Communication in Computer Science Classrooms: Understanding Defensive Climates as a Means of Creating Supportive Behaviors

KATHY GARVIN-DOXAS AND LECIA J. BARKER
University of Colorado, Boulder

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All learning environments are characterized by numerous communication and interaction practices, which lend themselves to an overall characterization of the climate as defensive or supportive. A case study of public communication and interaction in a large, research-intensive university's first year computer science courses illustrates a learning environment primarily characterized by elements and behaviors associated with a defensive communication climate. Descriptions of classroom interactions and behaviors illustrate what a defensive communication climate "looks like" in terms of behavior, based on extensive observational research. Interview data demonstrates that defensive communication practices can lead to attrition among women in the major and illustrates ways in which the communication climate that characterizes the major is experienced and interpreted by women in the courses. This data also links defensive communication behaviors with lower confidence among women toward their major – results consistent with previous studies of the causes of attrition among women in other Science, Technology, Engineering, and Mathematics (STEM) disciplines. Classroom experiences and behaviors that reflect a more supportive communication climate will be discussed within the context of practices and interactions that professors can engage in to ensure that their courses lean toward a supportive rather than a defensive environment as a way of making computer science learning environments more inclusive.

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1. INTRODUCTION

Learning environments are characterized by numerous communication and interaction practices that impact the perceptions of those who are choosing a major or determining whether or not to continue in it. These practices help students decide whether or not they belong, and the notion of belonging has been shown to be critical to both the retention and recruitment of women in Science, Technology, Engineering, and Mathematics (STEM) disciplines. This article explores a case study that highlights classroom communication practices that tend toward a learning environment that can be classified as "defensive" rather than "supportive," and on how these practices may create and maintain lower confidence levels among female students. In addition, a predominantly defensive communication climate can lead to missed opportunities in recruiting women to the major, particularly in entry-level courses, and contribute to images of CS as unfriendly or a learning environment that is otherwise unappealing to women by influencing the

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questions that women ask and how they ask them, by diminishing their level of comfort in participating in classroom interactions, and thus from fully benefiting from peer-learning situations like collaborative learning or project teams, and by undermining their confidence as good computer science (CS) students (e.g., Barker and Garvin-Doxas [2004]; Button and Sharrock [1996]; Colbeck et al. [2001]; Fisher et al. [1997]; Gurer and Camp [2002]; Margolis and Fisher [2002]).

This is a case study of introductory courses in a CS major at a large, research-intensive university. Interviews with women and men in those and other more advanced courses are used as a means of making both the successful and the unsuccessful communication practices and interactions found in this particular learning environment more vivid. The methods used are primarily ethnographic in nature and are designed to allow a detailed study of a specific context. The purpose of ethnography is not to make broad generalizations based on large samples of data, but to provide an in-depth picture that others can use to identify similar outcomes, interactions, and behaviors in their own settings. If there are similarities, the research presented here may be able to usefully inform practices in those settings. If not, ethnographic studies can be used to heighten awareness and recognition among researchers and practitioners of some of the issues that may arise, what can happen, how these issues can be identified, and potential outcomes.

The theoretical construct applied to this case study, as well as the discussion of the interaction between communicative practices and the experiences of women in this particular CS program, are intended to be useful and informative to teachers who are satisfied with student learning, retention, and the level of recruitment of women as well as to those who seek to improve them.

2. UNDERSTANDING CLASSROOM COMMUNICATION

Classrooms are social systems at work. Interactions within these systems can take on many characteristics, some of which enhance learning while others inhibit it. At times these characteristics can be very inclusive, and at other times exclusive. Here we explore a descriptive theory of communication that has been employed as an organizing principle for understanding classroom interactions, with a special emphasis on the experiences of women.

The communication climate is a central feature of the learning environment (e.g., Reis [2002]; Trent [2002]). In educational settings, communication functions to create shared meaning through the transmission of information (e.g., lectures, discussions); yet it has much more subtle functions as the vehicle for the development of roles, relationships, norms, and beliefs about a variety of social issues. The communication climate, like all social aspects of learning environments, is negotiated, maintained, and changed through all modes of communication (verbal, non-verbal, and para-verbal), both explicit and implicit; that is, through what we infer from routine, patterned interactions that take place in a particular environment.

Gibb [1961] developed a descriptive theory about communication in large and small groups, based on the coding and analysis of eight years of participant-observation and transcribed tapes of human-relations training sessions in industrial, educational, military, and community settings. This theory can be helpful in describing classroom communication climates, such as whether students feel comfortable asking questions, and what sorts of comments, discussions, and knowledge are valued. Gibb found that the characteristics of the communication behaviors in the settings he participated in as a researcher became habitual and patterned along a continuum from what he labels "defensive" to "supportive". These patterns may be negotiated in higher education, but

most frequently adult students enter formal learning situations with preconceived notions based on years of socialization via participation in traditional classrooms.

One of the greatest frustrations any teacher experiences is the inability to get students to ask questions when they fail to understand a subject. A critical component of the learning environment that is often overlooked, but critical to successfully engaging students in class discussion, is the need to create a communication climate that supports the level and type of learning we desire as an outcome. A learning environment where students feel free to ask questions during public, in-class interactions can only exist in a supportive communication climate where trust is high, ideas can be explored, and mistakes can be made safely. However, as Gibb notes, defensive communication is endemic to traditional learning environments. The traditional relationship between teachers and students in higher education is not one of collaborative exploration, but one where the teacher functions as an expert who transmits knowledge to those who are less (less experienced, less educated, less knowledgeable) than she is. Many of us involved in higher education seek to change this traditional relationship; Gibb's theory provides an organizing principle for understanding the communication and classroom practices shown to alienate women from certain courses and disciplines (e.g., Fisher et. al. [1997]; Hall and Sandler [1982]; Seymour and Hewitt [1997]), and thus provides a framework within which a discipline (like CS) can search for remedies.

