DESIGNING A COMPUTER SCIENCE CURRICULUM FOR BERMUDA'S PUBLIC SCHOOLS

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ABSTRACT

Beginning in 1998, faculty from Stanford University's Computer Science Department and the School of Education have participated in a collaborative effort to design, implement, and assess a new computer science curriculum in the Bermuda public schools. Since 2003, a complete curriculum consisting of three computer science courses supplemented by additional courses covering more applied topics such as multimedia design has been in place at Bermuda's public high schools. That curriculum has been well received by students, teachers, and the broader community and is beginning to provide a model for other school systems in the Caribbean.

Our curriculum effort has four essential components—pedagogical design, curriculum content definition, professional development, and assessment—each of which is outlined in this paper. From the beginning, an explicit goal of this curriculum effort has been expanding the audience for computer science beyond its traditional constituency so as to empower both male and female students from Bermuda's majority black population. In this paper we share survey and interview data from a sample of 98 senior year students who opted to take different numbers of courses during their senior school career. Our analysis of the results indicate that the new curriculum has enabled students to imagine new futures for themselves as they learn more about the opportunities available in computing and begin to see themselves as part of that technologically empowered world. In this paper, we assess how taking these courses affects student interest, confidence, and the value assigned to technological knowledge. Our findings suggest strong relationships between course taking and confidence, interest, valuing of technical knowledge, and projected career choices for both male and female students.

1. INTRODUCTION

As computing and communications technologies become more central to the global economy, countries throughout the world have an incentive to increase technological fluency and expertise within their populations. From an educational perspective, the rapid increase in the perceived importance of computing and the need to expand opportunities for students in this area has raised two critical challenges:

1. How to prepare students for a world that is technologically advanced and subject to constant change
2. How to recruit the next generation of computer scientists, inventors, and technology specialists

Each of these challenges raises fundamental equity issues. At present, computing disciplines are marked by a dramatic underrepresentation of women and minorities (Camp, 1997). To meet projected labor market requirements and to ensure that the design of that technology meets the needs of a diverse population, it is essential to increase the diversity of those in charge of innovation.

In the United States and other countries, opportunities to learn about computing technologies in school vary widely. Research on the use of computing in schools shows that only a small proportion of teachers use computers in ways that enhance various aspects of technological fluency and engage sustained interest in technological subjects (Becker and Riel 2000). Opportunities to take courses that focus specifically on programming or design are rare (Tucker *et al.* 2003). In a national probability sample of American high schools, Becker found that only ten percent of computing classes involved computer science or programming and that only four percent focused on multimedia or design (Becker 2000).

In this paper, we review patterns of participation in computer science classes by male and female high school students in the two public high schools in Bermuda, in which programming and multimedia courses are now available. In particular, we examine how students use these courses to advance their education and the extent to which their participation in these courses influences their perception of future learning opportunities and jobs. We also consider the influence of gender in these courses to see whether young men and young women react similarly or differently to the same opportunities.

We believe that students' participation in computing courses provides an important context for the development of their identities as competent and generative users of technologies as well as their identities as learners (Wenger 1998). Although such courses do not guarantee positive outcomes and may in fact lead to disengagement, our research indicates that exposure to more technical aspects of computing empowers a significant number of students, both male and female. At this point, our goal is to understand more about how learning experiences relate to motivation, interest, and goals to pursue further knowledge.

In this research, profiles of high-school students were developed based on the number of programming courses they had taken thus far. Using both gender and course-taking history as independent variables, we then looked at their association with confidence, interest, and valuing of computing knowledge. We also used these variables to examine students' projected ideal jobs and their ratings of imagined possible futures working in technical positions. Finally, we used interview data to present examples of how students who chose to take several computing classes applied their course-based knowledge to create new out-of-school learning opportunities.

