Pair Programming, Confidence and Gender Considerations at a South African University

Michael Mitchley, Yasmine Dominguez-Whitehead, and Sabrina Liccardo[1]

1 Introduction

As in most Science, Engineering and Technology (SET) fields, women in computer science continue to be underrepresented (Cohoon/Aspray 2006; Ilias/Kordaki 2006). This shortage of women raises critical concerns surrounding women's rights and their participation in education and science. In South Africa, this shortage is also relevant to the country's socio-democratic transformation efforts and critical skills shortages. Given that women are under-represented in computer science and that this has social and economic consequences, it becomes increasingly pertinent to conduct an examination that addresses discrepancies between women and men studying computer science at the university level. It is also relevant to examine pair programming as a teaching-learning strategy that may help students (particularly women) succeed.

Additionally, the concerning attrition rates of women studying computer science at university provide an impetus to investigate discrepancies between the two genders (Cohoon 2002). It has been noted that attrition for women is twice that of men (Cohoon 2002). This figure, coupled with South Africa's alarmingly high university dropout rate, which is estimated at approximately 50% (Beckmann 2008; Jama/Mapesela/Beylefeld 2008), suggests that university students and women in particular confront difficulties in completing their degrees. We are thus compelled to investigate discrepancies between the two genders in computational science courses and to investigate pair programming as a teaching-learning

1 Michael Mitchley | michael.mitchley@wits.ac.za | School of Computational and Applied Mathematics | University of the Witwatersrand | Johannesburg, Republic of South Africa
Dr. Yasmine Dominguez-Whitehead | yasmine.dominguez-whitehead@wits.ac.za | Wits School of Education | University of the Witwatersrand | Parktown, Republic of South Africa
Sabrina Liccardo | sabrina.liccardo@gmail.com | School of Human and Community Development | University of the Witwatersrand | Johannesburg, Republic of South Africa

B. Thege et al. (eds.), *Paths to Career and Success for Women in Science*,
DOI 10.1007/978-3-658-04061-1_8, © Springer Fachmedien Wiesbaden 2014

strategy that may help women succeed. Accordingly, the article presents research conducted on university students in a programming-intensive course at a major university in South Africa and focuses on gender discrepancies and pair programming. The data presented is derived from a questionnaire that elicited quantitative and qualitative information from students in a first-year computational mathematics course. The following overarching research questions were pursued: Do men and women report differences in programming experience and confidence? Is pair programming a helpful teaching-learning strategy for women?

2 Selected literature

The literature reviewed below provides a cursory overview of pair programming and its use as a teaching-learning strategy, as well as an overview of women in programming, including some of the barriers to participation and success that have been widely documented.

2.1 Pair programming: selected literature

Different styles of learning and their relevance for teaching and learning in computer science have recently received attention. More specifically, there are indications that gender differences relating to performance in computer science may be attributed to styles of learning and the ways in which learning takes place (Ames 2003). It has been argued that 'learning style-based pedagogical practices [in computer science] need to move from a gender neutral to gender sensitive approach' (Lau/Yuen 2010: 1090). In other words, environments that are women friendly and that encourage the participation of women should be promoted. In particular, it has been suggested that women in computer science courses have opportunities available for them to work with others (Ross/Schulz 1999).

Pair programming, a style of programming that can be used as a teaching-learning strategy, requires programmers to work together. It requires two individuals to sit next to each other at one computer to continuously collaborate on a design, algorithm, code or test (Williams et al. 2002). In some instances, the roles of the collaborators may be prescribed, with one acting as the 'driver' (the person responsible for typing) and the other acting as the 'navigator' (the person responsible for observing the work of the driver and looking for errors in the work) (Williams et al. 2002: 198). However, even when roles are prescribed, either of the partners can brainstorm spontaneously, and the prescribed roles can be exchanged periodically. Some of the benefits of pair programming include producing higher quality work within a shorter amount of time (Williams/Kessler 2001). Additionally, it has been found that, in using pair programming, students perform better on projects, are more likely to pass the class, and are more self-sufficient (Williams et al. 2002). Given that professional software developers spend about 50% of their time working with one other person and 20% of their time working with two or more individuals (DeMarco/Lister 1987), it would be good practice for students to become accustomed to working closely with others in their programming training. Moreover, this teaching-learning strategy may be well suited for students enrolled in introductory courses, since it creates a space for them to discuss problems and apprehensions that they may have as novice programmers with a peer. It is nonetheless a possibility that conflicts may emerge between partner students. It is worth noting, however, that even such conflicts provide opportunities for students to learn to work with others and to resolve problems that arise as a result of this collaboration.