It must be noted here that "traditional" learning environments (used in a negative sense) and lecture courses are not identical. Traditional models of transmitting information (like lectures) can be inclusive of all learners, and be characterized by communication that is predominantly supportive. However, it is also true that any learning approach that maintains social and communicative distance between students and teachers is more likely to be characterized by defensive communication behaviors, simply because it requires extra effort to practice supportive ones. Students have a lot of deeply held misconceptions about what appropriate communication behaviors are during lectures, most of which involve remaining silent and waiting for the expert to *tell* them the "right" answer. By the same token, teaching approaches that center around collaboration, peer-learning, and/or other forms of interactive engagement can and often do fail; failures due in large part to defensive rather than supportive communication behaviors.

Six over-lapping categories of communication and interaction behaviors define the supportive to defensive communication climate continuum. These categories and examples of accompanying behaviors are listed in Table I. The categories are not mutually exclusive; they form a continuum with the communication and interaction practices found in supportive climates at one end and those observed in defensive climates at the other. There will always be elements of each type of climate in any social setting, but in most cases the "balance" tends to swing more toward one end than the other. Over time, and through multiple similar interactions, a predominately defensive communication climate constrains social interaction and creates and maintains a culture that presents many challenges to teachers. A learning environment with a more supportive communication climate is desirable because it makes it possible for students to articulate their understanding and participate actively in the public discourse that comprises the majority of class time.

Defensive climates are characterized by a number of communication moves, which may become prevalent and typical, such as the tendency to engage in neutral communication which provides a sense of distance and objectivity to discourse rather than mutual involvement. For example, suppose that in response to a student's

Table I. Communication Climate Continuum [Gibb 1961]

Defensive	Supportive
Evaluative: passes judgment on an idea, question, behavior, person, etc. Characterized by blame or praise and can include a moral judgment of an interactant's motivation. An explicit or implicit questioning of another's standards or performance.	**Descriptive:** avoids passing judgment. Asking questions that are seen as a request for information. A presentation of emotions, events, experiences, etc. without an implicit or explicit request for other interactants to change their behavior, beliefs, and/or thinking.
Controlling: attempts to change or influence another. An explicit or implicit attempt to get interactants to change their beliefs, behavior, and/or opinions. The implicit assumption underlying this type of discourse is that something is wrong with their current behavior, beliefs, and/or ideas.	**Problem-Orientated:** expresses a desire to work together to solve a problem or challenge. Characterized by speech that really allows other interactants to set their own goals and to resolve their own problems. Does not imply blame or lack of worth and it uses inclusive speech – 'we' rather than 'I' or 'you'. Makes it clear that the authority (in this case, the teacher) is not attempting to impose a particular solution.
Strategic: discourse engaged in as part of an effort to manipulate another interactant and/or to make him or her believe that s/he is making her/his own decision. Often characterized by a certain level of ambiguity and/or by a tendency to 'see' the other as a guinea pig.	**Spontaneous:** genuine and natural rather than rehearsed and containing hidden or multiple motives. Perceived by other interactants to be straightforward and free of deception or ulterior motives.
Neutral: fails to express concern for the other interactants. Speech patterns that suggest objectivity, distance, and/or a clinical relationship; distance rather than engagement.	**Empathic:** clearly demonstrates respect for the other interactants. Includes behaviors indicating the speaker has taken on the role or perspective of other interactants, that s/he can identify with the others, and/or share his or her feelings or at least understand them.
Superior: indicates the speaker's higher position relative to other interactants – more intelligent, better educated, more experienced, etc. Tends to give others a sense that they lack worth and/or are in some way inadequate.	**Equal:** demonstrates a belief in and willingness to enter into a truly collaborative relationship with other interactants. Demonstrates trust, mutual respect, and gives value and importance to the others.
Certain: dogmatic and/or otherwise closed to discussion and a mutual exchange of ideas, feelings, etc. Seen in discourse where the speaker demonstrates a focus on winning an argument rather than solving a problem or when s/he treats his or her own ideas as though they are truths that must be defended.	**Provisional:** demonstrates a willingness to and interest in exploring the speaker's own behavior, ideas, thoughts, feelings as well as those of others. Focus on investigating ideas rather than taking sides; problem solving rather than a debate to be won or lost.

statement about experiencing difficulty with a homework problem, the TA says, "This is going to be really easy for you guys. It took me about fifteen minutes and won't take any of you more than an hour." The student works through the problem and is unable to finish it, even after working on it for four hours. The assignment is not due until after the next lecture, so the student attends the lecture session with the expectation that class discussion will help her complete the assignment. At the beginning of the lecture, another student mentions having a similar level of difficulty and seems to be stuck at the same place. The teacher fails to acknowledge that it is a difficult problem and is hard to complete by saying that "it's really not that hard. You should be able to handle this problem easily since it's something you've worked with since your first week in this course." The teacher then begins the lecture. The implication is that students who have been paying attention and doing their work should not experience problems with the assignment. Both the teacher and the TA used neutral communication (they each failed to demonstrate concern for or understanding of the students' experience by responding that the students "shouldn't have trouble with this"). If this communication behavior (which is indicative of a defensive communication climate) becomes routine and persists not only in that course but in subsequent courses, it can impact the students' learning experience. For example, it may lead to a phenomenon such as the "spiral of silence" [Noelle-Neumann 1984], in which students no longer feel free to engage in spontaneous and equal communication. Trust becomes compromised to such a degree that students fail to ask questions or for assistance when they experience difficulty because they do not want to be "the only one" with a problem. Ultimately, this can have a negative impact on their learning.