2. THE BERMUDA PROJECT

In many ways, Bermuda represents an ideal laboratory for curriculum development (Roberts 2003). The population of Bermuda, a self-governing British colony with a land area about the size of Manhattan, is just 63,000—comparable to that of a small city. The limited population makes it possible to develop a new computing curriculum on a national level without being overwhelmed by the scale of the effort. Bermuda also has the resources to make significant investments in its educational system. The national economy, based primarily on creating a favorable tax climate to attract international business, is extremely strong. Because those firms need a professional workforce skilled in information technology, both the government and the private sector have placed great emphasis on increasing the quality and depth of information-technology education in the Bermuda schools.

The initial funding for this project came from the business community through the aegis of the International Educational Collaborative Foundation (IECF). Much of industry's motivation for supporting computer science in the schools is to provide pathways for students to develop the kinds of competencies needed to go on to further education, or work in the companies present on the island. This issue has become more critical as tourism declines and international companies employ increasing proportions of the workforce. Unless they pursue higher education, Bermudian young people will be increasingly limited in their choices for work and less prepared to make decisions about the role of international business in their country.

Responding to many of the same social and economic forces that affect the island's industries, the government of Bermuda has been involved in a general reform of the public education system since the mid-1980s. This reform has included curriculum reform in all subject areas, the addition of a fourth year of secondary school, the introduction of middle schools, the elimination of most entrance examinations, and the mainstreaming of all special-needs students into regular classrooms. These reforms were designed to address significant inequities in educational opportunities. Prior to the opening of a new large school in 1997, students were tested at age 11 to determine their future schooling. Based on their scores, students were sent either to an academic public school or to a general public school. The general schools did not offer many courses required for college such as chemistry, physics, or foreign languages. In addition, the testing resulted in the majority of boys being assigned to the general school while the majority of girls were sent to the academic school. At the present time, there are only two public secondary schools—the Berkeley Institute and CedarBridge Academy—and student assignment is not based on formal testing.

As in many school districts in the United States, the demographics of public schools in Bermuda do not reflect those of the island as a whole. As shown in Figure 1, public secondary schools have a far larger proportion of black students than one would expect based on the population as a whole, largely because 72 percent of white students go to private high schools. A similar racial imbalance exists in employment patterns. According to the 2000 census (Bermuda Census Office 2001) only 22 percent of the black population holds jobs classified as professional, technical, administrative, or managerial. Most black Bermudians are employed in clerical, trade, or service industries. This disparity in employment—which reflects an underlying imbalance in economic class—was confirmed by our own surveys of students. As part of the survey described in section 4, we asked students to list their parents' occupations. Sixteen percent of mothers and 54 percent of fathers worked in trade or service industries (daycare workers, painters, construction). Sixty-five percent of mothers and 20 percent of fathers worked in professional or business settings (accountants, managers, medical). Three percent of fathers and no mothers worked in computer-related fields. The net effect of this disparity is that students enrolled in public secondary schools have far less prior exposure to computing-related occupations than their white counterparts in private school.

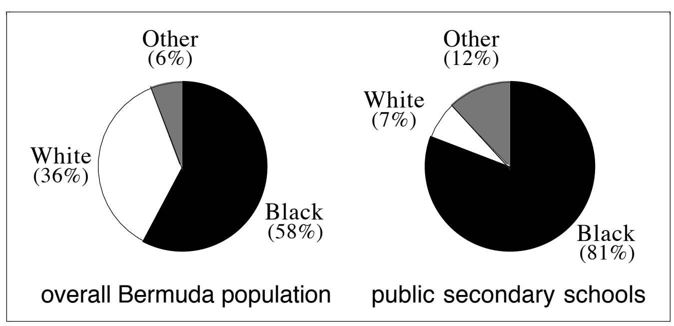

Figure 1. Racial composition of Bermuda high schools

3. PEDAGOGICAL DESIGN

The content of our courses is consistent with ideas outlined in the recent NRC report entitled *Being Fluent with Information Technology* (National Research Council 1999). In the United States, concerns about preparing youth for the future led the National Science Foundation to ask the Computer Science and Telecommunications Board (CSTB) of the National Research Council to initiate a study that addressed the subject of *information technology literacy.* The study's rationale was the increasing ubiquity of information technology in daily life and the importance of beginning to define what everyone should know in order to empower all citizens to participate in this new era. Rather than use the term *literacy* the authors of the report opted for the label *fluency:*

> While no term is perfect, the term fluency captures best for the committee connotations of the ability to reformulate knowledge, express oneself creatively and appropriately, to produce and generate information (rather than simply comprehend it). It entails a process of lifelong learning in which individuals continually apply what they know to adapt to change and acquire more knowledge to be more effective at applying technology to their work and personal lives.

