Girls and Science: A Review of Four Themes in the Science Education Literature

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Abstract: Despite valuable syntheses of the field of gender and science education, there has not been a systematic, comprehensive review of the literature on gender and science education in recent years. We examine the literature pertaining to girls' engagement in science and develop four themes (equity and access, curriculum and pedagogy, the nature and culture of science, and identity) that we believe provide a coherent picture of the different kinds of approaches happening currently, while at the same time allowing for discussion of how ideas in the field have progressed and changed over time. We present new questions and approaches for further research that arise when applying insights from these themes to ongoing work in gender and science education. © 2008 Wiley Periodicals, Inc. J Res Sci Teach 45: 971–1002, 2008

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Although by certain measures progress has been made over the last 30 years in narrowing the "gender gap" in science, girls and women continue to be underrepresented and marginalized in fields such as physics, engineering, and technology (American Association of University Women [AAUW, 1998]; Brickhouse, 2001; Fadigan & Hammrich, 2004; Gilbert & Calvert, 2003; Scantlebury & Baker, 2007). Therefore, there have been myriad approaches, evolving and growing over time, where researchers continue to investigate strategies for engaging girls in science. The resulting body of literature on gender and science has been discussed and synthesized in a number of ways. For example, Kahle and Meece (1994) reviewed the research on gender and science education from the 1970s through the early 1990s and identified the individual, sociocultural, family, and educational variables that contribute to gender differences in science achievement and participation, as well as the intervention programs attempting to address these disparities. In addition, several authors have described developing trends in gender and science research, such as Solomon's (1997) "rough categorization of the field" (p. 407), Rennie's (1998) application of Willis's (1996) four perspectives on issues of equity and social justice for mathematics to science education literature, and Kenway and Gough's (1998) analysis of the discourses that have shaped the field. In addition, authors have commented on trends and gaps in the literature in the form of editorials (Baker, 2002; Kahle, 2004; Krockover & Shepardson, 1995; Lederman, 2003). Furthermore, others have traced the historical development of feminist perspectives on science education as the movement has evolved in response to changing societal views toward women (Brickhouse, 2001; Calabrese Barton, 1998; Howes, 2002; Parsons, 1999).

Despite these valuable syntheses of the field, there has not been a systematic, comprehensive review of the literature on gender and science education done in recent years. Thus, the purpose of this review is to examine systematically the studies that have been published in the field of science education in relation to the issue of girls and science in the last 12 years. Scantlebury and Baker (2007) also provided a current account of research on gender and science education. In their study they discussed several important issues in the field, including the history of science education for girls, the situation internationally for girls and women in science, sociocultural issues related to science attitudes and classroom environments, and the impact of

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policies such as high-stakes testing on gender issues. Although the two studies complement one another and there is some overlap in the studies reviewed, our review of the literature takes a significantly different approach from that of Scantlebury and Baker. First, our review focuses specifically on girls and science at the elementary and secondary level, whereas Scantlebury and Baker addressed topics not covered in our review, such as higher education and women in science. Second, Scantlebury and Baker drew from a wide range of sources to select representative studies with which to support their arguments. In contrast, we systematically review everything written in select journals over a particular time period, providing a complete list and summary of each study.[1]

This review is organized into eight major sections. First, we describe the process by which we selected the studies reviewed and introduce the four themes we used to categorize the recent literature. Then we elaborate on our perspective on the meaning of the term "gender." Next, we briefly contextualize the four themes within the multifaceted feminist scholarship that shapes much of the literature reviewed. We then explore in depth each of the four themes and the studies that support them. Finally, from our current, detailed, and systematic look at the studies on this topic, and the empirical evidence and underlying beliefs with which they support their ideas, we identify areas for potential dialogue and future research.

Selection and Analysis of Studies

The field of gender and science is vast, spanning many areas of research (Solomon, 1997). Research in the areas of psychology, sociology, philosophy, and various branches of education has contributed to the discussion on this topic. In fact, a search of the ERIC database for work that includes the words "gender" or "girl(s)" and "science[2]" in the abstract yielded 2463 publications, 591 of which are from peer-reviewed journals, an indication of how much has been written on this topic. Therefore, we chose to confine our search to studies published between 1995 and the present (2006) in a selected set of journals that likely reflect the main trends and findings of the field as a whole. Specifically, we searched five major peer-reviewed science education journals, including *Journal of Research in Science Teaching* (*JRST*), *Science Education* (*SE*), *International Journal of Science Education* (*IJSE*), *Research in Science Education (RISE)*, and *Journal of Science Teacher Education* (*JSTE*), as well as *American Educational Research Journal* (*AERJ*) and *Gender and Education* (*GE*), journals with a focus not limited to the field of science education. We searched the databases ERIC, Education Full Text, and Article First for articles in these seven journals with the words "gender," "girl(s)," or "female(s)" in either the title, abstract, or keywords. For *AERJ* and *GE*, we added the search term "science" (see endnote 2). In addition to searching these three databases, we searched the portions of the table of contents of each of these seven journals that were directly accessible online.

We read all studies on issues related to girls or gender and science that focused on pre-college education and collected additional relevant studies from their lists of references. We did not include articles that focused specifically on the effectiveness of single-sex education, as this is a field unto itself and has been reviewed extensively (AAUW Educational Foundation, 1998; Scantlebury & Baker, 2007). We also excluded studies focused on higher education, unless they focused on science teachers in graduate programs, as well as those focused on women and science, unless they had a clear and direct connection to elementary and secondary education. Furthermore, we excluded studies where issues of girls or gender and science were not a primary focus, even if they made peripheral reference to these topics. Finally, although editorials informed our discussion and analysis of studies reviewed, we did not include them in our official list of studies reviewed.

Based on this methodology, we came up with the 107 studies included in this review. We analyzed these articles for their purpose, participants and setting, methodology, and major findings. Tables 1 through 4, which correspond to Themes 1 through 4, include this analysis for five representative studies from each of the four themes, providing relevant details. These representative studies illustrate the range of different research angles and approaches that constitute each theme. The complete list of summaries of all 107 studies reviewed can be accessed online (see endnote 1). Therefore, when we discuss the articles in the sections that follow, we refer primarily to the major findings and implications of these studies. Moreover, we focus on synthesizing the results of multiple studies to provide a narrative that describes the status of current understandings and research agendas. Also, it is important to note that the studies reviewed span the globe, which adds complexity to the synthesis of findings across this diversity of geography and culture. Although we acknowledge this by referring to the geographic location of studies in both the tables and text of this review, Scantlebury and

Table 1
Representative studies girls and science review theme 1- equity and access

Author and year	Purpose of study	Participants and Setting	Methods/Methodology	Major Findings
Catsambis (1995)	To examine gender differences in science attitudes and achievement of a large, multi-ethnic sample of students	24,500 Grade 8 students from 1,052 US schools, nationally representative sample	Analysis of survey data from NELS (National Educational Longitudinal Study) of 1988 by gender and race/ethnicity	Girls of all ethnic groups had more negative science attitudes and fewer science experiences than boys but achieved at equal or higher levels
Jovanovic & Steinbach King (1998)	To examine whether girls and boys participated equally in hands-on science activities in performance-based classrooms	165 Grades 5-8 students in 6 US classrooms, 76% Euro-American, 5% African American, 4% Latino(a), 3% Asian American, 12% other	Classroom observations using checklist protocol over school year, closed-response survey questionnaires	Active-leading behaviors were equal for boys and girls and led to better science attitudes, but boys were more likely to manipulate equipment than girls; girls' perceptions of their ability decreased over the school year
Bailey, Scantlebury, & Johnson (1999)	To examine how collaboration with cooperating teachers impacts preservice science teachers' equitable practices	59 student teachers from a US university	Comparative classroom observations using quantitative coding tool and qualitative notes over 3 years, interviews	Student teachers regularly observed by cooperating teachers demonstrated more equitable interactions with students than those observed only by university supervisors
Fadigan & Hammrich (2004)	To describe the educational and career paths of young women who participated in an informal science education program during high school	152 young women 4-9 years after participating in US program during Grades 9 and/or 10, 89.47% minorities, all from urban, low-income, single-parent families and interested in science	Longitudinal, descriptive case study using program documents, self-administered survey questionnaires, and semi-structured interviews	Most participants enrolled in college, almost half pursued science-related careers, and most described features of the program as influential in their future educational and career decisions
Miller, Blessing, & Schwartz (2006)	To examine gender differences in students' views and perceptions about science classes and majors, science, and scientists	79 Grades 10-12 students in small southern US city, 75% Euro-American, 25% minority (mostly African American), most college-bound	Closed- and open-response survey questionnaires	Girls liked biology, chose people-oriented majors, and chose science majors to help people or animals or to prepare them for a health profession; girls often perceived science as uninteresting, passionless, or leading to an unattractive lifestyle

Baker's (2007) thorough and useful discussion of the situation for girls and women in science in different countries helps to contextualize the findings discussed herein.

We organized the studies into the following four themes or approaches to the issue of engaging girls in science:

1. A focus on equity and access.
2. A focus on curriculum and pedagogy.
3. A focus on reconstructing the nature and culture of science.
4. A focus on identity.

These themes represent four different approaches in the literature that address the question of how we can more meaningfully and effectively engage girls in science. The first theme describes gender disparities and inequities in the classroom and emphasizes that if we want to engage girls in science we need to provide them with equitable science opportunities. The second theme emphasizes a need to change curriculum and pedagogy in the science classroom so that it includes the experiences, learning styles, and interests of girls. The third theme emphasizes a need to reconstruct how science is portrayed, viewed, and defined, both in school and society. Finally, the fourth theme emphasizes a need to support girls in incorporating science as a component of their diverse identities as people.

