Gender digital divide and challenges in undergraduate computer science programs

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Abstract

Previous research revealed a reduced number of female students registered in computer science studies. In addition, the female students feel isolated, have reduced confidence, and underperform. This article explores differences between female and male students in undergraduate computer science programs in a mid-size university in Ontario. Based on Kelly's (2008) three levels of digital divide (resources, instruction, and culture specific knowledge), we explored gender specific challenges for each level. The research shows that, while the first level of digital divide is difficult to detect and the second layer is easily detectable, the third layer of digital divide is particularly pervasive and has a disconcerting outcome.

Key words: digital divide; computer science education; higher education; gender equity

Résumé

Des recherches antérieures ont révélé un nombre réduit d'étudiantes inscrites dans les études d'informatique. En outre, les élèves restants se sentent isolées, ont réduit la confiance, et sous-performer. Cet article explore les différences entre les étudiants et étudiantes de premier cycle dans les programmes d'informatique dans une université de moyenne dimension en Ontario. Sur la base de Kelly (2008), trois niveaux de la fracture numérique (ressources, l'enseignement et la culture des connaissances spécifiques), nous avons exploré les défis spécifiques au genre pour chaque niveau. La recherche montre que, tandis que le premier niveau de la fracture numérique est difficile à détecter et la deuxième couche est facilement détectable, la troisième couche de la fracture numérique est particulièrement répandue et a un dénouement déconcertant.

Mots clés: fracture numérique, enseignement de l'informatique, l'enseignement supérieur, l'équité entre les sexes

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Introduction

The situation of female students registered in undergraduate computer science studies is considered by educational experts to be critical (American Association of University Women (AAUW), 2000; Canadian Association of University Teachers (CAUT), 2007). Research indicates that there is a great gap between male and female students in number and in performance in undergraduate computer science programs. According to many researchers, females feel less confident than males in pursuing computer science courses (Dryburgh, 2000; Hancock, Davies, & McGrenere, 2002; Harrell, 1998; Todman, 2000; Wilson, 2002).

Digital divide is defined as the gap between those with regular and effective access to devices, instruction, and knowledge to computational resources and those who miss them (Swain & Pearson, 2001) and reveals profound differences of the use of technology in society by showing how social inequalities are perpetuated through technology. While the term has a wide broad of significations and aspects, the concept of levels of digital divide was initially introduced by Attewell (2001) and extended by Kelly (2008), and illustrates social inequities in the use of computers in educational settings on three different levels. The first level of digital divide is related to physical access to computer sources. The second level relates to how the computer-based instruction is conducted. This means that the instruction of the existing technology is considered more important than the “official” existence of computer resources. Finally, the third digital divide level considers how culture and students’ backgrounds shape their behaviour and perspectives towards the use of computers.

Few studies about gender differences in computer science education have been carried out in Canada. In this study, we use digital divide to study gender differences in computer science programs in a mid-size university in Ontario. The reason for using digital divide is to analyze the potential inequality in core aspects of the design and use of computer technology. It is the place where computer discipline not only reproduces itself, but also has a major role in designing and creating a technological role essential in today's society. Therefore, the importance of studying equity issues in computer science education cannot be emphasized enough. In this study, we identify and explore the differences and challenges males and females experience as they proceed through an undergraduate computer science program. The goal of this article is to analyze differences, stereotypes, and inequities that take place based on Kelly's (2008) three-level digital divide paradigm: a) computational resources, b) instruction in computers, and c) sociocultural background in fostering technology. This study specifically explores factors that alienate undergraduate female students and exacerbate gender disparities in confidence, performance, attitudes, and experience in undergraduate computer science education.

This article is a part of a larger research project (Stoilescu, 2006; Stoilescu & Egodawatte, 2010) and it presents the findings of the following research question: What difficulties did male and female students in the undergraduate computer science program encounter? This paper is structured as follows. In the first section, literature concerning the challenges of female students in computer science programs is reviewed. Next, a short section containing methodological considerations is presented. The following section reports the findings and is divided into three subsections, each describing a distinct level of digital divide: access to computer resources, access to computer science instruction, and access to computing culture. The article concludes with some recommendations for improving teachers' pedagogies and faculty's policies.

