Imagining possible futures: Course taking and knowledge use within trajectories of technological fluency development

Brigid Barron, Caitlin Martin, Eric Roberts Emma Mercier, Sara McPhee,
Stanford University

Abstract

The concern with a "digital divide" has been transformed from one defined by technological access to technological prowess – employing technologies for more empowered and generative uses such as learning and innovation. In this paper we report on a design experiment comprised of curriculum, professional development, and research on student learning. Five courses were created to provide high school students opportunities to develop technological fluency. We report on our research that examines student learning and motivation. Interest, confidence, and valuing of technological knowledge as a function of both gender and course taking history is reported. Students' imagined future selves with respect to pursuing additional learning and possible jobs are analyzed. In order to provide richer data on how course experiences were important for males' and females' development, we present cases of students who took the maximum number of programming classes to illustrate the ways that they leveraged their course experiences for internships, competitions, further learning, and jobs. Our findings suggest strong relationships between course taking and confidence, interest, valuing of technical knowledge and projected career choices for all students, though the patterns differ somewhat for males and females.

Introduction

Computing sciences are quickly changing the ways in which disciplines from biology to history make progress while infusing daily living with devices that allow for new ways of communicating and learning. This rapid growth has raised two challenges: How to prepare students for a world that is highly technologically mediated (NRC, 1999) and subject to constant change, and how to recruit the next generation of computer scientists, inventors, and technology specialists. Both of these challenges include fundamental issues related to equity. The term digital divide was coined many years ago to capture the concern that the introduction of technologies might widen already significant gaps between economic groups that differed in their ability to afford computing tools. Differences in access to computers between genders, ethnic groups, ages, and more and less developed countries were also described as instances of digital divides.

Since the coining of the phrase "digital divide," the discourse has rapidly shifted from a concern about who has access to new information technologies to who will have the knowledge that will position them to design, create, invent, and use the technologies to enhance their personal lives and social worlds (Reich, 2002; Castells, 1996; New London Group, 1996). This concern is validated by research revealing substantial differences in the ways that technology is used by different demographic groups, how computing is used as a learning tool in more and less affluent schools (Warshauer, 2000), by qualitative studies of children who differ in their reading levels (Attewell, 2001), by survey research that shows greater advantage of the computer for school achievement for boys and the children of more affluent parents (Attewell & Battle, 1999), and by long-standing patterns of differential participation in advanced education that can lead to jobs that are at the forefront of technological innovation and design (AAUW, 2000; Camp, 1997).

In a dramatic portrayal of a possible consequence of widening divides between more and less educated people, Castells (1996) envisions a future in which people become members of one of two groups—the interacting or the interacted. "The interacting" will have the resources to choose, develop, and critique new technologies, whereas "the interacted" will be passively subject to its influence, perhaps without awareness. This re-definition of the digital divide problem shifts attention from concerns with physical access to technology to concerns with access to the learning opportunities that will allow for more empowered and generative uses of technology for learning and innovation (NRC, 1999).

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 might enhance various aspects of technological fluency and engage sustained interest in technological subjects (Becker & Riel, 2001). Opportunities to take courses that focus specifically on programming or design are quite rare. In a national probability sample of American high schools, Becker found that only 10% of computing classes involved computer science or programming. Only 4% focused on multimedia or design (Becker, 2001). Given that education offered through schools is the primary way of achieving equity of learning opportunities, we have worked to translate knowledge from the University into courses for high school students.

OVERVIEW OF RESEARCH

In this paper we present data from a project that was designed to address gaps in learning opportunities directly. The project involved creation of curriculum, professional development of teachers, and research on student learning and motivation. Although we describe the curriculum and professional development model below, our focus in this paper is on students' learning and motivation. Only the first course in the sequence was required, the remaining four were electives. We present quantitative data on patterns of participation in courses by males and females and examine how participation and gender are related to a number of variables. These include interest, confidence, and valuing of technological competence, perceptions of the climate in computing classes, educational and career plans, and use of other learning resources to enhance technical knowledge. We then turn to qualitative case study data that comes from interviews with students who took varying configurations of courses. Our goal in focusing on individual students is to better understand reasons for course taking and how knowledge gained in courses was leveraged to obtain internships, consider options for the future, help others learn, and build a sense of competence. Interviews, while subject to their own methodological limitations, provide richness of detail in life history and perspective that the surveys do not allow.

This project is located in the country of Bermuda and takes place in the two public high schools there. A question that reviewers of our work frequently raise is whether our findings can be generalized to the United States. We believe in many important respects they can be. Many of the school constraints are quite similar to those faced by high schools in the U.S. These include limited expertise of teachers with respect to computer science subject matter, little time for professional development, shifting educational standards, and no standard curriculum. The high schools also are challenged by extreme diversity in student achievement. All special needs students were mainstreamed in 1995 and so teachers must find creative ways to meet everyone's needs. Reports on the 2003 Terra Nova tests, standardized in the United States, indicated that in math and reading found that second year Bermuda high school students were scoring in the 30th percentile on average. This profile is like many of our more challenged schools in the United States.

