benefiting from gender diversity in IT at the K-12, undergraduate, graduate, and career levels.

This case study describes a research-inspired practice that may need further evaluation. Try it, and let us know your results.

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How Do You Introduce Computing in an Engaging Way?

with Case Study 4

K-12 Education | Undergraduate

Experience with computers between boys and girls has equalized, but boys continue to have greater knowledge of computing and programming *concepts* than do girls. Not so in biology, chemistry, or mathematics, where both boys and girls are encouraged to provide evidence of proficiency when they apply to college. High school study of these subjects familiarizes students with the content and concepts, and gives them confidence. The result is that women's undergraduate completion rates have neared parity in these disciplines.

Because IT study is elective in almost all K-12 schools, developing relevant and interesting assignments that appeal to a broader audience is recommended for:

- fostering a climate where the non-predisposed can belong both academically and socially
- recruiting students who are not predisposed to pursuing computing
- exposing fundamental computing concepts to inexperienced learners

Is prior programming experience required for students to be successful in an IT program? Most undergraduate departments would say no. That is, experience with programming is not the same as expertise in problem-solving, algorithmic thinking, or computing theory. Yet research shows that introductory courses and their embedded assignments work better for students who have *some* experience with programming.

Research also shows that students with programming experience are more confident and more successful in introductory courses than are their inexperienced peers. Students with lower grades or less confidence are less likely to persist in an IT major. What is more, when introductory courses have limited opportunities for talking to other students (e.g., collaborative learning), inexperienced students have little information on which to judge whether they belong academically in the major. Hence more women than men switch out of IT majors (most often to other sciences or mathematics).

MAKING IT MEANINGFUL

Educational researchers emphasize the importance of linking educational materials and curricular programs to students' existing knowledge and experiences. When class syllabi list topics and assignments that focus on unfamiliar concepts with limited, if any, relationship to a student's life experience or interests, she or he is unlikely to take that class. High school curricula contribute to low enrollments in college computing because, under the existing educational policy of election, computing is rarely required in secondary schools. This means that students are likely to have a narrow and inaccurate view of what IT study involves, what careers are possible, or what kind of people "do" IT. Given the very small proportion of females who study computing in high school, females are less likely to choose IT in college.

The challenge to educators at all levels is to develop engaging assignments and curriculum that can appeal to a variety of students with different learning styles, interests, socio-cultural backgrounds, and abilities, while maintaining the rigor of the discipline. Putting the concepts of computing in appealing contexts and building on existing competence can both reduce entry barriers and level the playing field for those with limited experience.

Creative assignments that teach algorithmic thinking while also calling on students' existing knowledge or interests, may serve to both recruit and retain students. When experienced and inexperienced students use non-computer-based assignments to learn computing concepts, they quickly realize that their peers with programming experience are not necessarily better at algorithmic thinking, just more experienced with programming. Building confidence through relevant and interesting assignments is a promising practice for motivating student enrollment and retention.

RESOURCES

Lecia Barker and William Aspray, "The State of Research on Pre-College Experiences of Girls with Information Technology." In McGrath Cohoon, J. and W. Aspray (Eds.) *Women and Information Technology: Research on the Reasons for Under-Representation*. Cambridge, MA: MIT Press, 2006.

Joanne McGrath Cohoon and William Aspray, "A Critical Review of the Research on Women's Participation in Postsecondary Computing Education." In McGrath Cohoon, J. and W. Aspray (Eds.) *Women and Information Technology: Research on the Reasons for Under-Representation*. Cambridge, MA: MIT Press, 2006.

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