Theoretical Framework

A considerable body of research has revealed that males and females perform differently in terms of: (a) confidence, (b) computer use and programming experience, (c) activities in classes, and (d) selecting computer science as a major (AAUW, 2000; Cooper & Weaver, 2003; Corston & Colman, 1996; DeClue 1997; Lewis, Lang, & McKay, 2007; Selwyn 1997; Scragg & Smith, 1998; Wright, 1997). Several studies showed differences between males and females in self-efficacy and previous computer experiences. For instance, Lewis, Lang, and McKay (2007) found that female students had significantly lower self-efficacy in computing, less previous computer experience, and had received less prior encouragement to work with computers.

Durndell and Haag (2002) showed that male students scored higher in computer self efficacy, lower in anxiety, and had more positive attitudes towards the use of the Internet. The researchers found that male students reported more confidence in tackling new tasks than female students. Males' greater confidence was also reported by Bandalos and Benson (1990). Selwyn (1997), on the other hand, found that, while gender appears to be almost insignificant in the use of the computers, male students outnumber female students when choosing computer science as a major.

Researchers found that females and males begin their undergraduate studies with different levels of experience (Cooper & Weaver, 2003; Dryburgh, 2000; Sanders, 2005a; Sanders, 2005b). For instance, Scragg and Smith (1998) revealed that female students had less previous experience in computers than their male colleagues at the beginning of the program and for most females, computer science was not their initial major. DeClue (1997) also found that female students in computer science have less experience. In another study, Corston and Colman (1996) noticed that male subjects showed greater competence and had less computer-anxiety than females. In addition, researchers noticed that female participants performed better in the presence of a female audience than alone or with a male audience.

Researchers noticed that social, ethical, and moral issues are often treated as peripheral by educators and teachers in computer science. These courses are not taught adequately in this regard and leave students unprepared (Sanders, 2005a; von Konsky, Ivins, & Gribble, 2007). In particular, these issues might aggravate the ethical and social problems that confront students in computer science education and might explain the lack of efficiency in dealing with the underrepresentation of female students in computer science courses.

Female students were reported as viewing computer science as a hostile culture for women (DeClue, 1997; Rajagopal & Bojin, 2003). Starting with the secondary level and continuing into undergraduate programs, male students were reported as taking control of computers to the detriment of female students (Beynon, 1993; Bhargava, 2002; Margolis & Fisher, 2002). Sometimes males could even become bullies in their attempt to control access to computers (Beynon, 1993). Researchers observed that male students were more active in classrooms and received more attention from teachers (Wasburn & Miller, 2006). Some females had the required skills to pursue a computer science program, but they would not select computer science courses.

In Western countries, gender stereotypes are often reported in computing. These prejudices start early in life. For instance, boys are directed to use machines and computers earlier than girls (Grundy, 1998; Moses, 1993). Also, research has shown that, starting from the first years of school until secondary school, computer science instruction is often poor (Pieterse & Sonnekus, 2003; AAUW, 2000). As a result, starting with elementary school, female students lack confidence in using software (Dryburgh, 2000; Margolis & Fisher, 2002). They also lack role models, and the software is often perceived as being designed mostly for boys (Margolis & Fisher, 2002). In their study of gender differences, Bunderson and Christensen (1995) found the low number of females enrolled in computer science courses was related to the absence of role models. Tully (1997) suggests that, while education with computers is expected to take place in schools, the acquisition of knowledge and skills takes place in informal environments. Another consequence of informal education substituting education in classrooms is that the informal social networks might consist of a smaller number of female participants. While this claim cannot be demonstrated rigorously or generalized, this opinion seems generally held by a great number of researchers and computer science professionals (Schaumburg, 2001; Lewis, McKay, & Lang, 2006).