The standards for technological fluency expressed in the NRC report share important characteristics with standards that have been defined for science and mathematics (National Council of Teachers of Mathematics 1989). They each articulate the importance of integrating knowledge with the ability to engage in the forms of collaboration, problem solving, and discourse that are characteristic of participation in the discipline. These learning goals require educators to design classroom-based experiences that differ fundamentally from traditional pedagogical approaches that emphasize lecture, discrete lessons, and factual recall (Bransford and Schwartz 1999).

In our work we meet this need by organizing our curriculum around project-based learning opportunities that provide students with opportunities to learn content in the context of creating meaningful artifacts. The design was guided by earlier work on project-based instruction and follows the design principles articulated by Barron, *et al.* (1998). These include

1. Defining learning-appropriate goals that lead to deep understanding
2. Developing social structures that promote participation and sense of agency
3. Ensuring multiple opportunities for formative self-assessment and revision
4. Providing scaffolding such as teaching tools, and beginning with problem-based learning activities before initiating projects

These principles were generative for our initial work though the specific content of each emerged (and is still emerging) in the context of the collaborative work with teachers. Building on our approach to project-based instruction, the curriculum strives to help students achieve self-perpetuating fluency by providing them with a set of fundamental tools with which to understand technology, from both a practical and social perspective.

As of winter 2004, we have completed three semester-long modular computer science courses designed for students in the first three years of secondary school:

- *Introduction to Computing.* This course, which is required of all students in their first year of secondary school, includes a range of topics that provide background understanding and offer opportunities for students to construct their own meaning. Students build timelines of computer history that identify themes in the evolution of the computer, such as size, power, and connectivity. Basic computer systems and networks are explored, grounding students' use of computers in how they work. The networks section includes uses of the Internet beyond "surfing the web." Students research issues in computing ethics such as computer crime, intellectual property, and censorship, and hold an in-class, small-group debate. The major course project is the collaborative development of a website, including content generation, graphic and navigation design, and implementation using HTML.
- *Introduction to Programming.* This course focuses on developing fundamental programming skills, starting with Karel the Robot (Pattis 1994) and then moving on to interactive web design with JavaScript. It also includes a section that explores the future of computing.
- *Intermediate Programming.* The third course in the sequence exposes students to higher level programming problems using MiniJava, a Java-based teaching language (Roberts 2001). As students write increasingly interesting and exciting programs they explore complex programming concepts such as typed variables, control statements, methods and algorithmic problem solving. A social computing section addresses the responsibilities of programmers, currently and historically, and discusses the importance and potential ramifications of these responsibilities.

Our intent is not to have students reach expertise with a particular language such as C++ or Java, but rather to gain a familiarity with multiple languages, to recognize similarities between languages, and to secure an understanding of introductory programming fundamentals. In addition to these courses, two courses focused on multimedia design were developed (Visual design and Interaction design). The curriculum strives to help students achieve self-perpetuating fluency by providing them with a set of fundamental tools with which to understand technology, from both a practical and social perspective.

Introduction to Computing was first offered in 1999-2000. As of January 2004, 2196 students had taken the course, an average of 439 students per year. Approximately 35 percent of these students elected to take Introduction to Programming, which was first offered in 2000-01. Approximately 23 percent elected to take Visual Design, which was first offered in 2001-02. Of the students who took Introduction to Programming, 17 percent continued on to Intermediate Programming, which was first offered in 2001-02. Of the students who took Visual Design, 11 percent continued on to Interaction Design, which was first offered in 2002-03.