2.2 Women in programming: selected literature

In South Africa, approximately 31% of degrees in computer science and information technology are awarded to women (Shapiro/Jacobs 1999). However, this figure alone does not provide an accurate account of the extent to which women are under-represented in computer science. We must take into consideration that women are less concentrated in computer science and more concentrated in information technology (Randall/Price/Reichgelt 2003). Thus, the women who enrol in computer science majors or courses at the university level are a minority who have undoubtedly challenged stereotypes about who can and should pursue computer science studies (Singh et al. 2007). It thus becomes that much more critical for the gender minority to receive the necessary support and access to helpful teaching-learning strategies in order to succeed.

It has been overwhelmingly documented across countries (South Africa included) and across institutions that women report having lower confidence (or self-efficacy) in their computer programming abilities compared to men; however, discrepancies between the abilities of men and women have generally not been found (see, for example, Beyer/Rynes/Haller 2004; Beyer et al. 2003; Galpin et al. 2003; Scragg/Smith 1998; Shashaani/Khalili 2001; Varma 2002).

In taking this into consideration, it has been suggested that women as a group need to develop an 'identity of competence'; that is, they need to be confident in working with computers in a male-dominated environment (Irani 2004: 195). This is not altogether an easy endeavour. While it is acknowledged that women have agency and can develop attributes that may help them succeed and in the long run encourage more women to enroll in computer science courses, the onus to change their situation should not rest on their shoulders alone. Educators should also proactively create environments that are women friendly and that introduce teaching-learning strategies that may be more helpful and amenable to women. Hence, our research is concerned with assessing the extent to which pair programming is a helpful teaching-learning strategy for women and with examining reported differences between men and women as they relate to experience and confidence in computer programming.

3 Methodology

Students in a first-year computational mathematics course were given six weeks of assessed programming work, with the option to complete each task in pairs. An optional online multiple-choice questionnaire was made available to the students, and the results of the questionnaire were paired with their marks. Sixty-six students responded to the questionnaire out of a class of approximately 240 students. Eighteen of the respondents were women and 48 were men, which was representative of the gender breakdown of the class (fig. 1). Ethics approval for this project was obtained from the Ethics Committee of the university in which this research was conducted.

Figure 1: Gender breakdown of the sample group, in total numbers

Separate counts of the frequency of each response were taken for the men and women in the sample group, which were then compared to the total count of each response. Owing to the sample size and lack of prior distribution, statistical measures were not considered appropriate.

4 Results

The students were asked what effect their gender had on their programming experience (fig. 2). No women reported a positive effect, and only one man reported a negative effect. Twelve of the 18 women (67%), and 35 of the 48 men (73%) reported no effect of gender on their programming experience.

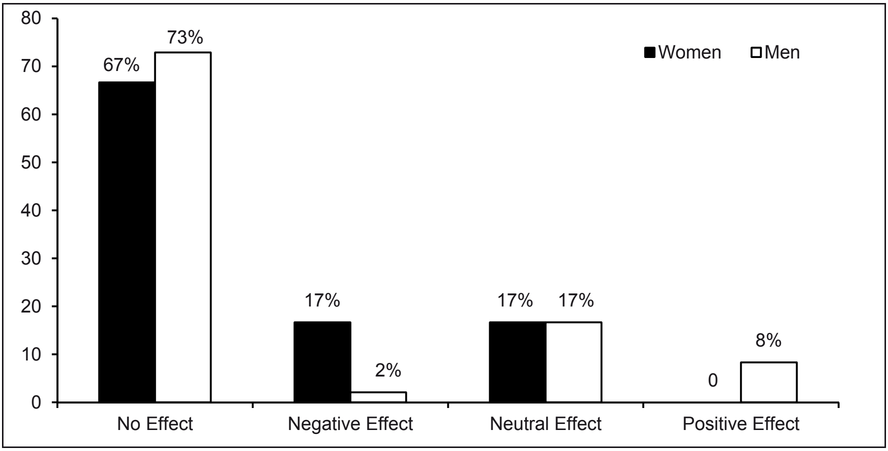

Figure 2: Self-reported effect of gender on programming performance, in %[2]

The students were asked what effect their gender had on their confidence as programmers (fig. 3). Most students (73%) reported no impact (61% of the women and 77% of the men), and 24% of all respondents reported either a slightly negative or slightly positive impact (33% of the women, 21% of the men).