As a main effect of emphasizing self-esteem as a career goal, Charles and Bradley (2006) consider that females probably would select stereotypical jobs such as teachers or nurses. Even when these traditional jobs pay less, women will prefer these jobs instead of constantly feeling anxious and unfit in a well-paid information technology (IT) related job. They go to traditional female jobs or at least in a place where there is a comfortable social network able to sustain their career expectations. This desire of self-esteem coupled with lack of support of female students in informal settings might explain why fewer females take computer science education since, to a great extent, the learning processes are not in classrooms, but in informal places that cannot be controlled and generally favour male students. Also, because of the fast pace of evolution in computer disciplines, there is significant pressure on students, teachers, and administrators to keep pace with the latest acquisitions. As a result, there are serious gaps between male and female students, when they are exposed with inadequate computer science instruction (Margolis, 2008; Stoilescu, 2005). Together, all of these factors have serious consequences in challenging the efforts of female students approaching computer science courses. These facts were not only encountered in literature review but also were acknowledged in our day-to-day practices in a large number of situations. After reviewing the literature review, we believe that the digital divide framework is suitable to provide a description in a systematic manner of cases of gender imbalance and propose steps for action, in order to implement a more equitable framework in computer science education.

Methodology

Participants and Setting

The study took place in a medium size university in Ontario. The part of the study presented in this article contains results from the qualitative research section (Creswell, 2003). The School of Computer Science has over 1,000 students with majors and minors in computer science programs and over 30 instructors. We observed seven courses of undergraduate students in computer science, from the first to third year, during the intersession and summer sessions of 2005. The intersession and summer sessions gave us a particular perspective. With fewer students registered in these sessions, students were more likely to be working on their own. We invited students to participate in the study. There were 16 participants (six female students and ten male students) who agreed to be interviewed or to answer a survey by e-mail. In addition, two scholars agreed to answer another survey, specially designed for computer science instructors. All participants' names reported here are pseudonyms.

This dynamic provided an opportunity to compare the characteristics of the new entrants to the program with the students who had already experienced the program and were about to graduate. The selection of the subjects took place at the end of each course, so that the sample of students consisted of subjects who persisted until the final exam. The courses taken by those in the sample represented the main areas of preparation for computer science undergraduate students (algorithms, data structures, programming language, web design, and object-oriented design).

Data Collection

Data was gathered using three distinct procedures: interviews, observations, and document analysis. The transcripts were divided according to each research question. First, the first author interviewed the subjects who opted for the interview. Based on the facts obtained from the interview, the survey was designed and sent the questionnaires by email to the other participants. In particular, students were asked to explain the ratio between female and male students registered in their program and the way they perform in classrooms. They were asked if they considered male and female students to be treated fairly. The findings from the interviews and observations were compared for the purpose of identifying points of departure and agreements. Students were observed in both theoretical lectures and practical labs in order to analyze their patterns of interactions between students and instructor and among students. These findings were correlated with the analysis of different documents. Open-ended exploratory questions were asked under the following categories: (a) level of knowledge before starting the program; (b) reasons why the students selected the program; (c) students' opinions and interests about computer science (use of computers, computer programming, and career attitudes); (d) students' perceptions about their capabilities; (e) difficulties that students have in the program; (f) awareness of issues specific to gender differences in computer science courses; (g) student's opinions about current teaching; and (h) suggestions to improve gender equity in computer science programs.

Data Analysis

Several patterns emerged from the three different data collection methods. First, the interviews were transcribed, compared with observations, and sifted for themes. The data was analyzed for the following aspects:

- Number of male and female students who attended the classes
- Knowledge and experience levels showed by males and females
- Confidence or anxiety levels exposed at labs during the assignments
- Communication among students
- Interactions with the instructor and teacher assistants
- Answers that students gave to instructors
- Pace of work that instructors and teacher assistants required
- Teaching style of the instructor, the teaching pace, the level of explanations
- How students from the same gender and from different genders interacted with each other

For discourse analysis protocol, the course outlines, textbooks, assignments, and course WebPages were analyzed. More specifically, the following issues were examined:

- Outline of each course and the way students adapted to accomplish the required tasks,
- Online resources that the instructor offered for the course,

- Typical errors that the software programs had during the labs, and
- Ways students attempted to complete the assignments during the labs.