A further example of how classroom interactions contribute to the overall climate begins with a student crying out, "oh I've got it!" and then presenting a solution to a question posed in class. If another student responds by saying, "what's the big deal, even an English major could figure it out! In Java what you would do is to… That's a more elegant solution." A teacher in such a situation has several options. If he or she fails to interrupt the cycle begun by the second student, it implies agreement with his evaluation of the problem (i.e., that it is so simplistic that "an English major could figure it out"). It also implies agreement with the second student's opinion that using Java is "more elegant." Such a choice sends the message to all the students in the class that the problem was easy, and so the solution developed by the first student was "no big deal." It sends the message that it is acceptable, and even desirable, to evaluate the solutions given by fellow students; and that one solution is "more elegant," and therefore more valuable than another. The typical response to an evaluation like this (not precisely negative, but certainly not positive either) is to defend oneself against the implication of inadequacy (it also fosters a sense of distrust among students). On the other hand, if the teacher were to interrupt the cycle after the comments the second student made by acknowledging both the enthusiasm of the first student as well as the value of his solution (simple is often elegant), she or he can still include and acknowledge the second student's contribution without denigrating the solution provided by the first student.

As these two examples demonstrate, communication practices have a great deal of influence on learning (e.g., by inhibiting students from asking questions); constrain the nature and focus of what can and cannot take place in the classroom (e.g., by limiting debate on the desirable characteristics of a solution); indicate who "belongs" and who does not (e.g., by according status to students who display their knowledge by speaking up in class); and help socialize the participants in the discipline they are studying.   While the theory described here has also been applied elsewhere [Barker et al. 2002; Barker and

Garvin-Doxas 2004], we discuss additional examples as well as analyze the content of interview data collected from women at various phases in their CS careers. Some of the interviewees elected to leave the CS major. Further, interviews conducted with men and women enrolled in first-year courses in a CS major demonstrate the impact that communication we classify as contributing to a defensive climate has on the students' interpretations of their own experiences.

Following a discussion of the methodology employed in the study, as well as our findings, we link the characteristics of CS classrooms to the confidence levels discussed by the women in the interviews, as well as describe ways in which a defensive climate can be shifted to a more supportive one.

3. METHODOLOGY

This case study took place over a three-year period and included document analysis, observations, and informal and formal interviews with participants. Additional results have been reported elsewhere [Barker et al. 2002; Barker and Garvin-Doxas 2004].

Documents associated with CS courses involved in the study, such as course syllabi as well as records (e.g., SAT scores), were collected and subjected to content analysis. Particular attention was paid to the communicative messages in the reviewed documents, as well as to the underlying assumptions embodied in these messages. Interviews with men and women pursuing their coursework in the CS major were also conducted and then analyzed using a similar content-analytic approach. We detail below the procedures for gathering observational data and analyzing it because they are critical to an understanding of the context in which all communication within a setting takes place and because they are perhaps the least understood of the ethnographic methods employed in our study.

Ethnography begins with observations of interactions that take place within a given setting. Observations for this study were conducted by five researchers and the procedure used was to describe in detail the communication and interaction that took place in each class. Observation notes are a richly descriptive and yet highly rigorous form of data. They consist of information about where students sit in the classroom; how many students attend, as well as their gender, race/ethnicity, and in some cases what they wore, and other elements of their self-presentation (e.g., electric-blue hair color); the exact quotes and paraphrases of questions asked by teachers as well as students and the responses; paraphrases and quotes of conversations among students, as well as other public discourse during class time (e.g., chit chat before and after class); notes on lecture and interaction styles (e.g., did the teacher stay standing at the front of the room, or did she or he circulate through the classroom); and descriptions of the content of the course in terms of what types of things teachers emphasize and their relationship to student questions and comments (which often take a direction other than that intended by the teacher).

More than 385 hours of CS classroom observation time were logged, and there were observation reports consisting of thousands of pages (see Table II). Many aspects of observational data lend themselves to quantification (e.g., statistics on how often women sat in the front of the room versus men; 90% of the women sat in front of the room in lecture settings). In an effort to address potential bias among observers, a rotation among the courses in any given semester was established. Ethnography is a methodology designed to probe the lived experiences of people in a setting. As such, there is a tension between being an insider and participant in a setting and being an outsider who is looking in at the setting.

Table II. CS Courses that Were Observed

Semester	Program	# Courses	# Students Women	# Students Men		Hours
Fall 2000	CS	2	8 / 6	25 / 21		46.25
Spring 2001	CS	2	6 / 8	30 / 12		70.34
	Mixed	2	6 / 8	14 / 13		37.5
Fall 2001	CS	2	3 / 6	28 / 17		103.25
	Mixed	2	7 / 6	17 / 9		47.5
Spring 2002	CS	1	14	60		20.83
	Mixed	2	8 / 9	9 /17		59.67
		13	**95**	**272**	**367**	**385.34**

One way that ethnographers ensure that they understand and interpret experiences similarly to those "native" to the setting is by conducting both formal and informal interviews with samples of participants. The time before and after class allowed observers to conduct informal interviews with participants to find out how they (the participants) interpreted interactions that were observed (e.g., students often forgot that the observers were not students in the course, but when reminded, they become curious enough to discuss their insights, opinions, and experiences). In addition to informal interviews, longer, formal interviews were conducted with samples of students that provided a means and time for students to explore and explain in detail how they experienced and interpreted what the researchers observed.

For the purposes of this article, we focus on a subset of the data collected for the project: first-year courses in the CS major. This segment of the study includes approximately 200 hours of observations spread over four courses, as well as observations of hybrid courses (those with a CS listing as well as a multi-media course listing), and some upper-level courses. Formal interviews that lasted between 40 minutes and 2 hours with students from introductory courses were conducted (see Table III). The effects of socialization and the learning environment are cumulative , thus we include interview data from groups of more advanced students as a means of tracking the long-term impact of interactions on students, in terms of their experiences and interpretations and their decisions about remaining in the major (see Table III).