2 The numbers in the figures have been rounded off to the nearest percentage.

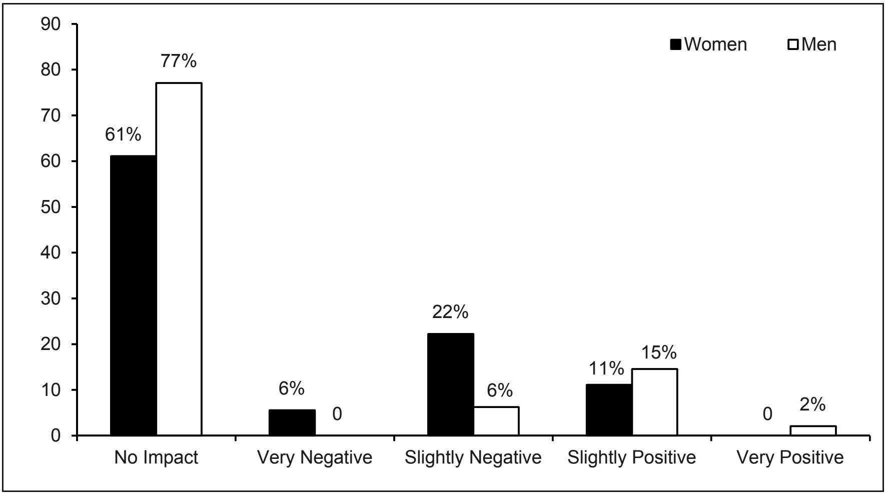

Figure 3: Self-reported effect of gender on programming confidence, in %

The students were asked to rate the programming abilities of those of the same gender, and those of the opposite gender. Numerical values were assigned to the perceived abilities of women and the perceived abilities of men (1 being very low, 5 being very high). The difference between the values assigned to the abilities of women and men was computed, giving a score from -4 (heavily biased towards the abilities of men) to 4 (heavily biased towards the abilities of women), where 0 is a neutral point at which both genders were perceived to have the same ability (fig. 4). No students reported a heavy bias towards the abilities of women. Men were more likely to report a neutral or slightly biased position while women were more likely to report a heavy bias towards the abilities of men. The average score for women was -1,33, while the average score for men was -0.52. The average total score was -0.75.

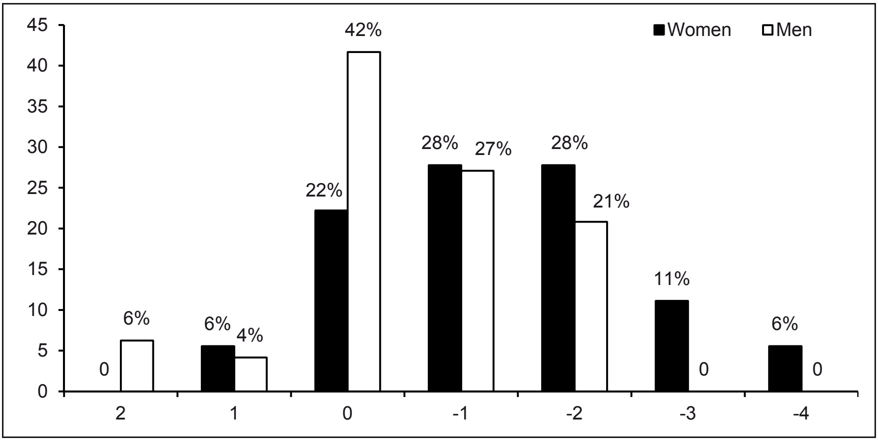

Figure 4: Bias present in views of the programming abilities of each gender, in %. A negative number indicates a bias in favour of men.

Students were asked to identify barriers or difficulties encountered in programming from a predetermined list of possible barriers. Students could select multiple options for this question. A count of each response is shown in figure 5. Interestingly, no students selected gender bias as a barrier or difficulty. Lack of prior experience was, by far, the most commonly reported difficulty, and was reported by 15 out of 18 women (83%) and 32 out of 48 men (67%).