Findings

The findings were structured based on the three levels of digital divide described by Kelly (2008): equity of resources, equity of computer instruction, and equity in accessing a culture fostering computer technology. Each of these digital divides will be described in detail.

First Digital Divide: Computing Resources

There were more computers than students in the computer labs; therefore, access to computers was not an issue. There was a lab open most of the day, where students could drop in and work on their projects and assignments. In addition, some teacher assistants were appointed to help students. We found that equity for access to computational resources was an important and basic requirement which was fulfilled for the undergraduate students registered in computer science programs. As Light (2001), Kelly (2008), and Margolis (2008) caution, digital equity should not be reduced to aspects of access to computing resources alone, but rather in discussing ways in which instruction and knowledge in computers are shared.

One aspect that could not be controlled in this study was the access to digital resources from home**.** We are interested in this aspect, as access to computers from home might be an issue in increasing the digital divide and pose serious concerns for some students, especially when we consider the extent of time and the flexibility that a home computer offers (Linn, 2005). Even though computers are affordable for most families in Canada, access time for females depends on many factors such as social equity inside families. In other words, inequity might not be in school, but might exist at home.

Second Digital Divide: Instruction on Using Computers

The second level of digital divide refers to technological instruction on using computers. Being in the same computer science department, male and female students were expected to have the same instruction. In fact, this was not true. Students had different majors and minors in computer science. While there was an equitable ratio between males and females in all computer science minor programs, there was an overwhelmingly higher ratio of male students among computer science majors, which might explain differences between academic and professional trajectories of male and female students.

When asked how gender inequity could be addressed, Mike, a third-year student participant, argued, “That is the difference between the female brain and male brain. I don’t think any motivation can help.” Ravi, another third-year male student participant, argued, “women might actually have been helped more than might generally seem to be the case.” He sustained an offensive and discriminatory posture by suggesting that “women aren’t that good at working hard. They should be encouraged to sit quietly more, maybe that helps.”

Another issue is the lack of preparation of computer science students for ethical, moral, and social issues involved in the use of computing in society. Unfortunately, the part of the curriculum that prepared students for ethical, moral, and social aspects was only peripheral for the computer science programs. This insufficient exposure of computer science students to social issues supports the findings of Sanders (2005a, 2005b), Quinn (2006), and von Konsky et al. (2007). The lack of awareness of socio-ethical issues that future professionals might add to the challenge of understanding the concepts of equity.

Third Digital Divide: Access to Cultural-Sensitivity Technology

The third digital divide focuses on how the culture and students' background shapes behaviour and perspectives towards the use of computers. The next sections describe themes that were relevant in analyzing challenges of female and male access to cultural differences. There were important differences in anxiety, social network, and experiences of the male and female participants.

Influence of peers.

At the undergraduate level, computer science degrees prepare students to become computer programmers. Therefore, unless students were attempting to enter graduate programs, they were only interested in acquiring experience. Computer science education might pose an important challenge to informal educational perspectives, as males and females receive different opportunities to work with computers (Tully, 1997). Therefore, especially for female students, gaining experience in computer programming is not easy. This journey might take additional time, well beyond the number of classroom hours available. For instance, we noticed that first-year students had problems with modular programming. Although they understood the theoretical points that underpin modular programming, they were often challenged when they attempted to implement subprograms (modules) and manage them properly. When students did not have enough practice in using modular programming, the amount of time and difficulty to complete assignments increased. If students were unable to become proficient in modular programming, the subsequent courses would be hard to master and their academic programs would start to be difficult and unsuccessful.

Another important factor was practical experience. Many male students had prior working experience in software companies. Four of the male participants had IT job experience. In contrast, none of the female students mentioned job experiences in programming, although Gillian mentioned that she was considering this possibility. The undergraduate male students were able to build a social network that supported them. In all cases in this study, male students had peers that helped them to cope with difficulties in computer programming. In contrast, female students did not effectively develop peer relations. Although credited in general with better communication and social skills (Sanders, 2005b), female students in this study generally did not form a social environment able to stimulate and encourage them in their computer science pursuits. While female students spoke mostly about the official academic record, male students instead discussed more about their interests, passions, and hobbies related to computers and less about their academic achievements. This tendency also might explain the lack of opportunities that female students have in participating in practical activities in computing.

