Robotics and environmental sensing for low-income populations: design principles, impact, technology, and results

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Abstract: Programmable devices have become very popular in schools, for robotics, environmental sensing, and even interactive art. However, in developing countries, their penetration has been limited due either to unavailability or high cost. In this paper, we discuss recent work on an open-source, low-cost platform mainly designed for developing countries. We discuss its design principles, based on extensive fieldwork, as well as the learning implications, use of low-cost materials, and local construction of boards.

Robotics and probeware in school environments

The use of probeware, robotics and sensors has a long history in education (Tinker, 2000, Papert, 1971). But it was not until the early nineties that designers succeeded in creating viable robotics and probeware products for educational settings (the Handy Cricket and the Lego Mindstorms kit, Martin & Resnick, 1993; Sargent, 1995). In recent years, the Lego NXT kit, the Pico Cricket, the MIT Tower (Lyon, 2003) and the Arduino platform have incorporated new features based on advanced sensing and modular design.

However, despite the potential of these technologies (Sargent, 1995; Tinker, 2000), their educational use has been limited to well-funded schools and organizations due to their cost and limited availability, in special outside the developed world. In low-income areas, even when the equipment was made available, we observed students who would not engage in the activities for fear of breaking it, and teachers who would vocally criticize the spending of thousands of dollars to benefit just a small number of students. We present a technology design to address those difficulties: the GoGo Board (see figure 1), a low-cost, open-source platform for probeware and robotics, tailored for educational use in developing nations. The platform is composed of the main board, add-ons mini-boards (such as displays, sound recorders, amplifiers, and wireless communication), libraries and APIs for most programming environments, and a collaborative website with documentation and sample projects from the user community. We discuss the design choices that made the board low-cost, multi-purpose, easy to assemble, and easy to be used with scrap electronics and simple materials.

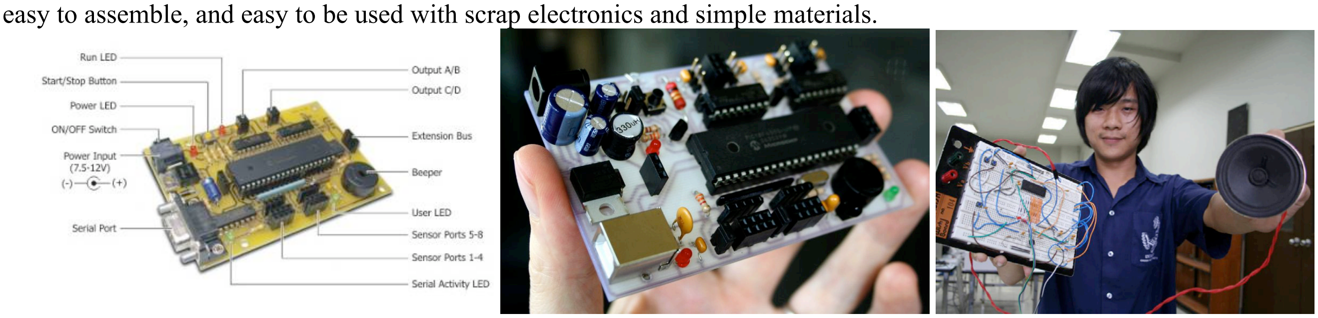

Figure 1: (Left to right) The original GoGo Board, the new USB GoGo, and a prototype of a sound recorder plug-in board.

Design Principles

Low-cost and local construction: Our field work indicated that importing equipment from the US or Europe more than doubles the local cost in many countries. This applies even for open-source hardware such as Arduino boards, which components are hard to find in many countries. Therefore, we designed the platform to be assembled locally, if needed, after extensive research for component availability in Brazil, Mexico, Thailand, and Malaysia. Also, the platform has been designed to make its construction process as simple as possible (see Results section). Differently from most commercial and open-source platforms, it does not incorporate the most cutting-edge features, but instead focus on ease of construction. It uses human-sized components, wide traces, a single-sided printed circuit board, and simple, inexpensive sensor connectors. While the Lego Mindstorms kit can reach as much as US$ 500 in developing countries, the GoGo Board costs US$ 25.

Dual mode: Our field observations in several schools revealed that probeware and robotics have traditionally employed different hardware (Sipitakiat, Blikstein, & Cavallo, 2004). One important design decision was to integrate both functions into one single platform. In the autonomous mode, the student writes a program and downloads it to the board's memory, which can then operate disconnected from the computer (to control robots or gather environmental data, for example). In the tethered mode, the board remains connected to the computer at all times, providing high speed sensing and control capabilities. As a result, students can develop scientific experiments or sophisticated interactive systems which rely on the higher processing power of the computer (see, for example, Blikstein & Wilensky, 2006).