On the other hand, Bermuda is unique with respect to its economy, geographical location, size, and cultural history. It is a British colony under self-rule. The country is small. There are 60,000 persons all living on an island of 60 square miles than spans 20 miles by 3 miles. Over the last 20 years, its economic base has shifted from tourism to international business. The relationship between government and business is unusual due to the fact that the businesses do not pay taxes to Bermuda and instead are expected to contribute voluntarily to the community. There are also important concerns about who is able to work in the companies. Corporate jobs are prized and many are taken by non-Bermudians. The companies claim that they cannot find Bermudian's with the requisite skills. Public schools are populated mostly by Bermudians. Private schools are more diverse ethnically and with respect to nationality. In addition, the employees of the large companies most often send their children to them rather than to the public schools. All of these factors create a unique developmental context for students. How these differences influence our interpretation of the results will be taken up in the discussion.

In the sections that follow we present a definition of technological fluency offered by the National Research Council that is consistent with our curriculum design and then turn to the theoretical rationale for the multi-context framework for understanding the development of technological fluency that guides our work (see Barron, in press). We then turn to the methods and results of the current study.

THE NRC FLUENCY REPORT

The term fluency was defined in a recent report sponsored by the National Science Foundation. Concerns about preparing college students for the future led the NSF 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 actively participate in this new era. Rather than use the term 'literacy' the authors of the report opted for the label 'fluency':

> *"People fluent with information technology are able to express themselves creatively, to reformulate knowledge, and to synthesize new information. 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."*
>
> *NRC, 1999 (p.2).*

The committee defined a tripartite approach to fluency (or "FITness") with equal attention to intellectual capabilities, domain-general information technology concepts, and contemporary information technology skills. The NRC definition of *intellectual capabilities* included managing complexity, engaging in sustained reasoning, collaborating with others, communicating with others, and expecting the unexpected. *Technology concepts* that were considered independent of particular exemplars and enduring even as technological advances are made included understanding that computational tasks involve discrete steps and that complex programs are written by people who have figured out how to define the essential steps in a process. Other general concepts include the idea of digital forms of information, computer networks, and the power of computing to model real world phenomena. Given that new concepts would augment rather than replace these ideas, the committee felt that they were particularly useful for helping one learn new technologies as they are developed. Finally, *contemporary skills* were defined to include goals of using the main genres of computing applications including databases, spreadsheets, research using the Internet, graphics and art-based programs, email communication programs, and word processing.

A LEARNING ECOLOGIES PERSPECTIVE

Ecological perspectives on development emphasize the need to understand the multiple contexts that children experience and in which they grow (Brofenbrenner & Evans, 2000). Micro-interactional processes that occur within any one physical context, such as face to face learning interactions, contribute to a child's development directly but also influence, and are influenced by, the kinds of interactions that occur in the other contexts in which children live. The phrase "learning ecology" is conceptually related though has been used in various ways by different theorists and is less focused on child development. For example, Levitt & March (1988) use the term to describe how organizations are collections of subunits of learning in an environment that consists largely of other collections of learning subunits. They propose that learning ecologies include various kinds of interactions among learners and that an important class of interactions are those between business competitors. These co-learners are linked through the diffusion of one another's failure experiences, successes, and through the sharing or keeping of secrets. More recently, the metaphor of a learning ecology as been used to describe how distributed resources on the web constitute a new kind of environment for learning (Brown, 2000; Looi-Chi, 2000). As resources become ever more interconnected, transformative effects on the nature of learning may emerge such that learning becomes a much more rapid, self-directed, spontaneous, and interconnected process (Collins & Halverson, 2002). Internet technologies offer students new possibilities for expression of creative agency and the ability to form new communicative and learning contexts. For example, Brown (2000) highlights the niche finding and developing capacity of the Internet. He proposes that virtual communities of niche interest will interweave with local, face-to-face groups allowing for cross-pollination of ideas. Nardi and O'Day (1998 p. 49) offer the related concept of "information ecologies" which they define as a "system of people, practices, values, and technologies in a particular local environment. Their goal in using this metaphor is to bring into sharper focus the human element of technological tool use and the importance of interpersonal relationships and values

In the current research, a learning ecology is conceptualized as the configuration of the learning resources which provide the learner with opportunities for learning. This use of the term ecology has the person as the organizing central node in the system and thus differs from more traditional uses of the term ecology, which usually refer to a single physical environment (though see Bateson, 1972; Levitt & March, 1988). In the framework presented here, the physical contexts where students live are considered crucial sources of learning but distributed resources are also recognized. Opportunities for technological fluency development arise at home, school, through peers, and in community contexts as well as through utilizing distributed resources such as books and on-line tutorials.

- Insert Figure 1 About Here –

The particulars of learning in any one context are shaped by learning histories and beliefs of partners, by mediational tools that are made available from the work of previous generations (computers, systems of symbolic representations, language practices), and by goals and practices of the communities. Within these contexts, developmental niches (Super & Harkness, 1986) defined by both the active efforts of the individual and the resources available provide opportunities for learning and may contribute to identity development. For example, informal learning that takes place when playing games with peers, through apprenticeships with family members, or being placed in a teaching role, allow for expertise development while simultaneously supporting one's sense of self as a competent user and adapter of technology. For example, by developing a sense of competence, refining interests, and sparking and the desire to participate in additional learning activities.