4. PROFESSIONAL DEVELOPMENT

Our model of professional development is consistent with research into teacher learning and new paradigms of teaching as an ongoing intellectual pursuit, focusing not on the mastery of static content but rather on the construction of meaning within a collaborative environment (Putnam and Borko 2000, Darling-Hammond 1998). Researchers and teachers jointly design the professional development sessions. The sessions are organized around the completion of collaborative projects similar to the assignments that students will later carry out. This approach allows the teachers to expand content expertise and also have reflective discussions around student work and how to assess student understanding. This helps ground each teacher's developing knowledge in discussions about classroom instruction. The combination of new content with real-world experiences and specific teacher expertise facilitates teachers' construction of their own knowledge, practices, and ideas (Putnam and Borko 2000).

Our model can be illustrated through a description of a session focusing on our Web Design module from Course A. As teachers work in teams to build a website from design through completion using a mini-version of the student module project, interrelated components are structured to guide their experience. New content, such as HTML, storyboarding, and the design process is introduced through small lessons; pedagogical ideas surrounding project-based instruction and collaborative work are discussed; teachers design and use rubrics to assess their own, each others' and students' design work; and student and teacher insights from video interviews, and teacher adaptations of course materials are used to promote reflection and further exploration of how the project and topic can work in the classroom. The explicit goal of these sessions is to familiarize the teachers with the course material and to help them construct a conceptual framework within which to understand it. Our implicit goal is to create a community of teachers who learn from each other and share emerging ideas and information.

Since 1999, we have offered multiple contexts for teacher learning, including three 1-3 day sessions throughout the school year, a more intensive 1-2 week session during the summer, and ongoing support via email, telephone, and video-conferencing. We have held eleven formal professional development sessions, totaling 288 hours—approximately 72 hours per year. All computing teachers from the two secondary schools attend the sessions, which usually have approximately six teachers in attendance. Four of the computing teachers have been involved from the beginning of the project and have completed all of the training sessions.

5. ASSESSMENT

A total of 98 third- and fourth-year students from Berkeley and CedarBridge participated by completing a survey. All students currently taking one of the advanced courses were asked to participate. In total, the available community of advanced course-takers consisted of 98 students, of whom 55 were male and 43 were female.

Survey and interview questions focused on four main areas:

1. Students' access to technology at home and school
2. Students' access to formal and informal learning opportunities
3. The regularity and breadth of uses to which technology is put
4. Motivational aspects of learning including interest, confidence, and valuing of technology as a subject and potential career

The surveys were administered during class time during the final month of the academic year (spring 2003) over a period of two weeks. Two researchers administered the surveys, letting students work through the questions at their own pace. These same researchers conducted interviews with students.

5.1 Course-taking Profiles

No differences were found in the total number of computing and design courses taken between males ($\mu = 3.02$, $\sigma = 1.13$) and females ($\mu = 2.65$, $\sigma = .99$). However, males on average took a significantly greater number of programming classes ($\mu = 1.15$, $\sigma = .82$) than females ($\mu = .77$, $\sigma = .65$) with $t(1, 96) = 2.46$, $\underline{p} < .02$. For the remainder of the analyses we compare students who took two, one, or no programming classes.

5.2 Confidence, Interest, and Sense of Value

Students rated their agreement with statements reflecting their interest, confidence, and valuing of computing knowledge on a five-point Lickert scale (with 5 being agree strongly).

Multivariate analyses of variance were carried out, using gender and number of programming classes taken as the independent variables. Two items measured students' interest in computing. Responses were averaged to create an interest score. There was a significant main effect of number of programming classes on students' interest score, indicating that students who took a greater number of programming classes were more interested than students who did not take programming classes, $F(2, 94) = 5.35$, $p = .006$. There were no significant gender differences on this construct.

Four items examined students' confidence in their ability to work with and learn about computers. Again, there was a main effect of number of programming classes taken, $F(2, 94) = 3.93$, $p < .05$. Post hoc tests indicate that the significant difference is between students who did not take programming classes and those who took two programming classes. There were no effects of gender.