Although there are many ways we could have categorized the recent literature on girls and science, we chose these four themes because we believe they provide a coherent picture of the different kinds of approaches happening currently, while allowing for some discussion of how ideas in the field have progressed and changed over time (which we discuss in the next paragraph). Furthermore, ideas about equity, curriculum and pedagogy, the nature and culture of science, and identity are also major themes that currently run through science education research generally, allowing us to examine how the literature on gender may interact with the larger body of work happening in science education. Although this categorization of the literature into these four themes provides a useful framework, it is important to note that the themes do overlap in many ways and are not mutually exclusive. Moreover, certain studies span multiple themes. Also, what we attempt to show in this review is that, although these four themes represent four different approaches to the question of engaging girls in science, there is much to be learned from potential partnerships and intersections between these four themes.

Although studies that relate to each of the four themes appear throughout the time period of our review, from 1995 to 2006, their emergence as trends in the field of gender and science education research is roughly chronological. In addition to the necessity of restricting our search criteria to allow for in-depth analysis of studies, we chose to begin this review with studies published in 1995, because, by this time-point, all four themes are represented in the literature. In the following paragraphs, we highlight briefly changes that have happened in the field of gender and science education over time and how our four themes relate to those changes. In particular, we highlight two broad shifts in the research on gender and science education since the 1960s, when the women's movement prompted an acknowledgment of prevalent gender inequities and disparities in relation to science (Calabrese Barton, 1998).

The first broad shift in research in gender and science education was from the perspective that girls needed to "be changed," to the perspective that school science needed to change to engage girls (Scantlebury & Baker, 2007). This shift was marked by a transition from a prevalence of studies related to Theme 1, focusing on documenting gender differences and trying to eliminate sexism and bias in existing science classrooms, to studies related to Theme 2, emphasizing creating new curriculum and pedagogy that address the "needs, learning styles, and values" of girls and boys while being accompanied by the use of more qualitative research methodologies (Rennie, 1998, p. 960). Several authors have noted the work that occurred in the 1980s to create and promote what came to be known as "gender-inclusive" science curricula (Gianello, 1988; Harding & Parker, 1995; Hildebrand, 1989; Rennie, 1998). Despite this research, Kahle and Meece (1994) noted that most of the science education studies up through the early 1990s that they reviewed continued to maintain a "deficit model," leaving the onus of the problem with girls rather than with schools. Similarly, Baker (2002) argued that, although studies in the late 1980s took on issues of equity and access for girls in science, the "focus on fixing school science" (p. 660) to make it more gender-inclusive did not become part of the mainstream science education discourse and literature until the 1990s. In her *JRST* editorial describing the trends in publication on gender equity issues, Baker also described the 1990s as a ‘‘breakthrough in terms of the official recognition that gender is a crucial issue in science education’’ (p. 661). Thus, according to Baker, this first shift in the field of gender and science education, from the promotion of equity and access to the revamping of curriculum and pedagogy, although addressed by some researchers in the 1980s, came into more prominent, mainstream focus during the early 1990s.

The second relevant shift in the field of gender and science education research, also noted by Baker to have occurred during the 1990s, is a move toward more critical, feminist, and ‘‘emancipatory’’ theoretical frameworks (p. 661). Research from these perspectives tended to challenge more deeply science inside and outside of schools and to look at intersections between gender and other factors such as ethnicity and class. However, by 1995, researchers were still not prioritizing these concerns, which led Krockover and Shepardson (1995) to urge researchers to address the ‘‘missing links in gender equity research’’ by studying the complex interactions of gender with race, ethnicity, class, and sociocultural identity across varying contexts (p. 223). It is primarily studies in our third theme in the current literature, related to the nature and culture of science, as well as our fourth theme, related to identity, that take up these shifting theoretical frameworks and concerns.

To assess more precisely the timing of this second shift, we did a preliminary search of the gender and science literature in the aforementioned seven journals between 1990 and 1994. We found that, before 1995, although a significant amount of research had been done related to equity and access (Theme 1) and curriculum and pedagogy (Theme 2), only two studies addressed the nature and culture of science (Theme 3), and there were no studies that addressed issues of identity (Theme 4). These themes, in line with the shifting theoretical frameworks described by Baker, do not begin to appear in the literature until 1995. Therefore, by beginning our review in 1995, we are able to provide a picture of both prior and newly emerging trends in the literature and how their evolution has progressed until the present time.[3]

Gender and Sex

The word ‘‘gender’’ is often used synonymously with the word ‘‘sex,’’ although they have different meanings (Rennie, 1998). Therefore, in this section we define these terms and make clear how we use them in this study. Typically, although not exclusively (Gilbert, 2001),[4] *sex* refers to the biological features that make one a female or a male. In contrast, *gender* often refers to ‘‘a set of traits, behaviors, and expectations that cultures train girls and boys to practice and hold,’’ usually described as those that are ‘‘feminine’’ and those that are ‘‘masculine’’ (Howes, 2002, p. 25). Similarly, Rennie (1998) described gender as referring to ‘‘the cultural meaning we construct around what it means to be male or female’’ (p. 952). The idea that gender is a ‘‘social construction’’ (Howes, 2002; Scantlebury & Baker, 2007; Thorne, 1993) means that it is not determined and fixed by biology and therefore can change. In line with these ideas, Gilbert and Calvert (2003) highlighted the fact that ‘‘femininity,’’ a culturally constructed aspect of gender, does not reside exclusively within females, and vice versa for masculinity and males, although our society typically associates particular gender attributes with one sex or the other. Defining gender exclusively as a function of one’s sex in this way creates limiting views of what is ‘‘normal’’ and therefore marginalizes individuals who deviate from those norms. For example, authors have highlighted how simplistic and dichotomizing understandings of the relationship between sex and gender perpetuate heteronormativity (Letts, 2001; Scantlebury & Baker, 2007).

This review addresses issues of sex as well as issues of gender. The historically inequitable situation for females in relation to science and science education, a situation based on sex difference, is the starting point for this review. We acknowledge, therefore, that discrimination and marginalization based on sex is a reality that needs to be addressed, which is why we frame this review around the situation for girls, who as a sex have been marginalized from science. However, because we take the view described earlier that gender is socially and culturally constructed and not necessarily linked to one’s sex, we acknowledge that *sex* inequities are largely rooted in socially and culturally constructed ideas about *gender*. Our review synthesizes a broad range of studies that approach issues of sex and gender in different ways, from those that document sex differences, to those that use ideas about gender to explain and address these differences, to those that pay explicit attention to and challenge the relationship between sex and gender.

The bulk of the studies we review did not pay explicit attention to the distinction between sex and gender and often used the word gender when talking about sex, a pattern noted by Rennie (1998). In the tables included in this review, we adopt the terminology used by the authors of each study, who mostly but not exclusively frame their work as addressing issues of gender. However, in our discussion of the literature and its implications, we attempt to use the word sex to refer to comparisons between males and females, and gender to refer to issues related to the cultural meanings frequently associated with sex.

Feminist Movements and Science Education

As noted previously, much of the literature on gender in science education is influenced and shaped by feminist ideas. However, feminism is a broad term that has multiple, dynamic meanings in science education. On a very general level, as stated by Brickhouse (2001), ''Feminisms are unique in their consistent focus on gender and the political commitment to changing those structures that have historically favored masculinities over femininities'' (p. 291).

However, beyond this general common characterization, the term feminism is used and applied in many different ways in academic literature, representing a broad range of theoretical perspectives (Brickhouse, 1998). In fact, various prefixes have been added to qualify the term, such as liberal, difference, socialist, poststructural, postmodern, critical, postcritical, and radical feminisms (Brickhouse, 1998; Howes, 2002; Parsons, 1999).

Some authors have also traced the historical development of feminist perspectives on science education over time. For example, Parsons (1999) applied Kristeva's three ''generations'' of feminism to science education, and Calabrese Barton (1998) described three ''waves'' of feminism in science education. In many ways, these ''waves'' parallel the four themes reviewed in this study. For example, the first ''wave'' of feminism, often called ''liberal'' feminism (Calabrese Barton, 1998, p. 3), stemmed from the women's movement of the 1960s and overlaps with studies in Theme 1 that call for equal access to science. In relation to science, such liberal feminists focused on equalizing access for males and females to the study and practice of science and did not focus on challenging the practice of science itself or its underlying epistemology (Brickhouse, 1998, 2001). Subsequent varieties of feminism that looked beyond an even playing field and began to advocate for the need to change inequitable societal structures underlie many studies in Theme 2, which focuses on changing curriculum and pedagogy, as well as Theme 3, which focuses on changing the nature and culture of science. For instance, ''second wave'' feminist analyses that attempt to acknowledge and incorporate different ''ways of knowing'' into science (Calabrese Barton, 1998, p. 8), sometimes referred to as ''difference'' feminism (Howes, 2002, p. 24), are the focus of many studies in Theme 2 that aim to make girls' learning, interests, and experiences central in science curriculum and pedagogy. Furthermore, ''third wave'' feminist ideas that place more emphasis on intersections between race, class, and gender, and take a more political, activist stance toward changing science education (Calabrese Barton, 1998), are appropriated by studies in Theme 3 as well as those in Theme 4, which look beyond gender to conceptualize identity more broadly. Moreover, ''poststructural'' feminist ideas, which raise complex epistemological questions about scientific knowledge and objectivity and also challenge binary oppositions that oversimplify understandings of gender, are central to many studies in both Themes 3 and 4 (for a more elaborate discussion of poststructural feminism in science see Brickhouse [1998]).

Although not all authors in the studies reviewed here explicitly took on feminist perspectives, the various feminist ideas just outlined are implicit in much of the literature. Therefore, in our elaboration on each of the four themes in this study, when relevant, we highlight the kinds of feminist thinking that underlie particular groups of studies. In addition, many authors explicitly used the terms ''feminism'' or ''feminist'' with different theoretical ideas in mind. Therefore, we also highlight areas of complexity and contradiction, where authors interpreted and applied feminist theories in different ways.