Like Nardi and O'day, we believe that to understand how technology is used and learned about, one must take into account the human values that underlie practices. However, we also think it is important to consider how an individual, who participates in many communities, might transfer practices from one to another. Individual agency in establishing learning opportunities is enhanced by the increasing independence that often comes with age, school contexts that allow for choice of electives, and by the utilization of distributed resources such as books and Internet mediated sources. Thus, even within the same general physical community, as youth get older they may evolve very different learning ecologies for themselves. New trajectories of development can be created as individuals become involved in new contexts and as they actively contribute to the creation of specific learning niches that they find comfortable and compelling.

While the metaphor of a learning ecology is useful for conceptualizing how new technologies make possible a variety of kinds of learning opportunities, it is also useful as a way to organize an empirical research agenda. While the processes mentioned above are plausible factors in producing differences in experiences, there is little empirical research that provides the details of how this happens. However, case studies of learning trajectories of individual students that arose in the context of our earlier classroom-based research (Barron, Martin, & Roberts, 2002) and in interview studies indicate that there is much to be learned about the connections between formal and informal learning experiences. For example, we have found relationships between histories of learning in the shared physical contexts such as classrooms and the probability that students will use distributed resources to create new learning contexts for themselves. In one case, an interest in learning more about HTML coding was sparked by a course where it was introduced and an introductory project was completed (Barron, Martin, & Roberts, 2002). This students' interest and assessment that its potential fit with his sense of himself as a very creative person, lead him to purchase several books and seek out resources and expertise available through the Internet. He later began a business with a peer designing web sites which allowed him to continue learning and developing his expertise. In another case, a student deeply involved in on-line games bought a programming text book in order to learn scripting that would allow him to modify aspects of the game. The idea of buying a textbook came about through a conversation with the father of a friend. This father was employed in the computing industry and suggested he look at the programming language Perl. In this particular case, the book did not turn out to be a useful learning resource. However, it did create an interest in taking a formal course.

A learning ecologies framework draws attention to these kind of bi-directional and reciprocal influences that have been understudied to date and suggests the need for much richer accounts of where, when, how, and why students choose to engage in learning. These examples suggest the worthiness of explicitly studying cross-context effects. In this research, we focus on the school as an important element of the learning ecology and through cases and descriptive quantitative analyses understand the roles it plays in the students' larger life context.

History of the Bermuda Curriculum Project

This research builds upon a design experiment that came about when government and business leaders in Bermuda, a small island country undergoing dramatic economic reorganization, realized that their students needed to be better prepared to enter both college and the workforce. From their perspective, better preparation was especially critical if they hoped to rely on local talent rather than continual recruitment of off-island workers. This concern led them to recruit university partners to help develop an approach to introducing computer science to their students. The project created five courses and carried out intensive professional development with teachers in the two public schools. These aspects of the project are described below,

Courses

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. The first course, *Introduction to Computing* was required of all students. The remaining courses were electives and included two sequential courses in each area of programming (*Introduction to Programming* and *Intermediate Programming*) and multimedia design (*Visual Design* and *Interaction Design*).

Introduction to Computing includes a range of topics that provide background understanding and offer opportunities for students to construct meaning through projects. 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 and censorship, and hold a small-group debate. The web design module introduces the basics of design and HTML. The major course project is the collaborative development of a web site, including content generation, graphic and navigation design, and implementation using HTML.

Introduction to Programming focuses on formal programming, including Karel the Robot to introduce basic logic concepts, interactive web design with JavaScript, and themes and topics in the future of computing. Students design, program, and critique a solution to a complex Karel problem, and present a futuristic design grounded in current themes through an interactive website. The following course, *Intermediate Programming* exposes students to the culture of computer programming. Students act as programmers as they work through long-term higher level programming problems using MiniJava, a Java based teaching language. The course problem set leads students to explore complex 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 promote an understanding of introductory programming fundamentals.

Visual Design introduces students to the basic principles of graphic and information design. Students engage in a number of design projects that guide them through experiments with design elements, principles, and multimedia authoring tools. Project examples include the design of a series of stamps using a variety of color schemes that conveys a sense of their local community and the small group development of a teen Public Service Announcement website. Balancing the conceptual and technical approaches to design, the goal of this course is to build student media literacy skills through an increased understanding of the design process, encouraging them to be active, critical participants in design who can constructively critique their own work and that of others. The following course, *Interaction Design*, exposes students to interaction design principles and theories and the tools, methodologies, and approaches of project management. Combining their design knowledge and project management skills, small groups of students work through the course to design and implement a dynamic web site for a local not-for-profit organization. Students establish project scope, set and monitor realistic deadlines, develop prototypes, meet with clients, and hold design critiques.

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% of these students elected to take *Introduction to Programming*, which was first offered in 2000-01. Approximately 23% elected to take *Visual Design*, which was first offered in 2001-02. Of the students who took *Introduction to Programming*, 17% continued on to *Intermediate Programming*, which was first offered in 2001-02. Of the students who took *Visual Design*, 11% continued on to *Interaction Design,* which was first offered in 2002-03.