Being aware that experience is the only aspect that matters for their future employers, male student participants declared their focus on long-term projects that provided hands-on experience. The majority of them were willing to dedicate time and effort in order to learn a software product beyond the current academic requirements. Most of the female participants had a relatively limited interest in learning software requirements not related to the academic coursework. For example, Melody was interested in developing financial software design. Other females were interested in web design and databases. In fact, students who were registered in computer science minors had many experiences of this type. Other research confirms the attraction of web design courses to female students (Scott-Dixon, 2004).

Evolution of students' expertise.

This study revealed that different levels of experience were perpetuated during the undergraduate program. Sometimes this caused students a lot of frustration. For male students who had previous computer programming experience, these previous experiences helped them to succeed in the introductory courses. Starting with the second year of study, male student participants extended their experience in all three aspects: user confidence, programmer confidence, and career confidence. For instance, when the study of object-oriented programming was required, most of the male students already had experience with software projects and easily mastered the new coursework. They were better prepared to learn object-oriented programming. When software design started to be taught in the third year of study, students with experience in programming, usually male students, were more able to design software architecture and extend their advantage in this way.

Some exceptions were noticed. For instance, Gillian wanted to be involved in developing games. She declared that "anything can interact with you once it has been successfully coded; it rewards you with a great sense of accomplishment." Playing and programming games were very attractive for her. She was a successful student as she was very confident in her skills and had a great passion for computers, games, and programming. In fact, she was the only female participant who had been familiar with developing software projects extending over the conventional level of school. Another female student was confident that her skills in mathematics would help her design software despite the fact that she did not have much experience now.

Levels of anxiety.

In analyzing the difficulties specific to female and male participants, a pattern of attrition was noted related to gender differences. For instance, two female students were observed working hard for several weeks in labs. At the beginning, both were enthusiastic. For them, it was “tough but doable.” However, during the midterm, they lost their initial optimism. They were unable to keep up with the pace of the course, and so they left the course after the midterm examination. Reflecting on these events, we will explain why we realized that the initial differences were not always going to decrease in time.

Informal discussions with computer science alumni and with professors revealed that the low female ratio has marginally increased. A former female student in computer science acknowledged the loneliness of her academic pursuit when, twenty years ago, she was the only female student registered in the program. As a consequence of isolation, she dropped the computer science program in the second year. A female alumna, who graduated in 2002, mentioned that there were only two females who finished the computer science major. A male alumnus who graduated in 1996 mentioned that there were only two female students and almost 50 male students in the final year of the computer science program. Reflecting on these aspects, we were alarmed that low participation for females has long existed in these programs. These tendencies continue in the present. For instance, the female instructor who was interviewed in this study also confirmed the small number of females registered in computing and also a small increase in the participation of female students.

Initiation in programming is a new type of literacy. A programming language is different from a natural language; it is another kind of language, artificial, simplified, and designed for computers, and it seems unfriendly to beginners (Margolis & Fisher, 2002; Turkle, 1997). When someone masters the requirements of one programming language, he or she starts to feel more confident with programming. Due to the fact that the majority of programming languages use almost the same few paradigms (structural programming, modular programming, and objected oriented programming), an additional programming language is usually easy to learn. Once one masters a programming language, it is easy to transfer the skills to learning other programming languages. Therefore, it is very important to observe how students learn their first programming language.