Table III. Interview Groups

	Groups	Women	Men	Total
1	Students in introductory CS classes	35	25	60
2	Students in Collaborative introductory CS course (experimental)	3	13	16
3	Students from CS advising sessions	10	10	20
4	Hybrid Courses	4	6	10
		52	54	106

Document analysis and record reviews are reported on in detail elsewhere [Barker and Garvin-Doxas 2004]. All other data was transcribed and entered electronically into an NVivo database (version 2.0) or into The Ethnograph (both are qualitative data-analysis software programs). This data was then content-analyzed by at least two people, and in most cases by four or more researchers involved in the project. The coding process focuses on identifying patterns within the data. Rather than *a priori* categories, the data is approached first in an iterative process designed to identify themes, patterns, and groupings in the data. Data of similar types is grouped and then assigned descriptive labels. At this point, the coding is very micro-focused, labeling types of patterns in small clusters. In a continuation of the iterative process, these labels are examined for broader patterns and often subsumed under more abstract labels (essentially, moving from micro to more macro-patterns). The nature of the moderately structured interviews leads to the use of question themes (rather than structured interviews, which always ask the same questions using the same wording of each interviewee). Content analysis is not a process that assigns an individual behavior to either the defensive or supportive side of the scale. Rather, since communication climates are the result of cumulative interactions, a series of interactions are weighted more toward one end of the continuum than the other. For example, if a student asks what sounds like a question but is really intended to demonstrate the student's greater experience with C++ programming, we would probably identify it as not being genuine question, but a superior communication (defensive communication). However, we cannot know how to weight and interpret that behavior without also considering the following factors: the teacher's response to the behavior; whether we have seen similar exchanges with the same conversational moves before; whether these behaviors are encouraged in the classroom, but discouraged in the lab or during recitation, and so on. As part of a continuum that describes complex human interactions, the defensive/supportive climate is not something that reduces to a binary classification scheme, but is only interpretable as part of an interaction. (The journey from coding to interpreting the codes and categorizations is both important and interesting, but beyond the scope of this paper.)

While not all of the patterns identified through analysis demonstrate communication behaviors consistent with either a supportive or a defensive communication climate, those in the first-year courses discussed here contribute to a cumulative pattern that leans heavily toward the defensive end of the climate continuum. This is not to say that no positive or supportive communication behaviors occurred or that other types of interactions that could usefully inform teaching practices in computer science were not also present. Rather, public communication behaviors in classrooms lead to a learning environment that can be characterized by behaviors associated with a defensive climate. Interviews with students indicate that not only is this pattern evident in public discourse and behavior, but it is also demonstrated in students' interpretations of their experiences in classrooms. In fact, women interviewed in this project, particularly those in introductory courses, employed very different communication behaviors than did the men.

4. FINDINGS AND DISCUSSION

Both students and teachers in higher education are highly socialized by the time they meet in the classroom, mostly in traditional learning environments characterized by communication behaviors that lead to defensiveness rather than supportiveness. We mention this again because it is important to understand that communication climates are not controlled by either students or teachers, but that it is the teachers (because they are

the authority figures) who can overcome the dominant socialization in ways that lead to more supportive communication practices. In addition, a defensive communication climate is not only problematic for women, but poses barriers to the exploration of new knowledge and the articulation of learning among all students. We say that, *in general,* the relational and communication preferences and practices of women have a tendency toward supportive behaviors rather than defensive ones [Gilligan 1982; Tannen 1999]. As with all stereotypes, there is a danger of over-generalization, even in research-based characterizations of preferred communication behaviors and relational roles among women. We seek to avoid this by grounding our work in the discourse of students.

4.1 Informal Hierarchy and Communication Behaviors

Hierarchy and status, whether equal or unequal, are characteristics of every social situation and relationship [Burke 1966; Watzlawick et al. 1967]. Hierarchy may be formal or informal, or have elements of both. Individuals learn what is valued by a group in subtle ways, primarily through interaction, and present themselves as members by expressing shared values. When people talk in ways that suggest that they excel at the types of skills or possess the knowledge valued in a particular setting, they are making a bid to be treated as higher-status members in that setting. In CS classrooms, status is regularly accorded to those who display technical skill or provide valued information (e.g., by solving a mathematical problem). Instructors involved in this study set the tone on the first day of class when they explain that the introductory course is for everyone; that those who "never programmed, did a bit of programming, and rocket scientists" are all in the same course.

Initially, this statement appears to indicate a learning environment characterized by equality. The message could be that, while there are many levels of experience represented in the course, all are welcome and (perhaps) equal. However, even though all students belong in the course, "rocket scientists" or students who have programming experience, are accorded special status later in the same class period when the instructor enthusiastically explains that they will often compete with themselves and one another for the sheer pleasure of it. In this way the instructor accords a positive judgment to students who are "rocket scientists," and their behavior is situated as something all students should aspire to. The instructor extends our understanding of this category when he gives an example of a student who designed a complex game for his final project by saying, "Did it help his grade [to go beyond the assignment]? No, but he had fun." Further information about who belongs in a setting was given by another instructor who, while demonstrating a possible project for the final component of the course (an extension of the peg-board game), asked "[who in the class] thinks it's a cool one?" When all of the students raised their hands, he said, "Good, because if you don't think it's cool, you're in the wrong class. This is about as good as it gets." In this and similar ways, which were observed and documented on a recurring basis in each of the courses, the status, definitions, and typical behaviors that characterize different types of belonging were established.   In each of these examples, the instructors employed evaluative rather than descriptive communication. These examples were all taken in the first week of introductory courses for CS majors. The alignment of smart with experienced was especially problematic for those with less experience, a group to which most female CS students belonged [Teague and Clarke 1996].