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 & Borko, 2000; Darling-Hammond, 1998). The design of the professional development sessions is approached jointly by researchers and teachers. Collaborative activities based on student projects expand content expertise, while critical, reflective discussions around student work assess quality, standards, and student understanding, grounding the new knowledge in actual 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 & Borko, 2000). The explicit goal 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.

Overview of Research

As described above, a total of five classes were created for the pupils in Bermuda. The first class is compulsory for all freshmen and introduces students to basic computer skills and web design using HTML. Students can then choose whether to continue with programming classes, multimedia classes or both. Thus, there are a variety of patterns that we see in the course-taking behaviors of students. Some do not continue after their first class while others take both programming classes, both multimedia classes, or a combination of some of the four optional classes.

We formed three groups of students based on the number of courses they have taken. The minimal exposure group consists of students who took one or two classes (33% of the sample) , the moderate exposure group took three classes (43% of the sample), and the maximum exposure group took four or five classes (24% of the sample). We use level of class participation as an analytic contrast and examine its relationship with a number of variables including home access to computers and the Internet, range and frequency of use for different kinds of activities, interest, confidence, and valuing of technical knowledge, future plans, and perception of climate in computer classes. We also include gender in these analyses. Given that this is not a true experiment (we did not randomly assign students to different numbers of classes) we are not able to make causal claims about courses and the variables we look at. However, we do think it is valuable to look at the relationship of courses to these variables. Finally, we use interview data to present examples of how students who chose to take several computing classes used their course-based knowledge to create new out-of-school learning opportunities.

Methods

Sample. A total of 98 third and fourth year students from two public schools participated by completing a survey. All students currently taking one of the advanced courses were asked to participate. Fifty-five of the students were male and 43 were female. Out of this group, 38 students were interviewed. 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.

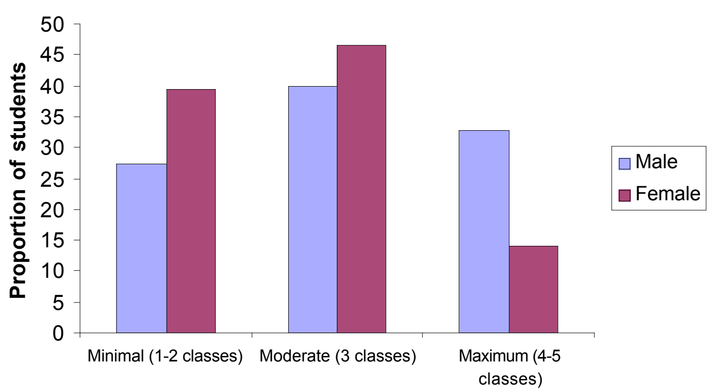
Survey & Interview. Survey and interview questions focused on four main areas: 1) students' access to technology at home and school; 2) students' access to formal and informal learning opportunities; 3) the regularity and breadth of uses to which technology is put; and 4) motivational aspects of learning including interest, confidence, and valuing of technology as a subject and potential career.

Procedures. The surveys were administered during class time during the final month of the academic year (spring, 2003). over a period of 2 weeks. Two researchers administered the surveys, letting students work through the questions at their own pace. These same researchers conducted interviews with students.

Results

Course taking profiles. No differences were found in the total number of courses taken between males (M= 3.02, SD=1.13) and females (M= 2.65 SD=.99). However, males on average took a significantly greater number of programming classes (M= 1.15, SD=.82) than females (M= .77, SD=.65, t (1, 96) =2.46, p <.02. However, when one looks at the proportion of males and females in each group, it becomes apparent that more males are taking the maximum number of courses. There are gender differences in these groups, with 32% of males in the maximum exposure group, but only 14% of females in this group (see Figure 2). However, this difference is not statistically significant, $X^2 = 4.82$, p = .09.

Figure 2. Class participation by gender



Home access to computers and the Internet. In order to determine whether there was an association between the numbers of classes students took and physical access to computing at home, an ANOVA was run using the class participation variable and gender as the independent variable and number of computers at home as the dependant variable. Results indicate that there is no difference in home computer access as a function of participation in courses and no interaction with gender. The average number of computers owned was 1.43. The difference between genders approaches statistical significance, $F(1, 92) = 3.612$, $\underline{p} = .06$, with males reporting higher levels of ownership ($\underline{M} = 1.54$, $\underline{SD} = .09$) than females ($\underline{M} = 1.24$, $\underline{SD} = .13$).

We also looked at Internet access. In previous interviews, many students had reported spending a significant amount of time at a relatives home, rather than their own family home. It was therefore important to measure Internet access in their relatives' homes as well as in their own homes. We created a dichotomous variable from this data to reflect access to the Internet either at home or in a relative's house. Chi Square analyses indicated that there was no difference in Internet Access as a function of how many courses students participated in.

Frequency of use. Students were asked how often they used a computer at home. The five point scale ranged from never to almost every day. Analysis of variance indicates that there is no effect of gender on frequency of use and no interaction effects. The effect of class exposure on frequency of use approaches significance, $F(2, 91) = 2.95$, $\underline{p} = .057$, with the minimal exposure group reporting the lowest use ($\underline{M} = 3.6$, $\underline{SD} = 1.26$), then the maximum exposure group, ($\underline{M} = 4.1$, $\underline{SD} = 1.28$) and the moderate group reporting the highest level (4.29, $\underline{SD} = 1.04$).