A further four items queried the value that students place on computing and learning about computers. There was a significant main effect of number of classes taken, $F(2, 94) = 8.27$, $p < .001$, a significant main effect of gender, $F(1, 94) = 4.68$, $p < .05$, and a significant interaction between gender and number of classes taken, $F(2, 94) = 5.03$, $p = .01$. These results are displayed in Figure 2. These results indicate that the more classes students take, the more they recognize the value of learning about computers, and that this effect is greater for girls who take multiple programming classes.

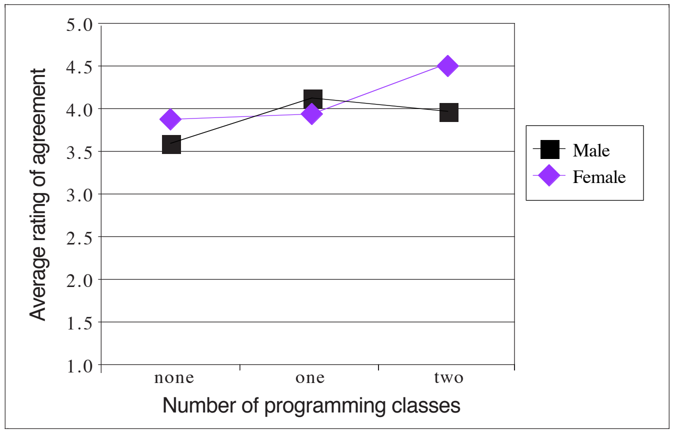

Figure 2. Perceived value of computing knowledge

These results indicate a correlation between the number of programming courses taken and level of confidence along with the students' perceived value of the field. Of course, such correlation cannot necessarily be interpreted as causality, given that students with greater confidence or those who were already persuaded of the value of the field would presumably be more likely to take advanced classes. To get a sense of the extent to which these courses actually shaped student self-identification, it was important to look at more qualitative data, such as the interview transcripts described in section 5.

5.3 Imagined Future Selves

Students were asked to rate the extent to which they could imagine possible futures for themselves on a five point scale that ranged from definitely no to definitely yes. We report on three of these here: Becoming a programmer, majoring in computer science in college, and taking additional technology-related classes. A MANOVA was used to analyze the data with gender and number of programming classes as the independent variables. No significant gender effect was found though it approached significance for *becoming a programmer* with males on average rating this more likely as a possible imagined self. There was a significant main effect of number of programming classes for the possible future of *taking more classes about technology* $F(2, 93) = 3.6$, $p = .03$ and it approached significance for *majoring in computer science in college*. The percentages of students who reported that they could see these possible futures for themselves as indicated by ratings of yes or definitely yes are provided in Figure 3.

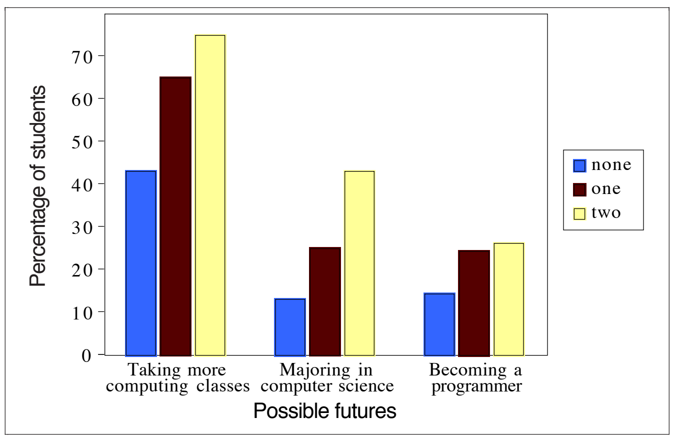

Figure 3. Student's ability to imagine various futures

6. CASE STUDIES

As noted in the preceding section, survey results are useful for establishing the existence of correlations but cannot always provide conclusive evidence about causality or why students make particular choices. To get a better sense of how students reacted to and were affected by the material, we conducted extensive videotaped interviews with 38 students. The three cases that follow illustrate the type of information we were able to obtain using this approach. The names of the students have been changed to maintain confidentiality.

6.1 Monica

Monica made extensive use of the resources available to her in school and sought out resources in her community to create new opportunities for learning and new ideas for her future. She took both programming courses and was interviewed in her fourth year of secondary school.