Theme 1: A Focus on Equity and Access

The studies included in this theme document the inequities that girls face in science and work toward eliminating them through increasing girls' access to equitable science experiences (Table 1). They describe situations where girls and boys are treated differently in the science classroom and where textbooks are gender biased. As a consequence, girls and boys have different attitudes toward and levels of participation in science. These patterns have contributed to women's persistent underrepresentation in the science work force.

Several studies have therefore attempted to address this unequal situation through teacher education and by providing girls with more access to science experiences and female role models through extracurricular programs.

The research in this theme stems predominantly from much work that has been done on gender in science since the women's movement of the 1960s, when liberal feminists were attempting to uncover and address a history of gender discrimination in relation to the teaching and practice of science (Brickhouse, 2001; Calabrese Barton, 1997, 1998; Howes, 2002). In this vein, a body of research accumulated through the mid-1990s that documented continued inequities in the classroom as well as resulting sex differences in science attitudes and achievement (for reviews, see AAUW, 1992; Guzzetti & Williams, 1996; Kahle & Meece, 1994; Steinkamp & Maehr, 1984; Weinburgh, 1995a). In what follows we first describe the research since 1995 that continues to document the inequities and disparities described earlier. We then describe the research that has analyzed the effectiveness of potential solutions, including teacher education and extracurricular programs.

Documenting Inequities

Although studies examining issues of gender bias and discrimination as they relate to the teachers and texts in the classroom were common in the earlier literature (Kahle & Meece, 1994), only eight studies in the science education literature since 1995 have examined these issues. They provide evidence of continued sexism and inequality but to varying extents. For example, Elgar (2004) and Whiteley (1996) found persistent male-biased and gender-stereotyped patterns in science textbooks in Brunei and Jamaica, respectively. In addition, consistent with prior literature (Kahle and Meece, 1994), studies from multiple countries examined biases in classroom interactions (She, 1999) and continued to find evidence that girls manipulate laboratory equipment less frequently than boys, even in classrooms with experienced teachers concerned with gender equity (Guzzetti & Williams, 1996; Jovanovic & Steinbach King, 1998). However, there are also instances of more equitable situations. For example, across a large group of students from grades K–12 in Hawaii, Greenfield (1997) found that girls engaged with science equipment as much as boys, although girls received less attention from teachers than boys. Greenfield hypothesized that the more active science participation of girls may be due to the fact that students in this district of Hawaii receive active, hands-on science experiences at the elementary level and are often strongly motivated to do well in science for college admission. In another instance, Jovanovic and Steinbach King (1998) found that girls were as likely as boys to take on leadership roles in hands-on activities, although they actively manipulated equipment less frequently than boys.

While the aforementioned findings are based on researchers' classroom observations, other studies investigated students' own perceptions of their learning environments (Dhindsa, 2005; Guzzetti & Williams, 1996; Huffman, Lawrenz, & Minger, 1997). For instance, although Dhindsa (2005) found that students in Brunei generally perceived their classroom environments to be gender equitable, Guzzetti and Williams (1996) noted U.S. students' perceptions of gender inequity. More specifically, Guzzetti and Williams found that physics students in an affluent school in the southwestern U.S., girls in particular, were very cognizant of the inequitable classroom situation and of gender bias in their textbooks; the authors therefore argued that students themselves need to be more directly involved in creating a classroom culture that is gender equitable.

The range of results in research on classroom interactions, from the perspectives of researchers and students, indicates variation across different geographical and classroom contexts. The studies in this section suggest that cultural factors, history of educational experiences, teacher awareness, and student involvement in addressing gender issues may all influence the equity of classroom interactions; however, the valuable question of what specific factors contribute to an equitable environment remains unresolved.

Documenting Disparities

In contrast to the relatively limited pursuit of investigations into inequitable classroom situations in the current literature, many studies since 1995 have documented sex and gender differences in students' science achievement, attitudes, and participation, mostly using quantitative data from survey questionnaires given to large groups of students. These studies reveal a mixture of promising and discouraging findings in terms of the situation for girls and science, which we discuss further in reference to achievement, attitudes, and participation. These studies also reveal certain persistent trends, while the situation for other phenomena is less clear. Therefore, throughout the following discussion, we highlight how differences in context and methodology (namely the use of qualitative versus quantitative methods or whether data are disaggregated by ethnicity and other factors) influence variations in findings and conclusions across studies.

In terms of achievement, although multiple studies have shown that girls achieve at an equal or higher level than boys (Catsambis, 1995; Greenfield, 1996; McEwen, Knipe, & Gallagher, 1997; Zohar & Sela, 2003), others across several countries documented sex differences favoring males in physics questions (Bell, 2001; Burkam, Lee, & Smerdon, 1997; Lee & Burkam, 1996; Preece, Skinner, & Riall, 1999), quantitative questions (Åberg-Bengtsson, 1999), and higher-level questions (Preece et al., 1999). Although some of these studies simply documented achievement differences, others attempted to elucidate the factors that contribute to these differences (Burkam et al., 1997; Lee & Burkam, 1996; Mattern & Schau, 2002; Muller, Stage, & Kinzie, 2001; Sencar & Eryilmaz, 2004). For example, Sencar and Eryilmaz (2004) showed that a difference in Turkish girls' and boys' misconceptions about electric circuits disappears when students' interests and prior experiences related to the topic are controlled for.

In terms of disparities in science attitudes, a widely studied topic, several studies, encompassing thousands of students over a range of ages in different countries, showed that girls' overall attitudes toward science are either less positive than boys' or decline more significantly with age (Catsambis, 1995; Greenfield, 1997; Jones, Porter, & Young, 1996; Jones & Young, 1995; Lee & Burkam, 1996; Reid, 2003; Weinburgh, 1995a). Along these lines, others have shown that girls often perceive science as difficult, uninteresting, or leading to an unattractive lifestyle (Huffman et al., 1997; Jones, Howe, & Rua, 2000; Miller, Blessing, & Schwartz, 2006). Also, studies have found that even where girls enjoy and are involved in science class, girls' perceptions of their competence in the subject are lower than boys' (Andre, Whigham, Hendrickson, & Chambers, 1999; Jovanovic & Steinbach King, 1998). The fact that parents have higher expectations of boys and perceive science to be more important for boys than for girls may contribute to this disparity (Andre et al., 1999). Finally, other studies found that both girls *and* boys have negative attitudes and minimal interest in science, which points to a need to focus on improving science education for all students (Dawson, 2000; Stark, 1999).

In contrast to these repeated findings of overall negative attitudes, however, a few studies indicated more positive findings (Baker & Leary, 1995; Harwell, 2000; Woodward & Woodward, 1998). For example, two studies conducted interviews with elementary and middle school girls to reveal that they are positive and confident about science and have strong opinions about women doing science as well as about the kinds of activities they would like to see happening in science classrooms (Baker & Leary, 1995; Harwell, 2000). As a possible explanation for this deviation from the predominant patterns identified in the literature, Baker and Leary (1995) argued that the quantitative methods used by other studies often do not accurately reflect girls' opinions, because they are very decontextualized, which is why they choose to use qualitative methods to provide a deeper and more thorough understanding of girls' experiences.

Like the aforementioned studies that described students' attitudes towards science, studies that investigated the extent of girls' participation in science also had mixed results, and context seems to play a role in the variation in findings across studies. For example, girls in the U.S. and The Netherlands, across ages, choose fewer science courses than boys (Farenga & Joyce, 1999; van Langen, Rekers-Mombarg, & Dekkers, 2006); in Northern Ireland, although boys took more science A-level courses than girls in 1995, the number of these courses taken increased over time for girls and decreased for boys (McEwen et al., 1997). Furthermore, girls are underrepresented in Israeli advanced placement physics classes (Zohar & Sela, 2003) and U.S. upper level physics, math, and chemistry classes (Jones et al., 1996). However, Greenfield (1996) found that, in Hawaii, girls enroll in advanced math and science courses more frequently than boys. Her context seems to be one where teaching strategies and college entrance requirements may improve girls' science participation, although further examination of this hypothesis is needed. Other studies identified influences on girls' choices of science courses and career plans, including factors such as peer and parental support, previous science experiences, teachers, course selection processes, and guidance counselors' career advice (Jacobs, Finken, Griffin, & Wright, 1998; Panizzon & Levins, 1997; Roger & Duffield, 2000; van Langen et al., 2006).

In addition to context, the ethnicity and ability level of students play a role in the patterns that emerge related to achievement, attitudes, and participation (Catsambis, 1995; Chambers & Schreiber, 2004; Greenfield, 1996; Mattern & Schau, 2002; Muller et al., 2001; Weinburgh, 1995a). For example, Greenfield

(1996) found that students' attitudes and achievement vary more by ethnicity than by sex. In addition, despite the overall trend that boys' science attitudes are more positive than girls', Weinburgh's meta-analysis (1995a) shows that, among high-performing students, girls have a more positive attitude toward science. Also, Catsambis (1995) found that, for white students only, girls are more likely than boys to be enrolled in high-ability classes. Only a small number of studies have explicitly acknowledged the need to analyze data for interactions between gender and other variables, and more research on this would provide a better picture of the situation for different populations of girls.

Despite this need for a more nuanced analysis of variations within groups of girls and boys and across contexts, there are several findings pertaining to disparities observed in multiple studies that seem to persist in a variety of contexts and at multiple ages: First, girls prefer and choose to participate more frequently in the biological sciences, whereas boys prefer and choose the physical sciences or have a broader range of preferences (Adamson, Foster, Roark, & Reed, 1998; Dawson, 2000; Farenga & Joyce, 1999; Greenfield, 1995a; Jones, Howe et al., 2000; Miller et al., 2006; Stark, 1999; Woodward & Woodward, 1998). Second, multiple studies showed that students from young ages (although boys more strongly than girls) hold stereotypical views about physical science topics and activities being ''for boys'' and biological ones being ''for girls'' (Andre et al., 1999; Greenfield, 1996, 1997; Jones, Howe et al., 2000). Third, studies consistently found that girls have less exposure to extracurricular science experiences than boys, particularly in the physical sciences (Catsambis, 1995; Greenfield, 1996; Greenfield, 1997; Jones, Howe et al., 2000; see Christidou [2006] in Theme 2 for a recent exception to this pattern). Fourth, as mentioned earlier, girls' overall interest in science often declines after elementary school. The combination of these trends points to a need to address issues of gender-equitable access to science at young ages, as many authors have noted (Adamson et al., 1998; Andre et al., 1999; Catsambis, 1995; Farenga & Joyce, 1999; Greenfield, 1995a, 1997; Reid, 2003; Woodward & Woodward, 1998).