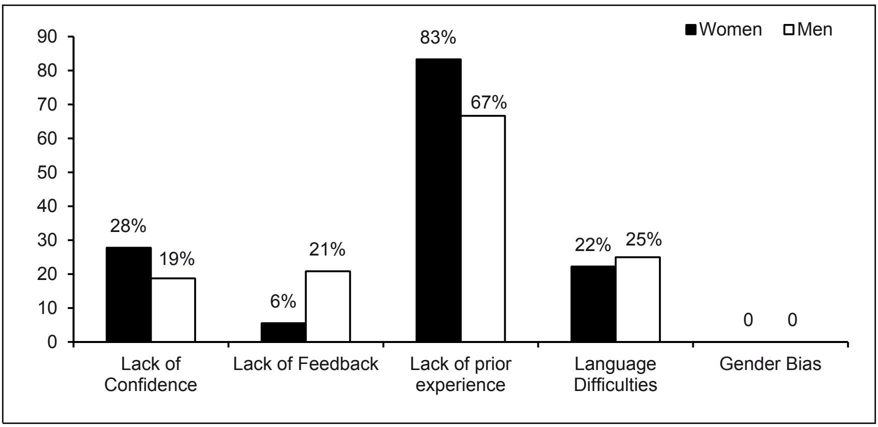

Figure 5: Reported barriers or difficulties encountered in programming, in %, multiple answers

The students were asked whether pair programming was helpful to them, with the option to report having worked alone rather than participating in pair programming. Accordingly, 87% of the students who participated in it found pair programming helpful (fig. 6). More women (89%) than men (75%) found pair programming either entirely, very or slightly helpful. No women and two men reported working alone.

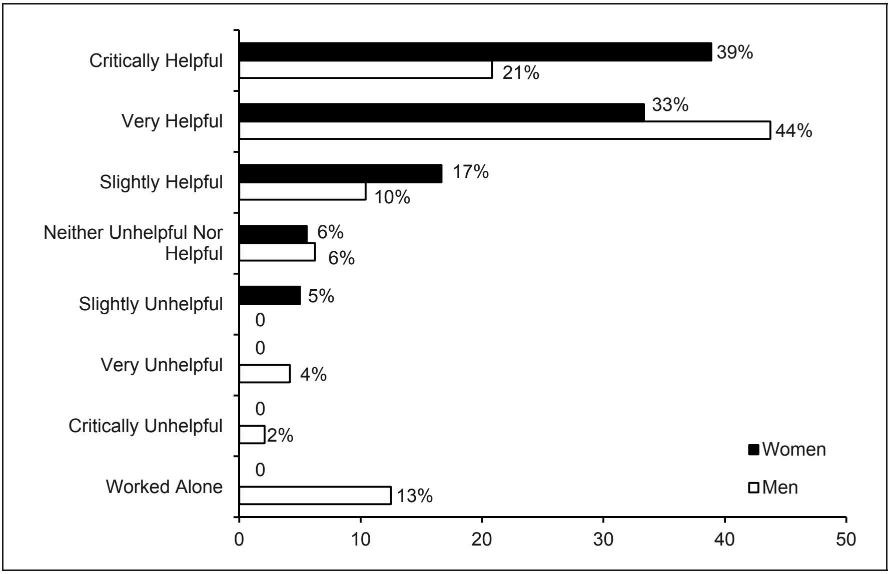

Figure 6: Reported helpfulness of pair programming, in %

Students were asked how the workload was shared between them and their partner if they participated in pair programming (fig. 7). Women exclusively reported either sharing the workload evenly (72%), or their partners doing most of the work (28%). Only one man reported his partner did all the work.