Monica came to secondary school with an interest in computers and knowledge of some basic programs. In middle school she taught herself a simple page-layout program on her home computer and used it to design invitations, flyers, and business cards. However, she was not familiar with programming, and had not considered a career in technology "I wanted to be an accountant at first, and then [my computer teacher] kind of pulled me in. I was like, 'Programming . . . Wow! This is great.' Then I noticed I could have a career in computers."

In the introductory programming course, she enjoyed programming problems that frustrated most of her friends, and was encouraged by her teacher and peers to continue on to the next course. The intermediate programming course proved to be more challenging, but Monica enjoyed working hard to complete the assignments and received satisfaction from the results.

> Wow, I have never been frustrated in any of my classes, but then MiniJava came along. I would print out my work, I would take my work home. You didn't have to, but I would take it home to fix that problem. You don't know how many times I did that…It's hard, but when you see your results – great. You see your work and it's nice. Everyone will come around to watch it.

In the summer after her third year, Monica called local IT companies to set up a job shadowing experience. Through shadowing an independent IT consultant, she met people in IT departments around the island and got their business cards. During her fourth year she used these connections to secure an internship in the IT department of a local insurance company, through which she learned how to create and deploy an online database.

Near the end of her fourth year, her computer teacher told her about a job opening and encouraged her to apply. Monica got the job and is currently working to design and program a website.

Though she once saw computer science as a male-dominated world, she now sees herself as part of that world and reports that her opinion is changing. She plans to go to the local community college for a year and continue working, and then go away to college in Canada to study computer graphics or software design.

6.2 Lakisha

Lakisha is a fourth-year student who has taken all of the computing classes that are offered at the school, including the two programming courses. She has a reverence for the field of technology and sees it as a creative profession, but though she has taken so many courses and is impressed with what she has accomplished, she does not feel that she is "a real computer person." She continues to take computing classes because she is confident that technological fluency is imperative in the world of business, which is her intended field of study.

> It was only at CedarBridge where I really got to know how the computer works, how to actually use it. Possibilities are endless with computers; it's just amazing. That's why every semester I always have a computer class in there just so I can learn, and besides, that's where the world is going today, to computers, so it's good to have computers in your background.

Lakisha is a diligent student who tries to figure things out on her own, uses references, works with her teachers, and stays after school to figure things out. She has met with significant success in her courses, which has given her more confidence in her abilities.

> I guess when you look at [the web page], what you have done, it's amazing. Like, "Wow, I actually did this." You would think you had to be some kind of specialist or something in order to do this, but you know, you don't have to be.

In addition to supporting her long-term business goals, Lakisha uses her technological knowledge in practical ways, such as removing red-eye from a digital photo, and in personal ways: "I consider myself to be a creative person and I get all these ideas, and by doing multimedia I am able to put those creativities on paper." Additionally she has helped her parents learn simple applications is planning to build a website for their business.

She is planning to get her associates or bachelor's degree in computers because "that's where the future is" and wants to be an entrepreneur and own her own business.

Though it is not her intended career field, her vision of what a computer scientist does is very positive: "Someone who creates technology to make things easier, like accounting programs for accounting. Creating technology to improve lifestyles."

6.3 Jamal

Jamal is a fourth-year student who has taken all five computing classes offered at his school. Though he had some basic experiences with computers in primary and middle school, he says most of his computing knowledge was learned in secondary school. Though he is not sure of his future plans, he has apparently gotten a lot of knowledge and recognition from his computing classes and seems to want to continue in the area of study in some way.

In his first multimedia course, Jamal worked with a group to design a Public Service Announcement website for teens in Bermuda about relevant issues such as road safety and teen pregnancy. The site won an award from the Ministry of Education and his team received Internet access for a year, a cell phone, and a Palm Pilot. He is currently working to design a website for a local battered women's shelter.

> Before, in primary school when you worked in a group you don't do anything that was really big. But now we're working for a nonprofit organization, like were doing something that's really big, something that's real, something that in ten years time we're going to say, "Oh, I designed that site back in high school."