In addition to this suggestion of early intervention, the findings from this group of studies have other implications for the science classroom. First, some studies highlighted the need for classrooms to address the portrayal of science as difficult, unattractive, or ''for boys'' (Jones, Howe et al., 2000; Miller et al., 2006), an idea that will be explored further by the studies in Theme 3 of this review about the nature and culture of science. Second, multiple studies found that girls and boys often prefer hands-on and experimental science experiences but may lack exposure to them, prompting the suggestion that these happen more frequently in the classroom (Baker & Leary, 1995; Dawson, 2000; Greenfield, 1995a; Greenfield, 1997; Harwell, 2000; Stark, 1999). Third, emphasizing social and societal connections with science as well as the links between biology and other subjects is a recommendation that follows from the findings that girls frequently like biology and, according to multiple studies, girls are attracted to topics that involve helping others (Baker & Leary, 1995; Jones, Howe et al., 2000; Miller et al., 2006).

Analyzing Attempted Solutions

The last set of studies in this first theme, focusing on equity and access, investigated strategies for addressing the inequities and disparities highlighted thus far. These strategies include increasing teacher awareness and creating additional extracurricular opportunities for girls to engage with science.

Teacher education. Teacher education is one strategy investigated for addressing the issues of inequitable or sexist treatment of girls in the classroom. Scantlebury (1995) highlighted the role of colleges of education in addressing preservice science teachers' frequent ''gender-blindness,'' by including gender issues in course discussions, holding teachers accountable for their understanding of gender equity issues, and educating teachers in both the theory and practice of ''gender-sensitive education'' (p. 140). Enacting these suggestions with preservice teachers, researchers demonstrated that partnerships with mentor-collaborating teachers attuned to gender equity issues prompt student teachers to then have more equitable classroom interactions with students (Bailey, Scantlebury, & Johnson, 1999; Scantlebury et al., 1996). Other researchers examined strategies for engaging teachers in reflection upon and application of gender equity practices through research projects, classroom observations, and analysis of their own teaching (Bullock, 1997; Hines & Mussington, 1996). In one study, Bullock (1997) found that, despite teachers' initial enthusiasm, they become less interested in focusing on equity issues when faced with the challenges of limited resources and the low academic skill levels of their students. This study points to a pressing need to create effective teacher education models that motivate teachers to prioritize issues of gender and equity despite being faced with so many day-to-day challenges in the classroom. Studies described in later sections of this review lend further insight into some of the complexities involved in creating teacher education models around issues of gender that teachers find meaningful and useful (McGinnis & Pearsall, 1998; Plucker, 1996; Richmond, Howes, Kurth, & Hazelwood, 1998; Zohar & Bronshtein, 2005).

Extracurricular programs. Supplemental science programs for girls, either as short-term interventions during school or as informal, enrichment programs during summers and after school time, are other strategies used to address the inequities and disparities that lead to girls' and women's underrepresentation in science. The five studies that investigated the influence of these extracurricular programs provided mixed results, showing some positive impacts on factors such as science attitudes and long-term career choices (Evans, Whigham, & Wang, 1995; Fadigan & Hammrich, 2004; Stake & Mares, 2001) and some neutral outcomes (Davis, 2002; Jayaratne, Thomas, & Trautmann, 2003). Two of these studies focused specifically on girls in high-poverty urban settings with different results: Fadigan and Hammrich (2004) found that an informal science program associated with a local museum served as a safe and positive place for girls that influenced their later educational and career paths, whereas Davis (2002) described an after-school club whose success was limited by factors such as lack of sufficient funding and political decision-making. Therefore, these studies indicate that, although it seems that there is a potential for these kinds of programs to impact girls in long-term ways, more investigation needs to go into identifying the key features of successful programs, and more investigation needs to go into the larger societal, political, and economic factors that may facilitate or inhibit a program's development.

Moreover, the majority of the studies just discussed describe supplemental science programs targeted toward students who are high-achieving and already interested in science (Fadigan & Hammrich, 2004; Jayaratne et al., 2003; Stake & Mares, 2001), pointing to a need for more research into the impact of these programs on girls who have not demonstrated as much prior science interest and achievement. Finally, in a related vein, other studies highlight the need to pay attention to gender equity within informal science experiences, such as museum visits, which, although often used as a way to bring all students into science, can also perpetuate inequities observed in formal classrooms (Greenfield, 1995b; Ramey-Gassert, 1996; Tunnicliffe, 1998).

To summarize, Theme 1 in part is about identifying classroom biases and inequities as well as differences in girls' and boys' achievement, attitudes, participation, and experiences in science. Although there have been relatively few studies of classroom inequities since 1995, indicating a shift in the overall research focus of the field, many authors, from many different countries, have continued to assess sex and gender disparities. Findings have been mixed. While many studies have reported girls' persistent negative attitudes toward science and less frequent choice of science courses, others have documented positive attitudes and increased enrollment for girls, even in the highest level classes. Variations in findings can be attributed to differences in both research methodologies and in contexts, and more research is needed into the specific features in particular contexts that create a more positive situation for girls. In addition, differences exist among girls of different ethnicities and ability levels, although few studies explicitly analyzed their data in ways that detect these differences. Despite the unresolved nature of some of these results, over and over again studies show that girls from young ages prefer and participate more in biological than physical sciences and have fewer extracurricular experiences with science than boys. In addition, boys in particular have stereotypical views about science being "for boys." Multiple studies also found that girls are motivated by topics that help others and like hands-on lab experiences, which leads to the curricular recommendations taken up in Theme 2.

Theme 1 also includes studies that propose strategies for ensuring that girls have equal access to pursuing science. They did this by attempting to eliminate gender discrimination from the classroom and by providing girls with more entry points into science through extracurricular programs that compensate for what girls are lacking in school science. Another line of research, which we describe next, focuses instead on changing the curriculum and pedagogy that is enacted in school science so that it is more inclusive of girls.

Theme 2: A Focus on Curriculum and Pedagogy

The studies included in this theme argue that we need to change curriculum and pedagogy in the science classroom so that it recognizes the experiences, interests, and learning styles of girls (Table 2). The data and

Table 2
Representative studies girls and science review theme 2- curriculum and pedagogy

Author and year	Purpose of study	Participants and Setting	Methods/Methodology	Major Findings
Harding & Parker (1995)	To review policy and practice around gender-inclusive science curriculum in 5 countries	Sweden, Denmark, England/ Wales, Australia, US	Description of major laws, policies, and programs related to each country's efforts towards a more gender-inclusive science curriculum	Progress towards gender-inclusivity has fluctuated with changing political and economic circumstances; policy and practice interact in multiple ways
Roychoudhury, Tippins, & Nichols (1995)	To explore the application of feminist ideas about women's learning to science teaching	45 prospective elementary teachers at a midwestern US university, all White middle-class, 90% women	Interpretive study using open-ended questionnaires, student reflections, videotapes of lessons, researcher's reflective journal	The course's focus on situated, collaborative learning and long-term open-ended projects triggered empowerment, competence, and ownership in the majority of students
Jones, Brader-Araje et al. (2000)	To examine how students use tools and equipment during science lessons	16 targeted students from 2 Grade 5 and 3 Grade 2 classes in a public urban school in southeastern US with population 50% Euro-American, 47% African American and other minorities, and 26% eligible for free lunch	Interpretive study using field notes from classroom observations of three lessons, interviews with students	Girls were more relational and cooperative than boys, followed directions more, and tinkered with materials less, while boys were more competitive and more exploratory with materials
Haussler & Hoffman (2002)	To evaluate the impact of a year-long curricular intervention on girls' interest, self-concept, and achievement in physics	456 students in 19 Grade 7 classes (12 experimental and 7 control) in 8 schools in Germany	Closed-response survey questionnaires and tests given at 4 time points to control group and three varying experimental groups	Curricular changes, teacher training, and small, single-sex classes combined, improved achievement, interest, and feelings of competence in physics for both girls and boys
Zohar & Bronshtein (2005)	To examine teachers' knowledge and views about gender gaps in physics participation	25 physics teachers from 25 high schools in a middle to high middle class, ethnically diverse Israeli city	Semi-structured teacher interviews	Most teachers underestimated the scope and importance of the gender gap in physics and did not know about gender-inclusive practices

recommendations from studies discussed previously in Theme 1 in part form the basis for studies in Theme 2. Some studies in Theme 2 empirically investigated girls' learning and interests in science as a basis for curricular adaptation. Others examined interventions that attempt to make curriculum and pedagogy more inclusive of both genders. Still others examined teachers' views and understandings around inclusive science teaching.

Studies attempting to change the curriculum originated in the 1980s (Rennie, 1998) and drew heavily from the perspective that women in many cases learn and experience the world differently from men, thus necessitating a change or expansion of the curriculum to accommodate both genders. Researchers in this theme frequently draw upon the work of Gilligan (1982), who showed that women's moral development differs from that of men's, in that women place a larger emphasis on issues of relationships and connection. The work of Belenky, Clinchy, Goldberger, and Tarule (1986) is also widely cited for its discussion of how "women's ways of knowing" involve connecting to the subject being studied (Zohar & Sela, 2003). Roychoudhury, Tippins, and Nichols (1995) also invoked feminist-standpoint theory (Harding, 1991), which says that "the difference in the social experience of men and women gives them different ways of looking at life and interpreting events, and hence, different standpoints" (Roychoudhury et al., 1995, p. 898). Finally, Howes (1998) drew upon "difference feminism," which highlights the biological and/or socially constructed differences between men and women. In what follows we first describe the empirical studies that investigate gender differences in students' learning and interests, which are used in combination with the perspectives described in this paragraph to create gender-inclusive curriculum and pedagogy. We then describe studies that evaluate these gender-inclusive interventions. Subsequently, we discuss studies that examined teachers' views and understandings in relation to gender-inclusive teaching practices.