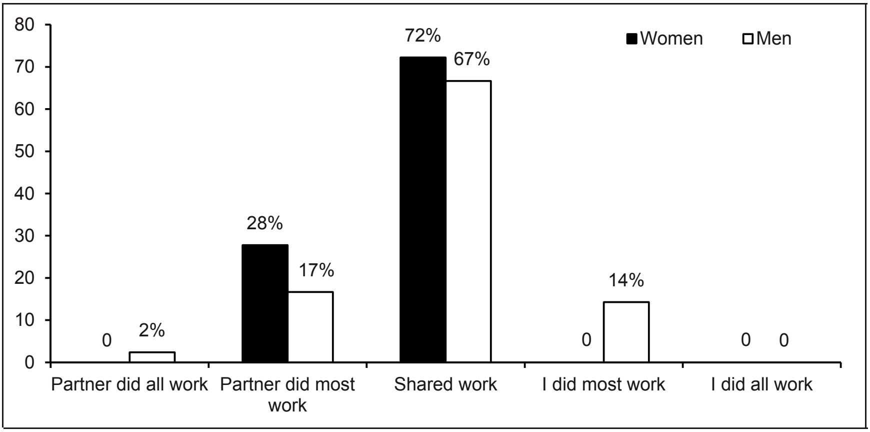

Figure 7: Reported sharing of workload, in %

The marks of the students from a previous programming examination conducted in a previous course were compared to those obtained during the pair programming assessment tasks. To control for different markers, the deviation from the average mark of the class was measured (fig. 8). In the previous course (wherein the students had to programme alone), the women in the sample group scored slightly lower than men and were slightly below the average mark of the class. In the course where pair programming was used, the averages of the men and women in the sample group were the same to two decimal places, with both groups scoring higher than the class average. Women exhibited a 12% increase in marks between the two courses.

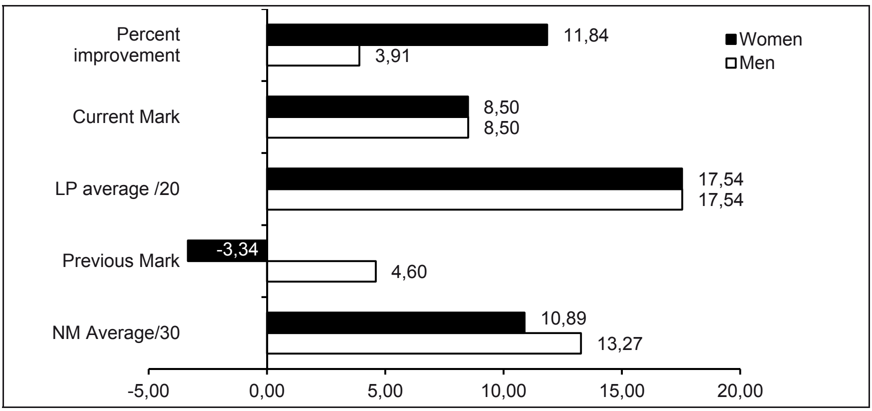

Figure 8: Mark comparison before and after pair programming

In the next section, we examine the discrepancies between the two genders in a first-year computational mathematics course and investigate whether pair programming as a teaching-learning strategy was helpful for women.

5 Discussion

Firstly, the sample, 27% women and 73% men, is representative of the gender ratio of the course. This is consistent with the low participation of women in computing which is an area of concern in South Africa, as only 31.1% of women obtained degrees in computer science and information technology over the period 1991 to 1998 (Shapiro/Jacobs 1999).

We now turn to addressing whether men and women report differences in programming experience and confidence. Although students self-reported that gender had 'no effect or impact on their programming experience or confidence as a programmer' (fig. 2, 3 and 5), upon closer examination of the gender-specific ratings of perceived programming ability, women appear to be less confident in the ability of their fellow women peers. As illustrated in figure 4, women reported more confidence in the perceived programming ability of men (than they did of other women), whereas men reported more confidence in the perceived ability of other men (than they did of women). This indicates that while women generally reported that gender had no impact on their personal confidence as programmers, they nonetheless view women in general as having lower abilities, and men as having higher abilities.

These findings are consistent with the literature on women having low confidence in their computer programming abilities. Despite obtaining equal or higher academic scores than their male counterparts, women consistently report lower confidence than men and underestimate their abilities in computing (see, for example, Zappert/Stansbury 1985; Clarke/Chambers 1989; Sanders/Galpin 1994; Scagg/Smith 1998; Henwood 2000; Shashaani/Khalili 2001; Varma 2002; Beyer et al. 2003; Irani 2004). For instance, research conducted at the same university as this study found that first-year male students in computer science had higher self-efficacy than their female counterparts with respect to their perceived aptitude for computing and academic achievement, although there was no difference in their marks (Sanders/Galpin 1994: 2). In another study that required students to rate their confidence in solving problems with computers, Irani (2004: 196) found that

> women rated themselves an average of a half point less confident than their peers in [a first-year course in computer science] while men rated themselves as an average of six tenths of a point *more* confident than their peers in the course (emphasis in original).