Cheryl, a female student in the first year of study, was in an introductory course in programming. She attended each class, along with her friends, always sitting in the first row. She mentioned that she is in a mathematics major program and that she loves mathematics, but hates computers, especially programming. She refused to give an explanation as to why she disliked computers. Her anxious behaviour was distracting during the course. She took breaks often or let others know that she was tired and could not follow anymore. The female teacher was quite understandable and flexible, trying to cut from the time and content of the current lesson, teaching only the core topics. In labs, Cheryl just started to type few lines of code required for assignments, without making logical sense. After a couple of labs, the student no longer tried to correct the programs; she gave up in the first few minutes of the labs. While the teaching assistant was checking the previous assignment, Cheryl regularly left the classroom. Her female colleagues were not able to help her either. They could barely cope with the content of the course themselves.

Lena, a second-year student, was observed several times during her lab in the Java course. In the beginning, she was very willing to work on her assignments. However, observing her more attentively, her behaviour showed a high anxiety level. Most of the time, she did not ask any questions at all. She just left disappointed at the end of the lab. As she recorded in the questionnaire, her level of confidence was 10 before starting the program, eight during the first year and had sunk to a two at the time of interview. Only at the final assessment, where a lot of new expectations appeared, did she repeatedly call teacher assistants to help her, but it was too late. At that moment, there were numerous demands from most of her peers, so the teacher assistants had very little time left to spend with her. When she was asked if she had any contacts with other computer science students or professionals, she mentioned not having any extra school contacts with experienced people in computer science.

The importance of having computer science students in personal social networks was obvious. In our case, this aspect made a great difference between Lena and Cheryl. Both were good in mathematics. Lena enjoyed using computers while Cheryl did not. While Lena did not have any social network to help her, Cheryl did. Lena did not have any friends, male or female, who could help with the coursework, so she struggled to finish her assignments without any social support. Cheryl had two female colleagues and a male colleague who worked with all three female students and assisted them outside of class.

Melody, a second-year female student, stated that what helped her to cope were two essential aspects: one was the social network and the second was previous experience at an entry-level IT job. Even though she had not practiced software programming or software analysis in Japan, her experience working as a user with financial software and discussing issues with different technologists helped her achieve a good perspective about the software. After courses in business and accounting, she hoped to qualify for co-op, and have more chances in her future career. Melody regularly ask*s* teacher assistants and the instructor for help. She emphasized that computer science required practice: “It is not enough to learn a theoretical concept; you should implement it, write code, and practice it in order to master the concept and to let the stress subside.” Very importantly, she established a solid social network of peers in the computer science program who were able to support her.

Social stereotypes.

Gender is not only a biological reality, but also a socio-cultural one (Cooper & Weaver, 2003; Sanders, 2005b). Asked if and why female students underperformed versus male students in computer science programs, the answers were generally diverse. Robert mentioned that the IT market had traditional male jobs; he asserted that social stereotypes are the reason why traditional female careers are in health care and education, but not technology. David accepted the theoretical existence of female experts in computer programming, but mentioned that he had never met one: “I admit the possibility to find female role models in computer science, although I never found any in my day-to-day experience.” He suggested that the relatively small number of female students may be due to traditional family obligations, arguing that females in traditional families might not have the time to invest in computer science careers that are changing at a fast pace.

Lena suggested that, “Probably women find it too challenging.” James mentioned, “Maybe they are less interested in computers.” Pamela suggested “probably females do not get attracted to this field. Maybe they like to use computers for other purposes, just not programming.”

Unfortunately social stereotypes of females in computer fields persist. Sometimes strong stereotypes are closely related to prejudice and discrimination. Steve mentioned that female students are not interested in acquiring logical skills in computation. According to Mike, "generally speaking, women do not have good logic in this field." Ravi expressed views which could be considered more chauvinistic when he said that "[computer science] is drier and more thinking, so women are not selecting a career in the IT industry." Margolis and Fisher (2002) mentioned that "the gender stereotypes associated with computing tend to pull boys in and push girls away. To balance this influence, a concerted campaign is necessary." (p. 119). Margolis and Fisher (2002) see these types of disparaging remarks as a major cause of female detachment from taking computer science courses. Failure to establish a nurturing environment that fosters learning computer science for female students is a deep-rooted problem.