Documentation: Another concern about the dissemination of the board was multi-lingual documentation. Most young children outside of English-speaking countries can only communicate in their native language. As a result, we developed a customized website engine to allow for easy, decentralized translation of the content, and set up a wiki and code repositories where multiple authors could contribute with localized documentation and code.

Results

For the past years we have collected usage data across several countries. There are over 2,000 GoGo Boards being used worldwide, two international foundations adopting it, and a growing user community of students and hobbyists in more than 10 countries. In many locations, middle- and high-students themselves build their own boards, using improvised equipment (Figure 2, top and bottom left) – and our data indicates that assembling the boards had a significant impact on their sense of technological competence and self-efficacy. Additionally, being an open-source project, users customize the board to their own use: undergraduate students in Brazil created their own version of the board (BR-GoGo) with different connectors better adapted to their use (see Figure 2, bottom, center). This group of students also developed their own multi-platform block-based visual programming environment (see Figure 2, bottom right), created a website for the project, and started to conduct projects in local schools. Students in Mexico managed to assemble a board with components almost exclusively scavenged from broken electronics.

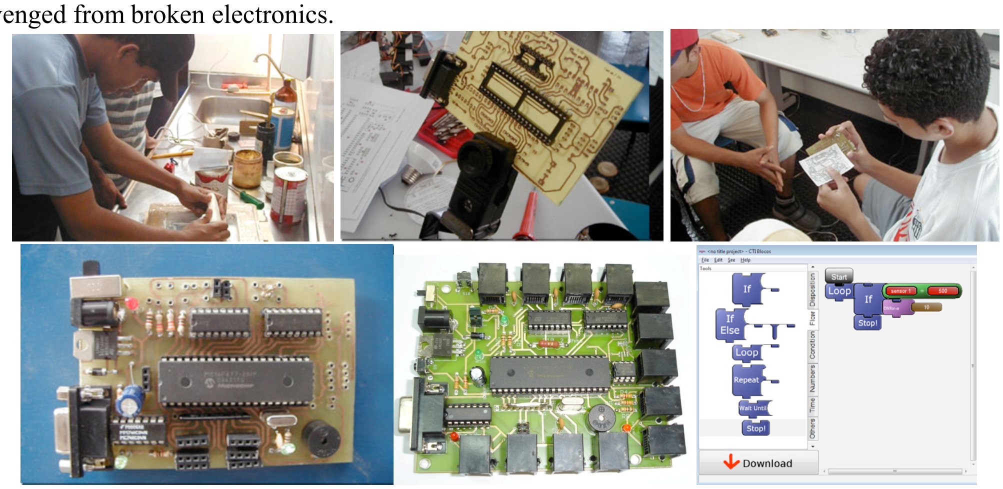

Figure 2: High-school students creating boards, the Brazilian version of the board, and the programming environment create by undergraduate students in Brazil (lower right).

Conclusion

Although the educational benefits of computational tools for robotics and environmental sensing have been acknowledged, their widespread sustainable use in low-income areas has been uncommon. The GoGo Board framework allows for sustainable, cost-effective, and appropriate implementation of these technologies in schools, especially in locations where accessibility, support, and economical limitations are an issue. Our results show that designing for low-cost, local assembly, local customization, and open-source had a significant impact on adoption, sustainability, and use.

References

Blikstein, P., & Wilensky, U. (2006). The Missing Link: A Case Study of Sensing-and-Modeling Toolkits for Constructionist Scientific Investigation. Proceedings of the 6th IEEE ICALT, pp. 980-982.

Lyon, C. (2003), Encouraging Innovation by Engineering the Learning Curve. Cambridge, MA: Department of Electrical Engineering and Computer Science Master's Thesis, MIT.

Martin F., and Resnick M. (1993). "LEGO/Logo and Electronic Bricks: Creating a Scienceland for Children", Advanced Educational Technologies for Mathematics and Science. Springer.

Papert, S. (1971). "Teaching children thinking". MIT Artificial Laboratory Memo #247, MIT, Cambridge.

Sargent, R. (1995), The Programmable LEGO Brick: Ubiquitous Computing for Kids. Cambridge, MA: Media Laboratory Master's Thesis, MIT.

Sipitakiat, A., Blikstein, P., & Cavallo, D. Moving towards highly available computational tools in learning environments. Proceedings of ICLS 2004, USA.

Tinker, R. (2000). A History of Probeware. Retrieved from http://www.concord.org/publications/detail.

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