In interviews with students in an introductory course organized around group work and collaboration, student discourse reflects their understanding of the kinds of knowledge valued in the major. Even in this course (where collaboration is meant to

create a more inclusive learning environment and success requires a more supportive climate), students used similar evaluative and judgmental discourse to demonstrate their status in the hierarchy during one-on-one interviews. The excerpt below is representative of the discourse found among other male students in the course. This particular excerpt is taken from a discussion by a male student of his experience working with three other students in an introductory course. The interviewer asked him to describe how the group worked:

> My group … I mean they're cool guys and all but they're not exactly the hardest workers you've met in your life and one of the problems for me coming into this is that I've already had a year of this in high school and this is just kind of to – I didn't want to jump ahead [by placing out of the first semester] because I've been jumping ahead with a lot of stuff in my other courses, like I'm taking Calc 2 instead of Calc 1 cuz I go the four which is the minimum requirement and um so I decided that also since said this was gonna be in C instead of C++ and so because of that I just decided to stick with this course and everything and the problem is is that [pause] one of my other group members … he says that he has taken C++ before, but he doesn't like remember any of it and um so it just kinda puts him at the base level with all the other guys […]
> [I get frustrated] Just cuz of lack of effort from the rest of the guys and so in recitation it's been divided up between me trying to get them caught up … Trying to prep them for the language checks that they'll be doing, but in the last couple meetings we haven't really even worked together. […]
> And you know I haven't been bringing the code and you know I probably should actually you know just to show 'em but I mean in my humble opinion I don't think they're gonna understand it … Which is really bad of me to think, but uh we've had a few meetings after kinda the break off point also and one of them was an organizational kind of meeting where I was like okay we all need to put our heads together again – we're drifting too far apart … Uh you know uh I feel that you know we're not all getting this at the same speed and everything so want to do what I can to help you guys. You guys gotta do what you can to help me. Um and pretty much I try to take the leadership role […]

This type of discourse was documented in observations as well, and is typical of students (both male and female) who see themselves as, and encourage others to perceive them as "experienced," and therefore high-status. His discourse is characterized by superior, evaluative, and neutral communicative behaviors. Rather than simply describing his experiences to the interviewer and/or responding to her questions, he went to great lengths to establish his high status by highlighting his superiority over his teammates (they are less because he has more programming experience). He even goes to considerable lengths to justify and explain why he is in an introductory course even though he is experienced (the "I didn't want to jump ahead because I've been jumping ahead with a lot of stuff in my other course" discussion). This type of account making was common among male students in first-year courses. The recurring patterns found in their accounts are illustrated by this example and serve to establish where these men believe they fit in the hierarchy, as well as to explain the reasons why they were in an introductory course. The motivation behind their need to explain themselves is to establish their status within the informal hierarchy as "experienced" programmers and to justify their presence in an introductory course that "experienced" programmers can place out of by taking a short exam. Their accounts demonstrate robust insider knowledge of what is valued in the program, how status is established, and the vocabulary and values

shared by those who belong. In our example, this student not only established his status in the hierarchy, but he did so using the same type of evaluative and judgmental language seen in the discourse of many instructors at the introductory course level. His need to justify and explain, however, is actually a response to a defensive communication climate (defensive communication behaviors engender a defensive response). This student is both responding to the communication climate he perceives as the norm in the program and is helping to perpetuate it.

   In the interview the student goes on to describe the types of interactions he has with his teammates (the helpful, but superior attitude and communicative behavior he describes was also observed during group interactions). He employs highly evaluative and superior language as a means of demonstrating to his teammates as well as to the interviewer that he belongs. In other words, his discourse reveals that he has internalized what he perceives to be the values of the CS major, which includes setting himself apart from less experienced students in a variety of ways. He claims to take a leadership role and that he should 'teach' the others the code, but that he believes they won't understand it. Later in the interview, he explains that he feels a responsibility to help and teach his less experienced team members, but that he has other responsibilities and must continue to progress in his education, too. By setting himself apart from his fellow team members by virtue of prior programming experience, this student both "buys in" to the informal hierarchy described here and helps to perpetuate it.

4.2 Defensive Communication Behaviors and Isolation

Other students' experiences are less affirming if their membership in the group serves to isolate them from the "in" or "high-status" members of the major.   Women's communication and values focus on their connectedness to those around them and their relationships with others much more than do those of men [Gilligan 1982]. Feeling that one doesn't belong, along with being a minority in the classroom and confronting various gendered stereotypes, results in a loss of confidence, which, as both Margolis and Fisher [2002] and Cohoon [2002] have shown, may precipitate a student's decision to switch majors. The excerpt below, taken from an interview with a woman who was switching from a CS major, illustrates how the values of the group as revealed through communication practices can serve to reinforce a sense of not belonging and isolation. The use of superior communication behaviors, as well as other types of defensive communication practices by others in her courses, caused this woman to leave the CS major:

> And sometimes, like the really smart people that were like really into Computer Science. Because there was definitely like that group. And then there was everybody else who was kind of like you know it was kind of like we weren't actually from the field yet. […] Like you get some people who've had a lot of experience, and it consumes a lot of their life. Before they're taking that class. And there's just a wide variety of levels. And so the people who were really good or whatever, I think a lot of times I don't know because I wasn't in that crowd with them, or because I was a woman they just assumed I didn't know. They would just, they would never like ask me questions. If I would ask them questions, they'd just go on with explanations, acting like I didn't even know a lot of it. You know what I mean.

   Here the student is both aware of and has internalized the values and communicative practices of the "in" group or experienced programmers, but she has done so as an outsider rather than as a student positioning herself to be an "in" member. Unlike the

man in the earlier interview, this woman seems not to have considered the possibility of establishing herself as an "in" member through her public discourse in the classroom. Rather, she uses descriptive communication to portray events and perceptions without really blaming the other interactants in her setting. She engages in some evaluative communication, but does so using indirect criticisms of the attitudes of male students. She appears to have no sense that she could participate in ways that would influence the perceptions of other students or actively define herself as a CS major using the terms recognized and valued in the learning environment. Her discourse is consistent with that of other female interviewees who were in their first year of coursework.

In a rare reversal of communication roles among female students, one female freshman discussed her experiences with collaborative group work and demonstrated what may be a feminine twist on the bid for status most closely associated with male students. (Note that only four female students among the 35 formally interviewed demonstrated this type of defensive communicative behavior; this behavior was not evidenced among women who were informally interviewed either.) The twist is that while she may have, and believes she does have, high status, it has left her with feelings of isolation rather than belonging.