Examining Girls' Learning and Interests

Several studies empirically investigated how girls approach learning. Across a range of countries and ages, the studies provide evidence that girls, on average, are more relational and cooperative and less competitive than boys (Alexopoulou & Driver, 1997; Ferguson & Fraser, 1998; Jones, Brader-Araje et al., 2000; Zohar & Sela, 2003), which has been shown by prior research as well. In addition, preliminary evidence indicates that girls in particular strive for deep conceptual understandings and reject more formulaic, rote learning (Meece & Jones, 1996; Zohar, 2006; Zohar & Sela, 2003). Furthermore, one study indicated that incorporating a visual depiction of the particulate nature of matter when learning about chemical phenomena improves achievement for girls, but not for boys (Bunce & Gabel, 2002). In another study, Malone and Cavanagh (1997) showed that girls and boys who chose to take high school physical science and math classes had similar cognitive preferences (measured by an instrument similar to the Myers–Briggs type indicator); however, girls who were recommended to take these subjects, but decided not to, had distinct cognitive preferences, whereas recommended boys did not. Although that study only looked at high-achieving girls, it raises the important point that there is a diversity of learning styles among girls, a point we will return to when discussing studies that focus on identity.

Multiple studies also pointed to the possibility that girls in particular benefit from hands-on or inquiry-based learning (Burkam et al., 1997; Cavallo & Laubach, 2001; Heard, Divall, & Johnson, 2000; Lee & Burkam, 1996). For example, Lee and Burkam (1996), in a large-scale analysis of national achievement data from 1988 for close to 19,000 eighth-grade students in the U.S., showed that girls' physics achievement, but not boys', was positively related to in-class laboratory experiences, which took place on a regular basis in only 25% of the schools investigated at that time. In a follow-up study analyzing the same students' achievement data, but from 1990 for approximately 12,000 tenth graders, Burkam et al. (1997) also found that, based on *student* reports of classroom activities, hands-on lab activities were particularly related to improved physics performance for girls; however, based on *teacher* reports of classroom activities, student-centered laboratory activities related positively to *both* boys' and girls' achievement in physics and biology. In a related study, Von Secker and Lissitz (1999) used the same national database with a smaller subset of tenth graders and also found, based on *teacher* reports of laboratory emphasis, that a focus on laboratory inquiry was related to higher achievement for tenth graders overall but that this emphasis did not significantly impact the gap in achievement between girls and boys. Therefore, these studies provide evidence that laboratory experiences may in fact be beneficial for both girls' *and* boys' science achievement; however, a more rigorous and consistent way of assessing the specific nature of classroom activities is needed to confirm these findings.

Like the aforementioned studies that investigated gender differences in learning, studies that examined students' interests in specific science topics found some differences, but also significant overlap between girls and boys (Baram-Tsabari, Sethi, Bry, & Yarden, 2006; Baram-Tsabari & Yarden, 2005; Christidou, 2006; Häussler et al., 1998). For example, Häussler et al. (1998), studying German students' interests in detail, found that most students in a given classroom, girls *and* boys, had a certain ''type'' of interest—they appreciated both practical and societal applications of physics but were not particularly interested in learning physics for its own sake. Of the minority of students who did not fit into this predominant interest type, boys were more likely to be interested in all aspects of physics study, pure and applied, whereas girls were more likely to only be interested in physics topics that relate to their lives and society. Similarly, Christidou (2006) found certain gender differences in Greek students, but also many areas that appealed equally to girls and boys, including astronomy, light, sound, plants, and animals. Both of these studies argued that the current science curriculum does not adequately address the interests of most students, boys and girls, and thus proposed curricular changes to address this problem. In what follows we elaborate on the curricular and pedagogical interventions that incorporate some of the empirical evidence described in this section.

Changing Curriculum and Pedagogy

Curriculum and pedagogy that attends to the learning styles, experiences, and interests of both genders has been labeled with a variety of terms, including ''gender-inclusive'' (Harding & Parker, 1995; Hildebrand, 1989; Parker & Rennie, 2002; Rennie, 2003; Roychoudhury et al., 1995; Weinburgh, 1995b), ''gender-balanced'' (Labudde, Herzog, Neuenschwander, Violi, & Gerber, 2000), ''female friendly'' (Rosser, 1990, 1997), and ''girl friendly'' (Harding & Parker, 1995). Harding and Parker (1995) traced the evolution of this terminology in Australia from ''non-sexist'' in the 1970s to ''gender-inclusive'' by the late 1980s, particularly highlighting the influence of the work of the McClintock Collective in developing this concept (Gianello, 1988). Harding and Parker also reviewed the policy and practice around gender-inclusive science curricula in five countries (one of only two studies in this review explicitly addressing issues of policy). Parker and Rennie (2002) referred to Hildebrand (1989) for the initial definition of the ''gender-inclusive'' approach and described its subsequent expansion (Parker, 1997).

Thus, there is certainly variation in what different researchers describe as gender-inclusive curriculum and pedagogy. However, in looking across the studies in this review, some common features emerge from the interventions they attempted. Specifically, a gender-inclusive science curriculum draws upon both girls' and boys' experiences, interests, and preconceptions; prioritizes active participation; incorporates long-term, self-directed projects; includes open-ended assessments that take on diverse forms; emphasizes collaboration and communication; provides a supportive environment; uses real-life contexts; and addresses the social and societal relevance of science. It also pays attention to issues of sexism and gender bias in curriculum materials, and includes ''the 'her story' and the 'lost women' of science'' (Parker & Rennie, 2002, p. 882), therefore incorporating ideas about equity discussed in the previous section.

According to qualitative studies, a curriculum that incorporates the aforementioned features can have a positive influence on students (Howes, 1998; Rennie, 2003; Roychoudhury et al., 1995). For example, in a widely cited study, Roychoudhury et al. (1995) found that situated, collaborative learning and long-term, open-ended projects in a physical science class for prospective elementary teachers triggered feelings of empowerment, competence, ownership, and an appreciation for the connection between science and their lives in the majority of teachers—most of whom were female. They argued that the ownership prompted by giving students choice in projects ''is imperative for bringing in those who have been marginalized'' (p. 916). Similarly, Howes (1998) designed a high school genetics unit on prenatal testing and found that girls talked extensively about their personal knowledge of pregnancy and childbirth. She therefore argued that topics where women are expected to be ''experts'' and have some real-life experience have the potential to engage girls in science.

However, larger-scale studies that quantitatively examined the impact of curricular and pedagogical interventions on science attitudes and achievement found either no difference between experimental and control groups (Labudde et al., 2000) or benefits for both girls and boys on certain measures (Häussler & Hoffmann, 2002; Lagoke, Jegede, & Oyebanji, 1997). Labudde et al. (2000) noted that, although certain features of a ‘‘gender-balanced’’ high school physics curriculum in Switzerland contributed to more positive attitudes for girls and boys, it led to higher achievement for boys only and did not alleviate sex differences in attitudes and achievement. In a similar study with middle school students in Germany, Häussler and Hoffmann’s (2002) ‘‘interest-guided’’ curriculum, in combination with teacher training, improved the achievement of both girls and boys over time. It also positively impacted boys’ interest in physics and girls’ feelings of confidence and competence in physics. However, more of an impact was made when they taught every other lesson in single-sex groupings, which is consistent with Parker and Rennie’s (2002) observation that gender-inclusive practices are more effective in single-sex than coed settings. Finally, Lagoke et al. (1997) also found similar positive outcomes for both girls and boys in high school classrooms in Nigeria (where girls are severely underrepresented in science) that incorporated ‘‘environmental analogs’’ comparing science concepts to ideas related to their sociocultural communities.

The idea that gender-inclusive strategies seem to be beneficial for boys as well as girls is not surprising, given that gender-inclusive science curricula are in many ways consistent with recommendations made by science education reform efforts in general, which attempt to improve science education for all students through constructivist approaches (American Association for the Advancement of Science [AAAS, 1993]; National Research Council [NRC, 1996]). In fact, Zohar (2006) made a similar point in her comparison of ‘‘learning for understanding,’’ a key idea in science education reform generally, and ‘‘connected knowledge,’’ a key idea in feminist thought. In the U.S., the *National Science Education Standards* (*NSES*) is one science education reform effort that claims to promote equity in science education for all students through curricular and pedagogical recommendations that are consistent with gender-inclusive strategies; however, Rodriguez (1997) critiqued the *NSES* for not making explicit the theory and evidence behind its recommendations. He argued that these theoretical rationales are critical if we are to convince frequently resistant teachers to change their practices. The next section elaborates on teachers’ responses to gender-inclusive curriculum and pedagogy.

Examining Teachers’ Views and Experiences

Multiple studies have shown that teachers have partial understandings of the research and issues around gender and limited knowledge and experience with gender-inclusive practices (Plucker, 1996; Zohar & Bronshtein, 2005). Moreover, teachers in multiple contexts express resistance to paying particular attention to gender inclusivity (McGinnis & Pearsall, 1998; Plucker, 1996; Zohar & Bronshtein, 2005), some describing interventions as reverse discrimination (Plucker, 1996). McGinnis and Pearsall (1998) described the challenges faced by a male professor of an elementary science methods class whose students resisted his attempts to enact gender-inclusive pedagogy. Therefore, as noted earlier, there is a need to find effective models of teacher education and professional development that better inform teachers of gender-inclusive practices and effectively articulate the rationale for and research behind these practices. Weinburgh (1995b) also noted the importance of asking teachers to examine their own views about gender issues as part of this process.