Learning Sources. Students were asked to indicate from a list of 11 items the places that they are learning about computers. These included classes in school, classes out of school, books, magazines, on-line, from friends, family and relatives, a job and from using the computer and tutorial alone. A total score was created to reflect number of learning sources. There was no relationship between patterns of course participation and the number of learning sources but a - significant main effect of gender, , $F(1, 92) = 5.74$, $\underline{p} < .05$, with males reporting that they learn in more places ($M = 4.55$, $SD = 2.22$) than females ($M = 3.51$, $SD = 1.92$). To further investigate the gender differences in number of places that the students report learning, a chi-square analysis was performed on each of the eleven learning resources by gender. Table 1 displays the four items that show a significant gender difference. For each resource, males report learning from it more often than females.

Table 1: Chi-square of gender and learning resources.

	Pearson's X^2	$\underline{p}$	% of males	% of females
Reading about computers in magazines	4.90	.03	24	7
Reading about computers on-line	6.22	.01	36	14
From a friend	3.79	.05	75	56
From a job	4.94	.03	20	5

Confidence, interest, and valuing of technological knowledge. Students rated their agreement with statements reflecting their interest, confidence, and valuing of computing knowledge on a five-point Likert scale (with 5 being agree strongly). Responses were averaged and combined to create a score for each construct. Analysesof variance was used to examine differences in students' scores on each construct in relation to participation in courses and gender. Results indicate that for each variable there is a significant main effect of class exposure but no effect of gender and no interaction effects.

Two items measured students' interest in computing. Responses were averaged to create an interest score. The main effect of class participation, $F(2, 88) = 9.78$, $p < .001$, indicates that students who took more classes are more interested in technology than students who took fewer classes. Scheffé posthoc comparisons showed that the minimal ($M = 3.71$) was different from the maximum group ($M = 4.59$), $p < .01$, and the minimal group was different from the moderate group ($M = 4.41$), $p < .01$. There were no interaction effects.

Four items examined students' confidence in their ability to work with and learn about computers. The main effect of participation in classes, $F(2, 88) = 8.48$, $p < .001$, indicates that students who took more classes were also more confident using technology. Scheffé posthoc comparisons showed that the minimal ($M = 3.77$) was different from the maximum group ($M = 4.36$), $p < .01$, and the minimal group was different from the moderate group ($M = 4.29$), $p < .01$. There were no interaction effects.

A further four items queried the value that students place on computing and learning about computers. There was a significant main effect of participation in classes, $F(2, 88) = 3.28$, $p < .05$, although there were no post-hoc differences between groups. Mean scores indicate that those in the minimal exposure group scored lower on the value construct ($M = 3.99$, $SD = .66$), than the other two groups (Moderate: $M = 4.27$, $SD = .61$ and Maximum: $M = 4.31$, $SD = .47$).

Experiences with technology. In order to obtain a broader picture of how students were using the computer and Internet, our survey included questions about four types of computer-mediated activities. These were Learning or Educational activities, Entertainment related activities, Communication, and Fluency Building activities (see Appendix 1 for the items that made up these scales). Students answered each of these on a frequency scale that ranged from never to almost every day for the educational, communication and entertainment activities, and from never to more than six times for the fluency building activities. In order to get a sense of students' range of experiences within each category, we created a total score based on the number of activities a student had ever engaged in. The means for this are presented in table 3.

A multivariate analysis of variance was used to determine if there were gender or class exposure differences in the number of technological activities students had engaged in. There were no gender differences, and no effects of class exposure for the educational, entertainment or communication activities. There was, however, a significant main effect of class exposure for the fluency building activities, $F(2, 80) = 5.67$, $p < .01$. When the means are examined it is clear that the more classes a student has taken the more fluency building activities he has engaged in. Scheffé posthoc comparisons showed that the minimal ($M = 5.37$) was different from the maximum group ($M = 7.76$), $p < .01$, and the moderate group ($M = 6.13$) was different from the maximum groups ($M = 7.76$), $p < .02$. There were no interaction effects.

Table 3: Range of technology related activities students' have experienced by class participation

	Educational		**Entertainment**		**Communication**		**Fluency**	
Participation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Minimal	6.71	2.41	3.45	1.21	3.78	1.99	5.37	2.66
Moderate	7.47	2.07	3.71	1.11	3.90	1.73	6.13	1.54
Maximum	7.63	2.43	3.69	1.22	3.50	2.15	7.76	2.26
Total	7.28	2.28	3.62	1.16	3.76	1.91	6.26	2.29

Frequency of engagement in technological activities. We were also interested in differences in the frequency that students had engaged in different technology related activities. The scale ranged from never to almost every day for the Education, Entertainment, and Communication activities.. Students' responses for each item were averaged to find a mean frequency score. The means are provided in Table 4. The Fluency items had a different scale as we assumed that they occurred so infrequently that life time occurrence would be a better measure. Multivariate Analysis of Variance indicates that there are no gender differences and that there is no effect of class participation on how frequently students engage in educational, entertainment or communication activities. However, there is a main effect of class participation on frequency of fluency building activities, $F(2, 75) = 6.33$, $\underline{p} < .01$. Scheffé posthoc comparisons showed that the minimal was different from the maximum group, $\underline{p} < .01$, and the moderate group was different from the maximum groups, $\underline{p} < .05$.