These findings raise critical concerns about women's attrition in computing. The negative affirmation of their capabilities has implications for their participation and persistence in developing a career in computer science and information technology. There are a number of factors that could account for why men and women express more confidence in the perceived programming ability of men (than they do of women). For instance, stereotypes that are associated with 'feminine' and 'masculine' careers (see, for example, Clegg/Trayhurn 2000; Fisher/Margolis/Miller 1997; Wilson 2003) tend to influence people's attitudes toward women in computing and the internalisation of these gender stereotypes by women could lower their self-efficacy and career aspirations.

Similarly, women may find that they are in a minority in a male-dominated culture in which 'gendered self-presentation and communication, rather than objective measures of ability, plays a large role in developing confidence [and perseverance]' (Irani 2004: 195). Bjorkman et al.'s (1998, cited in Singh et al. 2007: 516) theorisation of gender stereotypes as socially situated could account for why women rate the abilities of their fellow women as being lower than those of their male counterparts. Singh et al. (2007: 516) explicate that according to this theory of gender stereotypes, 'typical "feminine" behaviour is incongruent with academic success in computer majors, where implicit social rules work to maintain traditional success in computer majors [and] traditional male-dominated power hierarchies, and where myths of academic success are inconsistent with some female roles'.

As illustrated in figure 5, 83% of women indicated that lack of prior experience of programming was their greatest barrier; this may have had a negative impact on their confidence levels. These findings are consistent with those of Galpin et al. (2003: 17), who reported that university students without prior experience of programming had lower self-efficacy beliefs. This warrants further research, as many under-resourced and rural schools in South Africa have limited computers.

We now examine whether pair programming as a teaching-learning strategy helped students (particularly women) succeed. The majority of students reported that pair programming (or working in pairs in the labs for graded submissions) was helpful for them (fig. 6). It was particularly valuable for women, as 72% of them reported that pair programming was very or critically helpful, and none of the women reported working alone. The ways in which pair programming was beneficial for these students could be interpreted in a number of ways. For instance, pair programming may have created a cooperative and collaborative learning environment. In fact, the majority of the students in this research (especially women) indicated that they had shared the workload evenly with their partners (fig. 7). This environment is conducive to problem-solving activities in which students collaboratively construct scientific knowledge through discussions about their postulations and interpretations of results (Roth 1993; Abboud 1994; Priebe 1997). In this research, the majority of students found pair programming to be helpful.

Werner, Hanks and McDowell (2004: 4) discovered that 88.1% of paired women (compared to 79.5% of women who worked independently) passed an introductory programming course; thus they argue that pair programming increases the likelihood of academic achievement. Similarly, in this research, when we compared participants' marks in a previous course (in which students had to programme alone) with the course under study (wherein pair programming was implemented), we found that women as a group experienced a 12% increase in their marks (fig. 8). Although we cannot claim that pair programming directly caused an increase in their marks, the findings suggest that pair programming may have initiated other contributory factors (e.g. a collaborative learning environment, opportunities to discuss problems with others and a supportive environment) that increased the likelihood of academic achievement.

6 Conclusion

Given that women are under-represented in computer science and that this has social, economic and ethical consequences, this article addressed discrepancies between women and men studying computer science at the university level. Furthermore, we examined whether pair programming as a teaching-learning strategy can help students (particularly women) to succeed. Although students self-reported that gender had no effect or impact on their programming experience or confidence as a programmer, on closer examination of the gender-specific ratings of perceived programming ability, we found that gender does have an impact on how the abilities of women and men are rated. Women reported more confidence in the perceived programming ability of men (than they did of other women), whereas men reported more confidence in the perceived ability of other men (than they did of women). Put differently, despite obtaining equal or higher academic scores than their male counterparts, women rate the abilities of their fellow women as being lower than those of their male counterparts.

7 Lessons to learn for women in science

The female student population in computing and information technology across public higher education around the world is consistently lower than that of male students (Cohoon/Aspray 2006; Gadalla 2001). In South Africa, the widening gender gap in computer science raises critical concerns surrounding the country's socio-democratic transformation efforts and the advancement of science and technology. Several studies report that women's attrition in computing may be attributed to a classroom or workplace environment that is unresponsive to women (Weinberger 2004; West/Ross 2002); the perception that information technology thrives in a competitive atmosphere as opposed to a collaborative one (Werner/Hanks/McDowell 2004); the field's lack of engagement with social discourse (Weinberger 2004; Wilson 2003) and the masculine teaching methods and stereotypes associated with the field (Clegg 1999; Fisher/Margolis/Miller 1997; Wilson 2003; Clegg/Trayhurn 2000).