To summarize Theme 2, these studies are about adapting curriculum and pedagogy so that it is more tailored to how girls learn and what they experience. The studies highlighted differences between girls and boys, arguing that education often excludes the particular ways that girls learn and approach the world. As has been shown before, girls are, on average, more relational and cooperative than boys and more strongly seek deep conceptual understandings and active learning experiences, although their interests overlap considerably with those of boys, according to some of the studies reviewed (Christidou, 2006; Häussler et al., 1998). Curriculum and pedagogy that is gender-inclusive therefore includes features such as active, collaborative learning, which highlights the social relevance of science and pays particular attention to incorporating the life experiences of girls. In synthesizing the results of the studies evaluating gender-inclusive curricular and pedagogical interventions, two points are important to note. First, the studies alone did not provide any evidence that these strategies work *specifically* for girls, and they overlap with reform efforts to create equitable and high-quality science education for all students. Second, although there is some evidence showing the benefits of these interventions for both girls and boys, this conclusion would be better supported by more studies that cover more of a range of settings and use a combination of both quantitative and qualitative methodologies. Furthermore, only one study examined an intervention at the elementary level (Rennie, 2003). Finally, the studies in Theme 2 reveal that teachers are largely uninformed about gender-inclusive teaching and often disagree with its need to be prioritized.

By proposing specific ways to change and broaden curriculum and pedagogy, many of the studies described in this theme implicitly challenged the ways science is portrayed and practiced in the classroom. Some visions for gender-inclusive curriculum even called directly for the ''need to challenge dominant ways of thinking about science and about what kinds of knowledge are valued and legitimated in science'' (Parker & Rennie, 2002, p. 883). However, the studies we have grouped in Theme 3 focused more explicitly and directly on issues of the nature and culture of science that often exclude, alienate, and deter girls and members of other marginalized groups from the world of science.

Theme 3: A Focus on Reconstructing the Nature and Culture of Science

The studies in this theme argued that, to engage girls and other marginalized groups in science, we need to challenge portrayals of the nature and culture of science in the classroom and, in some cases, in the world at large (Table 3). One set of studies described these issues of the nature and culture of science and argued for the importance of acknowledging them, whereas another set attempted to translate them into practice through work with teachers. The studies in Theme 3, to a greater extent than the studies reviewed up to this point, consider intersections between race, class, and gender, and they overlap in some ways with discussions of multicultural science education, such as Hodson's (1999) call for the ''demythologizing'' of science. He argued that the ''distortions and falsehoods'' often perpetuated in science classrooms ''serve to exclude many girls and members of ethnic minorities from crossing the border into the culture of science'' (p. 783–4). This theme overlaps with the studies that focused on equity and access as well, which, in documenting gender differences, reveal the problem of girls' common perceptions of science as boring, uncreative, and passionless (Miller et al., 2006) or particularly ''difficult to understand'' (Jones, Howe et al., 2000, p. 180).

Carlone (2004) addressed the problem of science's portrayal in the classroom as inaccessible because of its difficulty—it is seen as a field in which only ''smart people'' with innate ability can excel. Carlone found that a reform-based high school physics curriculum both challenged and reinforced what she called ''prototypical'' meanings of science. More specifically, she found that, although the curriculum challenged prototypical science meanings through its focus on problem solving and the active nature of the scientist, it reinforced the prototypical meaning of science as difficult and only accessible to some, who usually ended up being the boys in the classroom. Carlone's study also addresses issues of identity, which we will come back to in the next section.

Several studies in Theme 3 used overlapping but varied feminist perspectives to critique science (Capobianco, 2007; Gilbert, 2001; Kleinman, 1998; Letts, 2001; Mayberry, 1998; Richmond et al., 1998). Although these studies diverge in their visions for applying these feminist critiques to the classroom, they overlap in that they critiqued scientific knowledge and practice for its associations with masculinity and objectivity. These critiques have three parts. First, some critiqued the ways in which science is often viewed as ''men's work'' because of the historical predominance of men in the field of science and the cultural messages that reinforce this association (Kleinman, 1998, p. 838). In fact, studies that asked students to draw scientists reveal that they frequently held these masculine stereotypes from young ages (Matthews, 1996; Newton & Newton, 1998).

Second, authors critiqued science for the ways in which it has been used to oppress women and other groups (Kleinman, 1998; Mayberry, 1998; Richmond et al., 1998). Kleinman (1998) gave the example of how, in the nineteenth century, scientists used scientific claims about how menstruation prohibited women from attaining intellectual equality with men to keep them out of scientific and medical professions. Kleinman further highlighted how scientists used their ''status as experts'' to legitimize these claims (p. 839). This second point highlights the powerful position science holds in society, facilitated in part by the common perception that scientific knowledge is objective and unbiased.

Thus, third, authors of the studies in this theme critiqued the portrayal of science as objective and unbiased. They drew from what Brickhouse (2001) described as the ''feminist epistemologies'' (p. 283) of thinkers such as Evelyn Fox Keller, Sandra Harding, and Donna Haraway (Haraway, 1988; Harding, 1986;

Table 3
Representative studies girls and science review theme 3- nature and culture of science

Author and year	Purpose of study	Participants and Setting	Methods/Methodology	Major Findings
Mayberry (1998)	To contrast collaborative learning and feminist pedagogy	NA	Theoretical discussion and description of feminist science classrooms	Collaborative learning reproduces inequitable and oppressive science systems while feminist pedagogy resists and transforms them
Kleinman (1998)	To examine feminist perspectives on the masculine ideology of science	NA	Theoretical and historical discussion	The masculine ideology of science perpetuated in society and the media impacts the practice of science and women and girls' participation in it
Richmond, Howes, Kurth, & Hazelwood (1998)	To explore students' responses to course assignments designed to prompt both connection with and critique of science	Prospective and practicing elementary and secondary science teachers from 4 researchers' graduate and undergraduate US university courses	Case studies involving teacher-researcher reflections on students' responses to course assignments	Teachers, particularly those at the secondary level, resisted critiquing science
Newton & Newton (1998)	To examine students' images of scientists over time	1,000 mostly White children ages 4+ to 11+ years from 35 classes in 5 schools in the north-east of England	Draw-a-Scientist Test compared between 1990 and 1996	At both time points, most children drew stereotypical, male images of scientists, and this trend increased with age
Carlone (2004)	To examine girls' participation in a reform-based physics curriculum designed to broaden ideas about science and scientists	28 mostly White Grades 11 and 12 students in 1 Active Physics class in an upper-middle class suburban town in the US	Ethnography using 6 weeks of participant observation, informal conversations, classroom artifacts, surveys, interviews with students, teachers, and administrators, and student focus groups	The Active Physics curriculum both challenged and reinforced prototypical meanings of science; girls resisted science meanings that jeopardized their identities as good students

Harding 1991; Keller, 1985) to argue that scientific knowledge, like knowledge obtained through other human pursuits, is in fact influenced by the people who acquired that knowledge and thus by the social, cultural, and societal context in which that knowledge was created. For example, people's and society's values influence the questions scientists decide to ask and the language they use to describe phenomena. Because these personal and societal values inevitably incorporate ideas about gender, it follows that it is impossible for scientific knowledge to be "gender-neutral" (Brickhouse, 2001, p. 283). Therefore, according to the three criticisms of science just described, sometimes called "feminist critiques of science" (Howes, 2002, p. 26–8), the fact that historically men were primarily the ones who did science not only has led to an association between masculinity and the *practice* of science, but it has also impacted the scientific *understandings* we possess.

One more important idea underlying many of the studies in this theme is the commonly made link between *masculinity* and traits such as objectivity, rationality, and lack of emotion, which are also often associated with science. This association between masculinity, objectivity, and science does two things. First, because femininity is viewed as mutually exclusive with masculinity, femininity also becomes viewed as mutually exclusive with science (Brickhouse, 2001; Gilbert, 2001). Second, science becomes viewed as unassociated with traits culturally defined as feminine, such as subjectivity, emotion, and creativity. Meyer (1998) attempted to counter and undo these long-standing associations in a course for prospective elementary science teachers that she called Creative Expression in Science.

As a whole, the studies in this theme claimed that exposing the fallibility and exclusionary practices of science by taking it off of the "epistemological pedestal," which holds its truths as absolute and unaffected by the values and beliefs that impact other human pursuits, has the potential to make it "more welcoming" (Richmond et al., 1998, p. 898). In addition, two studies focused on how countering the masculine and objective associations with science would be useful for engaging specific cultural populations: Chinn (2002) highlighted the complex and challenging relationship between masculinity and science for Asian and Pacific Islander women, and Parsons (1997) highlighted the ways in which science's human elements are consistent with the "black cultural ethos" (p. 748).

Although the studies described in Theme 2 about curriculum and pedagogy often share these underlying epistemological beliefs and critiques of science, the studies in Theme 3 argued that this critical examination of scientific knowledge and practice should be happening more explicitly in the classroom—as *part* of the curriculum, not just as part of the belief system that underlies it. For example, Gilbert (2001) argued that science teachers should educate students "*about* science" and "treat science as a series of texts, to be read, not as the 'facts' of nature, but as a series of stories" (p. 300). Her vision for a science education that promotes "critical literacy" is similar to Letts's (2001) call for "critical science literacy" as part of school science (p. 270).