Table 4: Mean frequency of experience with technological activities

	Educational		**Entertainment**		**Communication**		**Fluency Building**	
Exposure	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Minimal	2.39	.61	2.72	.89	2.53	1.16	1.63	.44
Moderate	2.63	.59	2.99	.73	2.72	.99	1.88	.34
Maximum	2.54	.68	2.93	.79	2.55	1.12	2.14	.42
Total	2.53	.62	2.89	.80	2.62	1.07	1.86	.43

Future Selves and Class Participation. Students were asked to rate the extent to which they could imagine six technology related possible futures for themselves on a five point scale that ranged from definitely no to definitely yes. These include, becoming a programmer, majoring in computer science in college, taking additional technology-related classes, becoming a web designer, becoming a network specialist or becoming a computer teacher. An ANOVA was used to analyze the data with gender and class participation as the independent variables. There was a main effect of class participation for two items: taking more technology classes, $F(2, 87) = 3.44$, $\underline{p} < .05$, and majoring in computer science, $F(2, 87) = 4.25$, $\underline{p} < 05$. Post hoc tests reveal that the significant differences are between minimal and maximum class exposure for intent to take more classes, and between minimal and moderate, and minimal and maximum for intent to major in computer science. There was also main effect of gender for becoming a network specialist, F(1, 87) = 6.14, p = 0.05, with males being more likely to see themselves in this career than females.

Reasons for taking computer classes

Students were mark from a list factors that motivated them to take the computer classes that were offered in their school. The number of items that they selected was added up to get a total score of number of reasons students took computer classes. Analysis of variance indicates that there is a significant effect of class participation on number of reasons, F(2, 95) = 4.72, $p<.05$. Scheffé posthoc comparisons showed that the minimal participation group (M = 3.28) was different from the moderate group (M = 5.28), $p< .05$. There is no difference between the maximum group (M = 4.6) and the minimal or moderate participation groups.

Each item was then examined using X^2 analysis. Results indicate that there are significant group differences for wanting to major in computer science, with the maximum participation group choosing this item more frequently then students in other groups. There were also significant effects for 'People who work with computers make a lot of money' and 'I enjoy working with and learning about computers' with the moderate participation group selecting this option more frequently with the other two group.

Table 4: Reasons for taking computer classes by class exposure group

	Class Participation				
	Minimal	Moderate	Maximum	X^2	P
My family members are in the computing field	6	5	8	0.34	0.84
My family members encourage me to take computer classes.	22	31	33	1.08	0.58
I want to use computers to do something useful	38	57	50	2.82	0.24
It's a smart choice for my future.	68	78	67	1.41	0.49
I want to major in computer science in college	6	26	42	9.88	0.01
People who work with computers make a lot of money	25	62	50	10.05	0.01
I enjoy working with and learning about computers	47	76	71	7.32	0.03
I take classes because of the intellectual challenge	16	33	25	3.01	0.22
I take classes for the chance to be innovative and creative	41	60	46	2.82	0.24
I take classes for the satisfaction of solving problems.	16	33	25	3.01	0.22
My friends are in the classes.	9	17	8	1.35	0.515
I want to see what my options are.	34	50	38	2.07	0.36

Perception of classroom climate in computer classes. Students were asked a number of questions about their perceptions of the culture in their computer classes. The descriptions included 'cliquish', 'competitive in a way I find exciting', 'competitive in a way I find frustrating and unpleasant', 'discouraging', 'collaborative' and 'exciting'. A MANOVA was performed with gender and class participation as the independent variables to determine if there were differences in the perceptions of culture. There were no gender differences and no interactions. There was a significant difference between class participation groups for 'computer culture is collaborative', $F(2, 65) = 4.14$, $p = .02$ and for 'computer culture is exciting', $F(2, 65) = 6.43$, $p = .003$, with those who have taken fewer classes disagreeing more with both statements. Post hoc tests indicate that for the item computer culture is collaborative, the significant differences are between minimal exposure and moderate exposure groups ($p = .03$) and for computer culture is exciting, the differences are between minimal and moderate exposure groups ($p = .03$) and between minimal and maximum exposure groups ($p = .03$).