Pair programming as a teaching-learning strategy grapples with the above-mentioned issues by displacing the masculinised notions of an emotionally detached autonomous self with a feminist approach to science that promotes collaboration (Hanson 2007). Within a 'pair-oriented culture' (Werner/Hanks/McDowell 2004: 6), gendered interactions are no longer located in male-dominated power hierarchies but rather in social relations (Hanson 2007). We argue that pair programming may assist women in their career development in science because it creates an environment that is conducive to the formation of support networks and the establishment of an 'identity of competence' (Irani 2004: 195). Given that professional software developers spend about 70% of their time working with one or more people (DeMarco/Lister 1987), peer programming promotes good practice as 'team-oriented activities in the classroom mode[l] real-world teamwork in industry' (Williams et al. 2002: 199). This kind of inclusive culture encourages the development of the social interaction skills necessary for collaborative activities. Furthermore, these support networks create a space for women to develop feelings of competence in working with computers, which consequently enables them to identify themselves with computer science and to create a sense of belonging in the SET fields.

References

Abboud, May C. (1994): Problem solving and program design. A pedagogical approach. In: Computer Science Education, 5, 1, pp. 63-83.

Ames, Pat C. (2003): Gender and learning style interactions in students' computer attitudes. In: Journal of Educational Computing Research, 28, 3, pp. 231-244.

Beckmann, Johan (2008): Aspects of student equity and higher education in South Africa. In: South African Journal of Higher Education, 22, 4, pp. 773-778.

Beyer, Sylvia/Rynes, Kristina/Haller, Susan (2004): Deterrents to women taking computer science courses. In: Technology and Society Magazine, IEEE., 23, 1, pp. 21-28.

Beyer, Sylvia/Rynes, Kristina/Perrault, Julie/Hay, Kelly/Haller, Susan (2003): Gender differences in computer science students. In: Proceedings of the 34th SIGCSE Technical Symposium on Computer Science Education. New York: ACM, pp. 49-53.

Bjorkman, Christina/Christoff, Ivan/Palm, Fredrik/Vallin, Anna (1998): Exploring the pipeline. Towards an understanding of the male dominated computing culture and its influence on women. In: ACM SIGCSE Bulletin, 30, 2: pp. 64-69.

Clarke, Valerie A./Chambers, Susan M. (1989): Gender-based factors in computing enrollments and achievement. Evidence from a study of tertiary students. In: Journal of Educational Computing Research, 5, 4, pp. 409-429.

Clegg, Sue (1999): Disciplinary discourses: A case study of gender in information technology and design courses. In: Gender and Education, 11, 1, pp. 43-55.

Clegg, Sue/Trayhurn, Deborah (2000): Gender and computing. Not the same old problem. In: British Educational Research Journal, 26, 1, pp. 75-89.

Cohoon, J. McGrath (2002): Women in CS and biology. In: ACM SIGCSE Bulletin, 34, pp. 82-86.

Cohoon, J. McGrath/Aspray, William (2006): A critical review of the research on women's participation in postsecondary computing education. In: Women and Information Technology. Research on Under-representation, pp. 137-179.

DeMarco, Tom/Lister, Tim (1987): Peopleware. New York: Dorset House.

Fisher, Allan/Margolis, Jane/Miller, Faye (1997): Undergraduate women in Computer Science. Experience, motivation and culture. In: ACM SIGCSE Bulletin, 29, pp. 106-110.

Gadalla, Tahany M. (2001): Patterns of women's enrolment in university mathematics, engineering and computer science in Canada, 1972-1995. In: Canadian Journal of Higher Education, 31, 1, pp. 1-34.

Galpin, Vashti/Sanders, Ian/Turner, Heather/Venter, Bernadine (2003): Gender and educational background and their effect on computer self-efficacy and perceptions. Technical Report TR-Wits-CS-2003-0, School of Computer Science, University of the Witwatersrand, Johannesburg.

Hanson, Sandra L. 2007. Success in science among young African American women. The role of minority families. In: Journal of Family Issues, 28, 1, pp. 3-33.