> [Interviewer: you don't do any input together?] Um, not – it just hasn't really worked out that way. I usually do the work. And um … I usually try to catch the boys up but they are kind of behind and they don't understand much of what's going on, so I usually do all the work. […]
>
> For me [it's been] a negative experience because I carry the work of 3 to 4 people. It's just frustrating because I'm always trying to get them involved and like – I always have to like – work to try to get them [pause] I don't know, to do something, which is effort and work for me.
>
> […] To tell you the truth, its not a very good structure for a programming class, it's really not
>
> [Interviewer: why do you think that?] Because I have had other programming classes [and this one isn't organized properly and we're not learning what we need to advance …].
>
> [Interviewer: So I take it you have had quite a bit of background then] Not quite a bit of background, I'm just a freshman, and I'm just trying to skate on by … but …
>
> [Interviewer: So you had programming in high school though?] Yeah, I had one class in high school. So, not as much background as it probably would appear that I have, if you watch from [the outside]
>
> […] I really enjoy working in teams, just … this is not something that you can work in teams to do. Programming is something that you either understand or don't understand and understand a logical process for writing and thinking about algorithms, and you can do it or you can't and as far as working in teams go, you can't develop that skill in a team. It's something that you need to develop on your own.

This discourse is similar to that of the experienced male student in Section 4.1, and yet there are striking differences. Here she moves to establish her position in the hierarchy as an experienced programmer, but when asked about her prior experience, she back-pedals and admits to having only one prior programming course (and that was at the high-school level). When male students who engaged in communication designed to emphasize their experience and status were faced with similar follow-up probes (even in informal contexts), they were very specific about having been self-taught and then listing

the number of programming languages they were familiar with and/or couched their responses in very vague terms (e.g., "oh yeah, I have a *lot* of programming experience").

The male student talked about his sense of responsibility to teach and help his fellow teammates, he also evaluated their abilities as being so much lower than his that they would not be capable of following him if he were to bother to explain. He does a lot of the work out of benevolence. Elsewhere in the interview, the female student quoted above explains the difference between herself and her three male teammates as one that is grounded in a lack of effort on their part. She implies that she was doing all of the work primarily because she has a good work ethic while they do not. She appears to connect her perception of the failure of her team as a result of programming being the type of skill that must be acquired individually rather than through collaboration and group interaction. She engages in defensive communication behaviors (evaluative, superior, and certain), but at the same time assigns blame to the instructor for selecting an inappropriate teaching approach, as well as to behaviors among her teammates that could be addressed (if only they applied themselves). Her explanation for why her teammates are to blame for the failure of the team (because they did not work hard) is different from that of the male student, in that he blames his team's shortcomings on their (his teammates) lack of experience (which demonstrates at least some level of empathy, but also enables him to distinguish himself as experienced). Interestingly, other students in the course felt that the female student quoted above engaged in communication that was extremely pushy and obnoxious (an assessment the regular observer in the classroom and the instructor agreed with). In contrast, during her interview her discourse comes across as less defensive and less self-important than that of the experienced men programmers in the classroom or of the male student quoted in Section 4.1.

The discourse of each of these women suggests that they understand the informal hierarchy found in the CS major as well as the attributes that confer status on members. At the same time, rather than empowering them, they appear to both function as outsiders in the setting. Future research must further explore the possibility that *even when women adopt the "in" norms and words, these communication behaviors are so foreign to them that they may instead use language and communication practices that result in an ambiguous or "wishy-washy" communication style rather than certainty and/or fail to recognize adoption of the vocabulary and norms as an opportunity to influence the social system that forms the boundaries of the learning environment.*

4.3 "Strutting" and Status

Most people prefer not to be at the bottom of a hierarchy, and since in this context experience is equated to high status, students often engaged in behaviors that demonstrate their status and experience or they elected to remain silent to avoid being noticed by their peers. The self-presentations identified here served to reinforce the informal hierarchy, as well as establish individual status within the hierarchy. About half of a group of 55 CS students interviewed by our research partners in this project found these behaviors to be intimidating to women and men alike [Pedersen-Gallegos, et al 2004]. These students believed that a large number of the students in the major fell into the category of "rocket scientists." On the other hand, faculty members and some older students with prior work experience (often not in computing) recognized that the actual number of students who were far ahead of others in the program was relatively small.

In observations of first-year courses, we found that groups of students designated their high-level status by engaging in behavior that could be characterized as "strutting." In all of these cases, the discourse of the strutters may be categorized as superior

communication, rather than behaviors indicating equality; this type of discourse is also inherently strategic. As we all know, some students tend to dominate classroom interactions. This is true in all disciplines, but the use of behaviors aligned with a defensive communication climate among CS majors in this program is noteworthy. In most disciplines, students who are perceived as dominant by faculty and other classmates generally control actual class time via discourse (e.g., they continually respond to questions; ask questions; and engage in other forms of public discussion). They can appear "snooty" to other students or overly enthusiastic, but they actually do speak out more during class. However, "dominating" behavior in this CS program differs in that students who are perceived as dominant often "hold the floor" by talking for extremely brief periods of time. They rarely pose genuine questions or raise their hands eagerly to respond to questions posed by faculty or other students. They do not dominate in terms of floor time during class, but in terms of their influence on classroom discussion. Instructors implicitly acknowledge the status of these students by responding to them, thereby indicating that what they (the dominant students) have to say is important. This in turn reinforces the view that what is most valued in the CS major is experience and that making brief statements or posing pseudo-questions during class time are acceptable ways to demonstrate status. Faculty members' public response to strutting sends the implicit message that such behavior is acceptable. In interviews, however, faculty said they found strutting behaviors to be disruptive, distracting, and rarely focused on the conceptual content being covered.

Students engage in this behavior in two primary ways. One is by correcting a mistake (often, typos on slides) made by the instructor. A challenging question calls attention to a mistake made by the instructor (e.g., "isn't that supposed to be a space rather than a back slash there?"). Although such questions were often trivial and focused on typos and other minor mistakes, rather than on conceptual understanding, instructors in most of the first-year courses rewarded this behavior by acknowledging their mistake and even offering explanations for it (e.g., "that's what I get for writing this lecture at the last minute and not debugging my slides"). While the questioner is publicly affirming his or her own status, other students in the class are exposed to the implicit message that not only is this sort of minute detail-focused question okay, it is even desirable (since the perception is that only high-status members engage in such behavior).