Other researchers attempted to apply the feminist critiques of science just described to pedagogy and found a mixture of resistance and enthusiasm from teachers (Bianchini, Johnston, Oram, & Cavazos, 2003; Capobianco, 2007; Haggerty, 1995; Richmond et al., 1998). For instance, Richmond et al. (1998) described prospective elementary and secondary teachers' responses to assignments, given in four different graduate and undergraduate education courses, which asked teachers to examine their own relationships with science, to critique and thus "re-envision" science, and then to create pedagogy from this work. A common challenge they faced was teachers' resistance, particularly at the secondary level, to being critical of science, highlighting the complex dilemma of how to get teachers, and thus their students, to both connect to science *and* critique it (Richmond et al., 1998). In contrast, Capobianco (2007)[5] conducted collaborative action research with practicing secondary teachers who were enthusiastic about incorporating a broad range of feminist ideas into their practice and thus did not encounter this kind of teacher resistance. Capobianco described teachers' development of a "cluster of pedagogical possibilities for inclusive, dynamic science teaching" (p. 27), some of which overlap with the recommendations made in studies dealing with curriculum and pedagogy, as described in the previous section.

Capobianco (2007) and Richmond et al. (1998) both described their studies as the enactment of "feminist pedagogy"; however, like the term feminism, this term has been described in multiple ways in the literature (Brickhouse, 2001; Howes, 2002). For example, whereas Capobianco defined feminist pedagogy as broad and encompassing multiple strands, Mayberry (1998) argued that feminist pedagogy is necessarily "resistant or transformative" and "invites students to critically analyze existing science systems in their relationship to social oppression and domination" (p. 444). The purpose of Mayberry's article was to contrast her vision of feminist pedagogy with collaborative learning, which she described as "reproductive" in that it "encourages students to gain proficiency in the dominant discourse of existing science systems" (p. 444), therefore sustaining those systems instead of challenging them. She highlighted collaborative learning as a strategy often associated with constructivist science education reform and the gender-inclusive practices described in Theme 2. Mayberry's call for a more political science education involving action in the world that aims at changing the status quo in relation to what science is, who practices it and how, and the issues of power and oppression that are involved, overlaps with what others have described as critical feminism (Howes, 2002) or "feminist liberatory science education" (Calabrese Barton, 1998). The fact that different authors used the term "feminist pedagogy" with different visions in mind of what this looks like in the classroom highlights the importance of studies that precisely articulate and examine specific teaching practices.

Like Mayberry, Hughes (2000) critiqued a feature commonly associated with the gender-inclusive curriculum and pedagogy studies just described, namely the incorporation of science–technology–society (STS) issues into the curriculum. Hughes critiqued a high school STS curriculum in the UK for the multiple ways in which its socioscientific aspects are treated peripherally in comparison to the more abstract, traditional scientific content covered. She argued that, because STS concerns are often associated with female concerns, marginalizing and thus devaluing those components reinforces a central, superior place for masculinity in science. Thus, Hughes advocated both that teachers make STS components of the curriculum central and valued *and* that they work against essentialist gender binaries that associate males with "hard" science and females with issues of the social and societal implications of science (p. 427). Along these lines, she warned against, "blanket emphasis on girls preferring a particular style of learning" (p. 435). Several authors referred to in the next section also critiqued this kind of essentialism and instead stressed the importance of understanding peoples' multifaceted identities.

In summary, this third theme in the recent literature argues that, to engage girls and other marginalized groups in science, we must address issues of the nature and culture of science in the classroom and in society in general. The studies highlight the fact that science is often portrayed to be especially difficult, to be something that men do, and to be completely objective and thus value-free, all of which deter girls and others from participation. These studies argued that this portrayal is inaccurate and that, in actuality, both scientific practice and knowledge are impacted by human beings that do and discover it, and thus by the societal and cultural values that influence human action and thought. Finally, these studies acknowledge the role of subjectivity, creativity, and personal expression in science, whose contributions to scientific thinking are not commonly recognized.

Some of these studies aimed to bring these ideas about the nature and culture of scientific practice and knowledge more centrally into the science classroom, by bringing them to the attention of teachers (Bianchini et al., 2003; Capobianco, 2007; Richmond et al., 1998). In so doing they raised important questions about both the benefits and challenges of bringing this critical perspective into the science classroom. On the one hand, several authors argued that we must overturn current ideas about scientific knowledge and practice in order to stop excluding girls and other marginalized groups from pursuing science—and that curricular and pedagogical strategies of the kind described in Theme 2 are insufficient in doing this (Carlone, 2004; Hughes, 2000; Mayberry, 1998; Richmond et al., 1998). On the other hand, they described the challenging task of both attracting students to science *and* asking them to be critical of it (Richmond et al., 1998). The studies in the next and final theme add an additional layer of complexity and subtlety to this question of making science more inclusive to diverse groups of students by arguing that students' decisions to pursue science are inextricably linked to larger issues of their identity as people.

Theme 4: A Focus on Identity

This final theme in the recent science education literature attempts to understand the role of identity in students' engagement with and learning in science (Table 4). Integral to this idea is that gender is one important part of identity—but not the only part. Therefore, these studies highlight the need to examine the diversity *within* gender groupings and to work against creating simplistic and essentialist binary oppositions

Table 4

Representative studies girls and science review theme 4- identity

Author and year	Purpose of study	Participants and Setting	Methods/Methodology	Major Findings
Gaskell, Hepburn, & Robeck (1998)	To present three versions of a gender-equity project in order to examine the impact of the way researchers report and discuss their work	20 high-achieving Grade 10 students in British Columbia	Interviews with students before and after the implementation of a curriculum module on electricity, classroom observations, collection of student assessments	Three versions of the same study yielded different conclusions and took into account the complexities and uncertainties in the data to varying degrees
Brickhouse, Lowery, & Schultz (2000)	To examine how 4 female students engage in science and form scientific identities in and out of school	4 Grade 7 African American girls from a low-achieving public school in eastern US town with student population 35% African American, 65% White, and 15% on free or reduced-price lunches	Case studies over 18 months using interviews of students, parents, and teachers, classroom observations, student journals, and focus groups	The girls were confident in science and engaged with it in a variety of ways that were connected to who they are; their science classes limited the ways in which they could engage with science, and teachers were more positive towards girls with more conventional gender identities
Hughes (2001)	To examine students' construction of scientist identities	6 ethnically diverse students from a UK city school and a city post-16 college (part of larger study of 60 students)	Critical discourse analysis of 3 interviews with mixed gender pairs of students	Students' scientist identities took on different relationships to dominant discourses of gender and science
Gilbert & Calvert (2003)	To pilot a new methodology for approaching issues of gender and science that explores women scientists' relationships with science and reasons for pursuing it	5 women scientists	Psychoanalytic techniques developed in narrative/family therapy in combination with conventional qualitative methods	Women were not alienated from but attracted to science for reasons unrelated to the recommendations typically given in the literature for how to engage females in science
Ford, Brickhouse, Lottero-Perdue, & Kittleson (2006)	To explore elementary girls' access to and choices of science books	45 Grade 3 girls and families from 6 classrooms in 3 suburban and urban schools in eastern US, 74% White, 11% African American, 3% Latina, and 3% multiethnic, families were middle class	Interviews with girls, families, and teachers, 25 classroom observations, field notes	Girls had access to science books in school and preferred informational narrative genres and books about animals; parents underestimated girls' liking of science books and frequented major bookstores where science books are not as available and gender stereotypes are reinforced

between ‘‘girls’’ as one unitary group and ‘‘boys’’ as another, consistent with poststructural feminist theories (Brickhouse, 1998). Several studies thus describe girls and women who *are* attracted to and engaged in science, contrary to generalizations about females’ frequent distaste for it. These studies also discuss the complex process of developing an identity as someone who does science. Furthermore, they highlight the ways in which considerations of identity add a new kind of complexity to thinking about issues of gender and science.

This theme of identity is the most recently emerging in the gender and science literature. The studies within it respond in part to critiques, such as Atwater’s (2000), that many studies dealing with gender largely fail to acknowledge the ways in which ethnicity, class, gender, language, lifestyle, and religion interact to create the experience of an individual, leading to the resulting message that ‘‘White females are the norm for gender issues’’ and ‘‘*gender* has become a code word in science education that refers to White females’ ideas’’ (p. 387). Scantlebury and Baker (2007) also called attention to the dearth of studies related to gender and science that highlight race or ethnicity. The recent identity studies reviewed here begin to address this issue by investigating girls’ engagement in science through the lens of identity in a broader and more nuanced way than prior work.

Brickhouse and colleagues used a situated cognition framework to argue that, for students to learn science, they need to see their own multifaceted identities coinciding with the pursuit of science or as ‘‘compatible with scientific identities’’ (Brickhouse, Lowery, & Schultz, 2000, p. 443). According to situated cognition, learning is viewed as a ‘‘matter of deciding what kind of person you are and want to be and engaging in those activities that make one a part of the relevant communities’’ (Brickhouse, 2001, p. 286). Thus, according to this framework, ‘‘identity formation’’ is essential to learning. That is, how and why students learn science connects to who they are and are becoming in their own lives and communities inside and outside of the classroom and whether or not they see their identities coinciding with the communities of practice that engage in science. Brickhouse (2001) argued that situated cognition provides an effective way to understand learning from a feminist perspective, because, unlike prior work based in constructivist models, it makes consideration of gender, a part of identity, central to understanding learning. However, integral to this approach is the idea that gender is one of *many* factors contributing to a person’s identity. Whereas the literature on gender and science often places girls in one group that experiences a similar alienation and marginalization from science, this work acknowledges ‘‘the diversity that exists among both boys and girls,’’ arguing that, in fact, many girls connect and engage with science in a range of positive ways (Brickhouse et al., 2000, p. 442). Thus, Brickhouse et al. (2000) argued that, to understand why girls are or are not succeeding in school science, it is necessary to ‘‘know more than that they are girls,’’ but to instead know ‘‘what kind of girls they are’’ (p. 457).

Exploring these ideas, Brickhouse and colleagues described qualitative case studies of low-income and minority girls who *are* interested in science to carefully examine the ways in which they adopt or struggle to adopt ‘‘scientific identities’’ (Brickhouse et al., 2000; Brickhouse & Potter, 2001). Both of their studies on this topic found that girls who approached science in ways more consistent with school and gender norms were received more positively by teachers. Furthermore, one of these two studies described the challenges girls faced when they wanted to be competent in science or technology but did not want to take on the identity associated with belonging to school science or computing communities.