Henwood, Flis (2000): From the woman question in technology to the technology question in feminism. Rethinking gender equality in IT education. In: European Journal of Women's Studies, 7, 2, pp. 209-227.

Ilias, Aristidis/Kordaki, Maria (2006): Undergraduate studies in Computer Science and Engineering. Gender issues. In: ACM SIGCSE Bulletin, 38, 2, pp. 81-85.

Irani, Lilly (2004): Understanding gender and confidence in CS course culture. In ACM SIGCSE Bulletin, 36, pp. 195-199.

Jama, Mpho/Mapesela, Monnapula Liteboho Ednah/Beylefeld, Adri (2008): Theoretical perspectives on factors affecting the academic performance of students. In: South African Journal of Higher Education, 22, 5, pp. 992-1005.

Lau, Wilfred Wing Fat/Yuen, Allan Hoi Kau (2010): Gender differences in learning styles. Nurturing a gender and style sensitive Computer Science classroom. In: Australasian Journal of Educational Technology, 26, 7, pp. 1090-1103.

Priebe, Roger (1997): The effects of cooperative learning in a second-semester university Computer Science course. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Chicago, IL.

Randall, Cindy/Price, Barbara/Reichgelt, Han (2003): Women in computing programs. Does the incredible shrinking pipeline apply to all computing programs? In: ACM SIGCSE Bulletin, 35, 4, pp. 55-59.

Ross, Jonathan/Schulz, Robert (1999): Can computer-aided instruction accommodate all learners equally? In: British Journal of Educational Technology, 30, 1, pp. 5-24.

Roth, Wolff-Michael (1993): Construction sites. Science labs and classrooms. In: The practice of constructivism in science education, pp. 145-170.

Sanders, Ian/Galpin, Vashti (1994): A survey of attitudes to computing at the University of the Witwatersrand. In: Proceedings of the IFIP TC9/WG9. Fifth International Conference on Woman, Work and Computerization: Breaking Old Boundaries – Building New Forms. New York: Elsevier Science, pp. 209-223.

Scragg, Greg/Smith, Jesse (1998): A study of barriers to women in undergraduate computer science. In: ACM SIGCSE Bulletin, 30, pp. 82-86.

Shapiro, Yvonne/Jacobs, Johan (1999): South African Graduate Statistics, 1999: Profiles and recent trends. Labour Market Analysis. Human Sciences Research Council, Pretoria: ERIC.

Shashaani, Lily/Khalili, Ashmad (2001): Gender and computers. Similarities and differences in Iranian college students' attitudes toward computers. In: Computers and Education, 37, 3, pp. 363-375.

Singh, Kusum/Allen, Katherine R./Scheckler, Rebecca/Darlington, Lisa (2007): Women in computer-related majors. A critical synthesis of research and theory from 1994 to 2005. In: Review of Educational Research, 77, 4, pp. 500-533.

Varma, Roli (2002): Women in information technology. A case study of undergraduate students in a minority-serving institution. In: Bulletin of Science, Technology and Society, 22, 4, pp. 274-282.

Weinberger, Catherine J. (2004): Just ask! Why surveyed women did not pursue IT courses or careers. In: Technology and Society Magazine, IEEE, 23, 2, pp. 28-35.

Werner, Linda L./Hanks, Brian/McDowell, Charlie (2004): Pair-programming helps female computer science students. In: Journal on Educational Resources in Computing, 4, 1, pp. 4.

West, Margaret/Ross, Susan (2002): Retaining females in computer science. A new look at a persistent problem. In: Journal of Computing Sciences in Colleges, 17, 5, pp. 1-7.

Williams, Laurie A./Kessler, Robert R. (2001): Experiments with industry's 'pair-programming' model in the Computer Science classroom. In: Computer Science Education, 11, 1, pp. 7-20.

Williams, Laurie/Wiebe, Eric/Yang, Kai/Ferzli, Miriam/Miller, Carol (2002): In support of pair programming in the introductory Computer Science course. In: Computer Science Education, 12, 3, pp. 197-212.

Wilson, Fiona (2003): Can compute, won't compute. Women's participation in the culture of computing. In: New Technology, Work and Employment, 18, 2, pp. 127-142.

Zappert, Laraine T./Stansbury, Kendyll (1985): A comparative analysis of men and eomen in graduate programs in science, engineering and medicine at Stanford University. Working Papers, Institute for Research on Women and Gender, Stanford University.