For example, in a first-semester course, one male student, who other students identified as experienced and high-status, consistently sat in isolation (leaving at least one empty chair between himself and people on either side of him) in the back of the room and read a newspaper during every class period. He never looked at the board and rarely at the instructor, never took any notes or bothered to open a book or notebook, and seldom spoke. However, he always asked at least one challenging question per class period, and if the instructor asked him a question during the lecture, the student always had an answer, even though (documented by multiple observers) he never appeared to be paying attention. In recitations and other courses, we overheard classmates characterize students who engage in this kind of behavior as "smart," with experience beyond what was needed in class, and perhaps even in the CS major.

Content analysis of classroom discourse revealed that students also engaged in strutting by asking "pseudo-question"; that is, statements demonstrating their experienced disguised as questions. In these cases, students said things such as, "but in Java wouldn't you…?" or "wouldn't you write a simple function there to take care of that?" The problem being discussed in class may have nothing to do with Java, and functions may not yet have been covered in the course, but by publicly communicating a relationship

between whatever is under discussion to a different programming language or by using insider vocabulary, the student asking the "fake" question implies that he or she possesses status and experience. By allowing this sort of communication, instructors imply that it is appropriate classroom discourse and behavior.

Despite the view among students in the major that those who engaged in "strutting" actually had more knowledge and experience, we found evidence in observations and during formal and informal interviews, that at least half the "strutters" had successfully presented the façade of experience and high-status, without actually possessing either experience or knowledge. During observations of a course at the junior level, a female student was overheard saying to one of the "strutting" males that she was surprised to see him in the course since it was all "old hat" to him. He responded by explaining that his presence in the JAVA course was due to a desire for an easy course. Providing an account explaining why he was in the course despite his vast experience is consistent with other behavior used to establish one's place in the informal hierarchy. The strutting behavior the male student engaged in during lecture as well as recitation reinforced his status based on programming experience. However, it became clear after the first major assignment that he was no better prepared or more experienced with the course content than students who saw themselves as being less so. On the day the assignment was passed back to students during recitation, one of the female students happened to see his grade and expressed her shock that it was so low. He never spoke again in the course while it was under observation, except when asked a direct question by the teacher or TA. In observations of the second-semester, first-year course, we noticed a male student who engaged in such strutting behavior at least once per class period. Midway through the semester an instructor, in responding to a question like the example above, said "yes, you're right about that, would you explain to the rest of the class why that is the case?" The student was unable to do so, and it soon became clear that while he could "talk the talk" he could not "walk the walk."

Research finds that women often have lower confidence in their abilities than men do (e.g., Lundeberg et al [1994]; Sax [1995]). For example, women often feel they are failing or not good at something even when their grades are equal to or higher than those of men. The strutting behaviors described here can serve to reinforce the lower levels of confidence women tend to have in themselves as learners. When strutting behaviors are coupled with the very real difference in the prior experience with programming found between women and men, it can lead to the perception that many if not most of the students in the class have much more experience (and status) than you have. This can in turn contributes to difficulties in both the recruitment and retention of women in CS majors in several ways by creating, maintaining, and/or compounding women's sense of isolation and/or outsider status in a major where they comprise only about a quarter of the students.

5. CONCLUSIONS

We have explored a case study through the lens of Gibb's [1961] theory of defensive communication climates, and illustrated what this communication behavior looks like when observed and heard. We also examined the ways in which students maintain this behavior in their own discourse and its impact on their perception of others. Recurring evidence in STEM and IT research shows that women are more likely than men to lose confidence in their ability to complete the tasks required for earning acceptable grades, even when their performance is equal to that of men (e.g., Beyer et al. [2003]; Brown and Gilligan [1992]; Cottrell [2002]; Farenga and Joyce [1998]; Fisher et al. [1997]).

Consistent with this line of research, when interview responses were coded for students' level of confidence in their abilities, Piedersen-Gallegos, Seymour, and their colleagues [2004], found that men were more likely to say that they had a high level of confidence than women (~70% of the interviewees who expressed confidence in their abilities to succeed in the CS major were male). Women were more likely to express lower levels of confidence, with an almost even distribution among the three categories of confidence (33%), mixed confidence (36%), and lack of confidence (31%). Since the women interviewed also had less prior programming experience (or at least were less likely to consider their previous experience as similar to that of high-status students), confidence levels functioned here as a critical gender difference. In fact, half of this subset of interviewees indicated a link between their confidence in their abilities and an awareness of "experienced", high-status students as intimidating.

One possible explanation for the difference between the discourse of the women and that of the men, as well as the greater degree of influence that defensive communication behaviors had on women's experiences is that the men in the program had integrated these communication behaviors into their own repertoire better than the women did. Women and men in the program did not have statistically significant differences in their graded performance on course material, but the women found their experiences discouraging, while many of their male classmates appear to have successfully adopted the dominant discourse in the setting. By adopting the discourse, norms, and beliefs, the men were able to make themselves at least appear to be insiders, while the women interviewed generally did not. The old adage of perception being reality may apply here. What may begin as only an *appearance* of belonging can and does cause others to treat you as though you *do* belong and *are* an insider. If women are not successfully able to adopt or appropriate the communication styles that are most commonly accepted in the setting, they will remain outsiders. While instructors are not the only participants in the creation and maintenance of any learning environment, they are the people who have the greatest authority to change the culture of the learning environment described here.