Summary of Quantitative Findings

There were no difference in home access to a computer or the Internet for students who took different numbers of classes. The quantitative analyses indicate that students who took more classes were more confident, had a greater interest in technology, and a greater valuing of technical knowledge. They also suggested that in general, the groups did not differ with respect to the range or frequency of use of the computer for education, entertainment, or communication. They did differ with respect to fluency building activities – that is those activities that are more likely to build the knowledge and skills outline in the fluency report. Students who took more classes were exposed to these kinds of activities and thus these findings suggest that without the classes, students may not have engaged in them. The results also showed that students who took more classes had a higher likelihood of seeing themselves as a computer science major, and continuing to learn about technology. This was consistent with their report on motivations for taking computer classes at school, as one motivation that was listed by the majority of students in the maximum participation group was a desire to major in Computer Science in College. Gender differences were observed in learning sources and this is something that deserves further study. Finally, students who took fewer classes were less likely to report that they found the classes exciting or that they found them collaborative. Whether they actually had different experiences this turned them off to more classes or whether they simply perceived them differently perhaps because of pre-existing differences in liking the subject matter cannot be determined but needs further study. Below we share some case stories of students who took at least three classes in addition to the required introductory class. We focus on how they used their classes to leverage other learning experiences and what they feel they got out of them.

Interview-based case studies

The above data is useful for providing overall trends in how course taking relates to a number of outcomes. However, it is theoretically useful to understand how individuals make sense of the knowledge they are developing in these courses and how their growing competence becomes integrated with their sense of self. Along with Wenger, we see identity development as a highly social process that is built up through shared experiences and involves reflection and assessment about who one is in relation to these experiences. Courses provide opportunities to imagine future selves and to develop competencies that have more immediate value. However, how this happens for individuals is unique, and the active process of using and leveraging growing expertise for various purposes needs to be better understood as we seek to design courses that are engaging for all students. For this reason we use interviews with students along with survey data to provide both nomenthetic and idiographic portraits. We provide an examples below students who has taken several of the courses and who have used resources in her school and community to create new opportunities for learning and new ideas for their future.

Case 1. Monica – *"Programming . . . Wow! This is great"*

Leveraging course knowledge for internships and a job

Monica came to high school with an interest in computers and knowledge of basic applications but 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 to continue. 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. Everyone will come around to watch it."

The summer after her third year, Monica called local IT companies to set up a job shadowing experience. The following school year she used connections made from her job shadow to secure an internship in the IT department of a local company. Near the end of her fourth year, her computer teacher encouraged her to apply for a salaried position in IT she knew of. 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.

Case 2: Alretha – *"The possibilities are endless"*

Alretha is a fourth year student who has taken almost all of the computing classes that are offered at the school, including the two programming courses and the first multimedia class. 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."

Alretha uses a broad range of resources to learn. Though she first tries to figure things out on her own, she 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 goals business goals, Alretha 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 bachelors 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

Case 3: Jakai - ***"I like the challenge of it"***

Jakai is a fourth year student who has taken all 5 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, Jakai 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 non-profit 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.'"

Jakai 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.

Jakai 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 2 years to get an associates degree in business administration, and then wants to go abroad to receive a Bachelors degree in business management and computer science.

CASE 4: Noreko – ***"I just had a love for the programming"***

Having never had a new computer, Noreko grew up tinkering with old machines to get them to run. Noreko is a third year student who has taken all of the programming courses that are offered and has excelled in the classes. He has not yet taken any multimedia courses. Unlike students who take the computer classes as a smart move for their future, Noreko's passion for the discipline seems to be the deciding factor. When asked why he continues to take programming classes, he replied that he "just had a love for the programming" His initial interest in programming stemmed from playing video games.

> "It was the games and I thought, I really enjoyed this [flight simulator game] and it was such an experience I thought I want to be a pilot, but them I realized I really actually I like more of the computer than the game. So as I grew I became more mature and realized what I really liked."

After taking the first programming course he found some C++ tutorials online and learned some basics of the language building on his prior knowledge from Karel the Robot. When he went into intermediate programming he found that he was familiar with some of the material.

> "I was looking for some programs like C++ on the Internet, I didn't really know that much about it but just I learned, got some programs that teach us the basics of programs. So when I got to the [Intermediate Programming] classroom she was teaching us something and I said, 'Yeah, I know this. Just from my own research I was like ahead of the class.'"

His plans for the future look more toward training than toward an academic college, however, he is being encouraged by friends, family, and teachers to look at technology focused academic institutions like Georgia Tech and MIT. He has one more year of secondary school and plans to take a course in Multimedia, but he wants to eventually go into Robotics design. His feels that he is prepared for further study in this area, be it technical or academic. When asked how he thought the courses would be valuable later he replied:

> "Basically you learn your foundation. You will probably learn it when you go into college, but I think that if I take these courses now, I will be flying through If I take these courses now, when I get to college I'm going to be flying through, just flying through, and be able to comprehend and keep up with the teacher."

His programming interest extends beyond the classroom and into other areas of his life, such as creating, mixing, and compressing music to produce CD's.

Case 5: Richard – "*It's the one thing I do in school that I can enjoy*"

Richard is a very articulate high school student with a great interest in computers and technology. He has taken most of the computer classes available to him, including both programming classes, and Multi-Media I. He credits the courses he has taken with developing his interest in computers and claims he would not have an interest otherwise.

> "I like doing computers. It's the one thing I do in school that I can enjoy. I had used computers before (the classes), but not in that way. Having someone teach me and having it right in front of me, that's a great thing. Web design has been the most exciting, the HTML stuff."