Discussion

By exploring these distinct layers of digital divide, we noticed a difference between male and female student experiences in an undergraduate computer science program. In the first layer of digital divide, equity in accessing computer resources, we did not find much difference between male and female students. The second layer, equity with instruction in computers, showed consistent differences, and the third layer, opportunities to foster computers' culture, gave cause for serious concern. High anxiety, lack of confidence, and underachievement of female students continued during the program.

Since males were working in different informal settings, these complexities of experiences and efforts helped them to extend and diversify their expertise. During the program, the differences between the levels of experience changed. The differences in experiences and expectations between males and females increased. We cannot infer that the digital divide was based only on social inequality but also might have roots in cultural and social traditions and prejudice (Cooper & Weaver, 2003; Margolis, 2002). In trying to identify socio-cultural stereotypes, both males and females tended to be convinced that computer science is a male domain.

Making Computer Science Education Aware of Social Stereotypes

The influence of negative stereotypes in computer science education has become ubiquitous. A difficult problem is how we can fight against these. An important issue in social stereotypes is the overstated importance of “geeks” in the past. These people, although they exist, are not as widespread as previous research reported (Margolis & Fischer, 2002). The participants in this study mentioned the myth of the pure “hacker” as a false image of what a computer scientist should be. This issue requires further reflection. Even though, at the beginning of computer science undergraduate studies, students are more individualistic and aloof, these attitudes gradually change over time. Now the IT industry emphasizes collaboration with many people working together in large projects. The participants mentioned that the pressure to socialize and work in teams is high in IT careers.

Gender remains by far one of the most important stereotypes in our society. We should not reduce this approach only to formal education. More exactly, we should give the same informal and academic opportunities to both males and females. We should let them decide about their personal relationships with computer science and not consider their gender an obstacle or advantage in interacting with computers and later studying computer science. Therefore, we should reflect on the opportunities that we provide to other students, reflect on our biases, and manage to give them the same opportunities to interact with computers, regardless of their gender.

There has been success at some universities in encouraging females to enter computer science programs. For instance, some courageous ideas, strategies, and actions implemented at Carnegie Mellon were revolutionary (Margolis & Fisher, 2002). For instance, accepting a certain number of females each year, even with lower levels of experience, was a good method to protect them from the devastating effects produced by tokenization (Cooper & Weaver, 2003). The counselling support for female candidates and registered female students was successful. A real success was their course for secondary school teachers in computer science when they not only explained about teaching, but also presented the difficulties that female students have. Their efforts to build a network of peers for female students were effective.

Improving Computer Science Education in Secondary and Tertiary Levels

As Tully (1997) cautions, informal education plays an important role in shaping the programming skills of students. As noted, informal education had an important role in configuring students' experiences, confidence, and anxiety. In particular, female students received fewer opportunities to practice computing. An immediate inference is that teachers should use pedagogy to negotiate with the informal educational aspects of computer science. Informal education should be seriously considered and it should be treated as an opportunity to provide parallel gender equality in regards to computer science experience.

Charles and Bradley (2006) argued that countries with adequate female representation in computer science seem to have a strong requirement in the curriculum for substantial coursework in mathematics and science. It is the role of colleges and universities to provide effective opportunities and agency for female students to achieve adequate computer experience and learning. However, the university also has power to spread its ideas about computer education in the local community. These battles against negative stereotypes should be widely targeted by faculty and administrative officials together. Some educators have opted to include social, moral, and ethical issues in computer science education (Quinn, 2006; von Konsky et al., 2007). We wholeheartedly agree with them and believe that this should be done in computer science education. In fact, other “hard” disciplines—such as mathematics, science, and medicine—have already implemented these measures.

Conclusion

Arguably, it is the digital divide framework that offers a fruitful theoretical account of our observations and experiences on the nature of gender-specific computer science education relationships. While the computer science programs offered equitable policies on paper, female students did not have sufficient opportunities to achieve valuable experiences in this field. Few of them were able to graduate from these programs and feel confident about the prospect of a career in computer science. Therefore, as the analysis of the third level of digital divide shows, the process of fostering and nurturing a welcoming atmosphere of practice for all in computer science remains an untapped resource.

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