The descriptive Communication Climate theory [Gibb 1961] is only one lens through which classroom interaction and interview data can be seen. Re-examination of this case study through other theoretical perspectives, as well as the collection of other case studies, will further our understanding of the complex processes involved in CS learning environments, and may impact the recruitment and retention of women to the field. At the same time it is important to address the impact of defensive communication behaviors by providing strategies that teachers can use. To close, we offer suggestions for teachers that can shift the balance from the defensive end of the continuum to the supportive end:

- Use students' names
- Create opportunities for natural and personal self-disclosure (like small group work or relevant ice-breakers)
- Acknowledge, take seriously, and be open to any sort of question
- Ask students who posture to explain what they mean
- Explain to students that experience is good, but that it should not be equated to intelligence
- Create other opportunities for students to talk about what they are learning and to hear how others articulate their understanding

- Acknowledge the difficulty of mastering the content and conceptual (rather than rote) understanding
- Support diversity
- Support students with as well as without programming experience
- Use more than one instruction method for each concept to support differences in students' experiences and learning needs
- Support students who need to understand how they might apply the knowledge before they can learn the details

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REFERENCES

BARKER, L. J., GARVIN-DOXAS, K. AND JACKSON, M. 2002. Defensive climate in the computer science classroom. In *Proceedings of the 33rd SIGCSE Technical Symposium on Computer Science Education*. ACM Press, New York, 43-47.

BARKER, L. J. AND GARVIN-DOXAS, K. 2004. Making visible the behaviors that influence the learning environment: A qualitative exploration of computer science classrooms. *Computer Science Education 14* (2004), 119-146.

BEYER, S., K., RYNES, J. PERRAULT, K.,HAY, AND S. HALLER 2003. Gender differences in computer science students. In *Proceedings of the 34th SIGCSE Technical Symposium on Computer Science Education* (Reno, NV). ACM Press, New York.

BUTTON, G. AND SHARROCK, W. 1996. Project work: The organization of collaborative design and development in software engineering. *Computer Supported Cooperative Work: The Journal of Collaborative Computing 5* (1996), 369-386.

BURKE, K. 1966. *Language as Symbolic Action*. University of California Press, Los Angeles..

COHOON, J. M. 2002. Recruiting and retaining women in undergraduate computing majors. *ACM SIGCSE Bulletin 34*, 2 (2002).

COLBECK, C.L., CABRERA, A. F., AND TERENZINI, P.T. 2001. Learning professional confidence: Linking teaching practices, students' self-perceptions, and gender. *Review of Higher Education 24,* 2 (2001), 173-191.

FARENGA, S. J., AND JOYCE, B. A. 1998. Science-related attitudes and science course selection: A study of high-ability boys and girls. *Roeper Review 20,* 4 (1998), 247-251.

Fisher, A., J. Margolis, and F. Miller 1997. Undergraduate women in computer science: experience, motivation, and culture, *ACM SIGCSE Technical Symposium, pp. 106-110.*

GIBB, J. R. 1961. Defensive communication. *Journal of Communication* (1961), 11-12, 141-148.

GILLIGAN, C. 1982. *In a Different Voice: Psychological Theory and Women's Development*. Harvard University Press. Cambridge, MA.

GURER, D. AND CAMP, T. 2002. An ACM-W literature review on women in computing, *Inroads: ACM SIGCSE Journal, 34(2), pp. 121-127*

HACKETT, G. 1985. The role of mathematics self-efficacy in the choice of math-related majors of college women and men: A path analysis. *Journal of Counseling Psychology 32* (1985), 47-56.

HALL, R. AND SANDLER, B. 1982. The classroom climate: A chilly one for women? Project on the Status and Education of Women. Association of American Colleges, Washington, DC.

LUNDEBERG, M., FOX, P., AND PUNCOCHAR, J. 1994. Highly confident but wrong: Gender differences and similarities in confidence judgements. *Journal of Educational Psychology 86*, 1 (1994), 114-121.

KLAWE, M. AND LEVESON, N. 1995. Women in computing: Where are we now? *Communications of the ACM 38*, 1 (1995), 29-44.

MARGOLIS, J. AND FISHER, A. 2002. *Unlocking the Clubhouse: Women in Computing*. MIT Press, Cambridge, MA.

MARGOLIS, J. AND FISHER, A. 1997. Geek mythology and attracting undergraduate women to computer science. http://www.cs.cmu.edu/~gendergap/papers/wepan97.html.

MARGOLIS, J., FISHER, A., AND MILLER, F. The anatomy of interest: Women in undergraduate computing. http://www-2.cs.cmu.edu/~gendergap/papers/anatomyWSQ99.html.

NOELLE-NEUMANN, E. 1984. *The Spiral of Silence.* University of Chicago Press, Chicago, IL.

PEDERSEN-GALLEGOS, L., S. LAURSEN, E. SEYMOUR, R. DONOHUE, R. CRANE, T. DEANTONI, R. HAENFLER 2004. Attracting and retaining women in information technology programs: A comparative study of three programmatic approaches. Unpublished report on NSF grant #0090026.

REIS, R. 2002. Tomorrow's professor listserv. Stanford University Learning Laboratory. National Communication Association, TP#400.

SEYMOUR, E., AND HEWITT, N. 1997. *Talking About Leaving: Why Undergraduates Leave the Sciences.* Westview Press, Boulder, CO:

SAX, L. J. 1995. Predicting gender and major-field differences in mathematical self-concept during college. *Journal of Women and Minorities in Science and Engineering 1,* 4 (1995), 291-307.

TANNEN, D. 1999. The display of (gendered) identities in talk at work. In *Reinventing Identities: The Gendered Self in Discourse.* M. Bucholtz et al. eds. Oxford University Press, 221-224.

TEAGUE, J. AND CLARKE, V. 1996. Improving gender equity in computing programmes: Some suggestions for Increasing female participation and retention rates. In *Proceedings of the 1st Australasian Conference on Computer Science Education* (University of Sydney, Australia). ACM Press, New York.

TRENT, J. S. (ed.) 2002. *Included in Communication: Learning Climates that Cultivate Racial and Ethnic Diversity.* American Association for Higher Education and National Communication Association.

WATZLAWICK, P., BEAVIN, J., AND JACKSON, D. 1967. *Pragmatics of Human Communication*, W.W. Norton, New York.

WESTON, T. J. AND BARKER, L. J. 2002. Student computing in higher education: A profile of student use, training, and proficiency. *Journal of Computing in Higher Education 14,*1 (2002), 107-127.