He is very active in his classes and serves as a teaching assistant in one of them. Richard has learned the most about computers from his teachers and also through efforts to teach himself. He enjoys reading books about technology and teaching himself concepts. He has few opportunities to utilize technology outside of school, as he is busy with his job in maintenance. However, he takes the time to learn through his reading and also teaches computer skills to his family members.

> "I prefer just looking at books….it also helps visually. Reading about it really touches me and then going on the computer and doing it." "That's how I acquired how to learn how to do web pages with Dreamweaver and Flash. I actually have books at home and I taught myself how to do those two."

Richard described how he built up his skill set in a series of steps. He started out learning HTML and moved into Java coding. He also learned how to use Microsoft Word and Excel before moving into learning how to do Powerpoint Presentations. Richard's career goal is to enter into web design. His desire is to attend a college in Arizona and get a degree in technology. He does not to live his entire life in Bermuda, as he feels it is too small.

Richard has a positive viewpoint of a computer scientist. He denies that there is any stereotype for who a computer scientist is. He indicated that a computer scientist is someone who analyzes a computer, makes chips and boards for a computer, and who also does programming networks and databases.

General Discussion

The goal of this research is to begin 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. 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. However, there are still a significant number of females who choose these courses and do well. There were few gender differences within class participation groups and we have little evidence that their experience is different within the courses.

Do courses such as these help bridge divides? From the evidence we are collecting we believe that significant numbers of students are leveraging our courses to build fluency and to imagine possible futures for themselves in careers or educational trajectories that they do not see represented in their immediate families. The data reported in this paper suggest a correlation among course taking, confidence, interest, and valuing of technology. Students who take more courses have also engaged in more fluency-building activities than those who have taken fewer. While our design does not allow us to make causal claims, the qualitative interview data do 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 to acquire internships, win contests, learn more from distributed resources and teach others including parents and friends. Though projects, students are teaming up with non-profit agencies to build functional web sites for them. Students' agency in creating learning opportunities for themselves is an understudied learning phenomena and our work suggests it deserves additional research.

We promised to discuss issues of generalizability due to issues of cultural and economic differences. This is a challenging question. We believe that our model of professional development and our curriculum could be transferred to schools in the US easily. In fact, we have had uptake of the courses for US classes in a couple of cases. We also have been studying processes of learning in one context sparking learning in other contexts here in the United States. We believe the Bermuda results in this regard are generally generalizable. In a similar way, teaching parents or others in the community, when parents are less competent, is something that we believe occurs in the US and we are collecting data on this. Whether students would leverage the courses in the same ways for internships or jobs is unclear. The smallness of the country of Bermuda perhaps makes it easier for students to gain entry into corporate environments. With respect to continued engagement in education, we cannot make any conclusions at this point. In general, the Bermuda public school students often attend the local community college for additional study before going on to a four-year college abroad. We realize that their success in college will be dependent on a broader range of competencies than they are acquiring in our courses. We hope to follow some of these students to see if their goals are realized and whether their beliefs that these classes helped to prepare them for college or work are confirmed. Hopefully there will be good news to report.

References

AAUW (2000). *Tech Savvy: Educating girls in the new computer age.* Washington, D.C.: AAUW.

Becker, H. & Riel, M. (2000). *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.

Becker, HJ (2001) Unpublished data from the *Teaching, Learning, and Computing 1998 National Survey*. Univ. of Calif. Irvine

National Research Council. (1999). *Being fluent with information technology.* Washington, DC: National Academy Press.

Wenger, E. (1998). *Communities of practice.* Cambridge, UK: Cambridge University Press.

Darling-Hammond, L. (1998). Teacher learning that supports student learning. *Educational Leadership*, 55(5), 6-11.

Putnam, R. & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher*, 29(1), 4–15.

Appendix 1

Table 2: Items that constituted the experience measure.

Activity Category	Items
Educational	Play games that help you practice math, spelling and science.
	Analyze data for science problems
	Write letters, stories or reports for school
	Do research for school
	Make graphs or charts
	Create or use a spreadsheet
	Download educational software from the internet
	Look for information on the World Wide Web
	Hold conversations with experts/mentors about a topic I am studying
	Participate in online projects (e.g. story exchanges, webQuests etc)
Entertainment	Play games for fun
	Participate in multi-user online games
	Buy things
	Download songs or music files
	Play CDs
Communication	Read or send email
	Read information from newsgroups or on bulletin boards
	Participate in online discussions in chat rooms
	Communicate with people in other countries
	Communicate with people in other schools in Bermuda
	Use Instant Messaging / IM (e.g. Yahoo messenger, MSN messenger)
Fluency building	Created a multimedia presentation (images, sounds, movies, text etc)
	Written code using a programming language
	Made a publication such as a brochure or newspaper using a desktop publishing program like Quark or PageMaker
	Started your own newsgroup or discussion group on the Internet.
	Created a web site using an application like Dreamweaver or FrontPage
	Hand-coded a web page using HTML
	Published a site on the web
	Created a piece of art using a media authoring tool like PhotoShop, PaintShopPro, or other art programs
	Designed a 2-d or 3-d model using a design tool like CAD or Modelshop
	Built a robot or created an invention of any kind using technology
	Used a simulation to model something: like population over time, or speeds with varying resistances
	Made a database
	Created a digital movie.