Jamal cites his most advanced programming class as his favorite "because I like the challenge of it" and reports that he feels prepared to take computer classes in college because he has some prior knowledge and feels confident of the fundamentals. "It wasn't very hard, but it made us have to think very critically and analytically. You have to be really focused on what you are doing." This idea of focus comes up again when he is asked what makes a good computer scientist.

> A person who has patience and likes to be focused. A lot of people say that computer scientists are like brainiacs and different things like that, but I think that if you are really focused and are patient, you can go a long way in that type of field.

The view of a computer scientists as focused and patient makes the position seem much more attainable than an elite level of "smartness" that is often associated with the profession.

Jamal does not have a detailed plan for a specific course of study and is not yet sure what he wants to be. He is going to the local community college for two years to get an associate's degree in business administration, and then wants to go abroad to receive a bachelor's degree in business management and computer science.

7. DISCUSSION

Our primary goal in this research is to develop a better understanding of the ways in which computing experience obtained through courses relates to the development of interest and future engagement in learning. The data reported in this paper suggest a correlation among course taking, confidence, interest, and valuing of technology. While our design does not allow us to make causal claims, the qualitative interview data indicate that students feel their own course-related developing competence is important to their futures and that they make broad use of their technological competence. We believe that students' agency in creating learning opportunities for themselves is an understudied learning phenomena; our work suggests it deserves additional research. A second goal was to examine patterns of participation for males and females. In our sample we are finding that more males are opting to take programming than females. Even so, there are still a significant number of females who choose these courses and do well. We plan further analysis of the interview data to determine whether there are changes that we can make to the curriculum to reduce the gender gap.

REFERENCES

[1] American Association of University Women. Tech Savvy: Educating girls in the new computer age. Washington, D.C.: AAUW, April 2000.

[2] Barron, B. J., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., and Bransford, J. D. Doing with Understanding: Lessons from research on problem and project-based-learning. Journal of Learning Sciences, 7(3&4), 1998.

[3] Becker, H. J. and Riel, M. M. Teacher professional engagement and constructivist-compatible computer use. Report from the Center for Research on Information Technology and Organizations, University of California, Irvine and University of Minnesota, 2000.

[4] Becker, H. J. Unpublished data from the Teaching, Learning, and Computing 1998 National Survey. University of California, Irvine, 2001.

[5] Bermuda Census Office. The 2000 census of population and housing. Hamilton, Bermuda 2001.

[6] Bransford, J. D. and Schwartz, D. L. Rethinking transfer: A simple proposal with multiple implications. In Iran-Nejad and Pearson, Review of Research in Education, 24, 61-101. Washington DC: American Educational Research Association, 1999.

[7] Camp, T. The incredible schrinking pipeline. Communications of the ACM, 40:10, 1997, pp. 103-110.

[8] Darling-Hammond, L. Teacher learning that supports student learning. Educational Leadership, 55(5), 1998.

[9] National Council of Teachers of Mathematics. Curriculum and evaluation standards for mathematics. Reston, VA: 1989.

[10] National Research Council. Being fluent with information technology. Washington, DC: National Academy Press, 1999.

[11] Pattis, R. Karel the Robot (second edition). New York: John Wiley and Sons, 1994.

[12] Putnam, R and Barko, H. What do new views of knowledge and thinking have to say about research on teaching? Educational Researcher, 29(1), 2000.

[13] Roberts, E. An overview of MiniJava. Proceedings of the Thirty-second SIGCSE Technical Symposium on Computer Science Education, February 2001.

[14] Roberts, E. Expanding the audience for computer science. Keynote address at the thirty-fourth SIGCSE Symposium on Computer Science Education. Reno, Nevada, February 2003.

[15] Tucker, A. Deek, F., Jones, J. McCowan, D. Stephenson, C., and Verno, A. A Model Curriculum for K-12 Computer Science: Final Report of the ACM K-12 Education Task Force Curriculum Committee. Association of Computing Machinery, October 2003.

[16] Wenger, E. Communities of practice. Cambridge, UK: Cambridge University Press, 1998.