Although the two studies just described (Brickhouse et al., 2000; Brickhouse & Potter, 2001) raise questions about the ways in which schools and teachers can reject girls’ unconventional scientific identities, and thus marginalize students who are otherwise interested and confident in science, other studies have examined the role that more conventional and gendered identities play in girls’ decisions around science participation. For example, Carlone’s (2004) study, discussed in the previous section (see Table 3), indicated that the girls she studied in a class implementing a reform-based curriculum, who were from a largely white, upper middle-class suburb, resisted classroom practices that challenged their ‘‘good student identities’’ (p. 392). Thus, the curriculum’s intention to be more inclusive and ‘‘promote broader meanings of science and scientist’’ (p. 392) was rejected by girls who favored more traditional approaches that did not threaten their ability to get good grades and appear to be good students. Solomon’s (1997) theoretical discussion is related in that it highlighted various interventions that are well intended but unsuccessful in increasing girls’ participation in science. Solomon argued for more in-depth examination of the complex factors that contribute to girls' choice of science, which she described as an "identity confirming action which relates to national and home cultures, to adolescence, and to solidarity with gender groupings" (p. 407).

Also exploring the complex connections between issues of identity and engagement in science, Ford, Brickhouse, Lottero-Perdue, and Kittleson (2006) highlighted the fact that young girls "often construct identities as strong readers and writers" much more easily than they construct scientific identities (p. 272). Thus, in an attempt to examine a potential entry point for girls into science, their study explored elementary girls' access to and choices of science books, finding that they were both available and appealing to the girls in their study, despite parents' underestimation of their daughters' attraction to science books. In addition, they found that these largely middle-class families frequented major bookstores, which typically carry a limited collection of science books and instead cater to marketable books that reinforce stereotypical ideas about girlhood. The authors therefore alerted parents to this young age being a "window of opportunity to get girls interested in science reading" (p. 285), highlighting the potential for encouraging science reading both inside and outside of the classroom.

In addition to illustrating the importance of issues of identity in science education, a related claim raised by the identity literature is that schools, as well as society in general, need to make room for identities that defy commonly held, stereotypical norms about both gender and science. For example, Hughes (2001) analyzed the diverse ways in which students construct scientist identities that uphold or challenge dominant discourses about science and gender. For instance, one girl in her study developed a scientist identity by separating herself out from most females, who she viewed as not drawn to the difficult, high-pressure character of physics, while another girl developed a different kind of scientist identity that defied these typical notions of femininity and science. Instead, this latter girl's scientist identity was based in the belief that women can pursue science careers and the belief that science is not "authoritative" knowledge (p. 284), but can be contested and modified. For Hughes, broadening views on the nature and culture of science, as discussed in Theme 3 earlier, is therefore a way of broadening the kinds of scientist identities available to students. Although Hughes highlighted the potential role of curriculum in achieving this, Hatchell (1998) highlighted the role that teacher encouragement can play in making alternative scientist identities accessible to students. In their analyses, Hughes, Hatchell, and others (Ritchie, 2002; Volman, van Eck, & ten Dam) used poststructuralist theories of positioning to describe the ability students have to take on particular positions in relation to common-sense ways of thinking about gender and science—and to change these positions. Positioning theory challenges the idea that who we are and how we define ourselves is fixed—instead, it highlights the ability people have take on a shifting array of "subject positions" (Davies, 1994, p. 20).

As the aforementioned studies involving students across different contexts indicate, examining varying and nuanced issues of identity as they arise for individuals introduces new layers of complexity into the conversations around issues of gender and science. Multiple studies in this theme have alluded to this complexity and challenged current approaches to research on gender and science (Bianchini, Cavazos, & Helms, 2000; Gaskell, Hepburn, & Robeck, 1998; Gilbert & Calvert, 2003; Ritchie, 2002; Volman et al., 1995). For example, Gaskell et al. (1998) called attention to the fact that the way researchers report and discuss their work impacts the extent to which complexities and uncertainties are acknowledged. They demonstrated how researchers can look at the same data about, for example, a gender equity curriculum project, and either tell a straightforward story about its impact on students or highlight complicated and challenging issues related to the students', teachers', and researchers' identities that lead to "more questions than answers" (p. 873). Similarly, in acknowledging intricate questions about gender, ethnicity, and identity through their exploration of science teachers' and scientists' diverse ideas, Bianchini et al. (2000) called for "increased sophistication in the ways professional developers conceptualize and attempt to locate solutions to the 'problem' of women and ethnic minorities in science education" (p. 542). Specifically, they recommended that professional developers ask teachers to explore the role of their *own* identities in their experiences and teaching, that they engage teachers in discussions of feminist scholarship, and that they encourage teachers to critically examine their views of students, so as to help them to "balance recognition of systemic bias with acceptance of individual differences" (p. 540).

Finally, Gilbert and Calvert (2003) also called for a new approach to "the 'problem' of gender and science," which, they argue, along the lines of Solomon (1997), "has not been solved" by prior approaches

(p. 861). Like the other authors in this section, they critiqued the lumping of all women into one unitary group associated with what is culturally defined as ''feminine'' (p. 863). Like Brickhouse and colleagues' case studies just described, Gilbert and Calvert sought to understand how women *do* engage in science. They asserted, ''There is a very large body of research which investigates the reasons for science's unattractiveness to women: however, very little research has attempted to investigate why some women find it *attractive*'' (p. 865). In fact, Gilbert and Calvert found that the women in their pilot study were attracted to the rational, unemotional, analytical aspects of science that are often characterized as masculine and that this was a source of ''internal conflict'' for these women (p. 875). Gilbert and Calvert therefore argued for a '''paradigm shift' in research on gender and science'' that recognizes the ''existence of elements of both genders in all of us'' (p. 876). They are arguing here that masculinity and femininity are cultural constructions that have come to be seen as mutually exclusive—associated exclusively with either males or females—when in fact traits culturally associated with masculinity can be part of females' identities and vice versa. Furthermore, they are arguing that, until we undo this idea that masculinity is necessarily associated with males and femininity with females, attempts at bringing girls and women into science by the strategies described in the other themes of this review have limited potential.

In summary, Theme 4 is currently emerging in the literature and makes understanding the role of identity, in a broad sense, central to issues of gender and science. Studies in this theme argue against binary oppositions that focus primarily on gender and ignore the diversity that exists within gender groups. Some studies have highlighted the need to support girls in viewing scientific identities as consistent with their own identities as diverse and complex people, and they described the ways in which teachers and schools can hinder girls' adoption of scientific identities (Brickhouse et al., 2000; Brickhouse & Potter, 2001). Others have provided evidence for the need to understand the ways that girls' often gendered identities as good students and as strong readers can impact the choices they themselves make around science (Carlone, 2004; Ford et al., 2006). Yet others have provided examples of how curriculum and teaching can support students in accessing a broad range of scientist identities and positioning themselves within atypical discourses about gender and science (Hatchell, 1998; Hughes, 2001). Also, authors in this theme discussed the additional layers of complexity that arise when considering issues of identity for students, teachers, and researchers (Bianchini et al., 2000; Gaskell et al., 1998; Ritchie, 2002; Volman et al., 1995). Finally, these studies give voice to girls and women who *do* like and engage in science for a variety of reasons (Brickhouse et al., 2000; Brickhouse & Potter, 2001; Gilbert & Calvert, 2003). They emphasize the fact that there are women who are attracted to the very aspects of science typically associated with masculinity and men, and that these women pursue science *because* of these aspects, not despite them (Gilbert & Calvert, 2003). Therefore, the identity research, as a whole, calls attention to larger, deep-rooted ideas held by culture and society that need to be addressed if we want more girls to see themselves as the ''kind of people who would want to understand the world scientifically'' (Brickhouse et al., 2000, p. 443).

Next Steps and New Directions for Research on Gender and Science

In what follows we explore questions and directions that emerge from our discussion thus far of the four themes in the recent literature on gender and science. Rennie (1998) argued that understanding different perspectives on gender research in science education has the potential to provide a ''shared language'' (p. 957) to improve communication between prospective science teachers, researchers, and science teacher educators. Along these lines, we believe that our systematic analysis and categorization of the recent field has the potential to facilitate much needed communication between educators and researchers as well as between researchers themselves. However, we also believe our categorization of this recent work has the potential to highlight new directions for research in the field of gender and science and to enrich directions currently being pursued by examining them through the multiple perspectives we have described. Looking through the lens of all four themes, in what follows we propose questions for further research, grouped according to significant topics within each theme.

Equity and Access

This theme describes research that stems from efforts to address a history of gender discrimination in schools and society. We have reviewed the recent studies within it that aim to document continued inequities and gender disparities and to address them through teacher education and by increasing girls' access to science experiences through extracurricular programs. We propose the following research questions related to documenting inequities and disparities and strategies that attempt to address them:

- What gender inequities exist across different contexts in the classrooms of the present day? What are the science attitudes, preferences, and experiences of a more diverse range of girls across different settings, and how can we examine this qualitatively as well as quantitatively? How do we more effectively involve girls' families in issues of gender equity and, at the same time, address the persistent finding that boys often have particularly stereotypical views of science as a male domain?
- What contextual factors both inside and outside the classroom contribute to creating equitable classroom environments? What role does a school's culture play in creating equitable classroom environments and influencing girls' attitudes toward science? How are girls' out-of-school science experiences changing with the advent of an increasingly technological society, as Christidou's (2006) data suggest?
- What insights can we gain from exploring more deeply the experiences of girls who *do* enjoy and engage in the *physical* sciences at various ages, along the lines of Zohar and Sela (2003) and Gilbert and Calvert (2003)? Similarly, what insights can we gain from exploring the experiences of girls who *do* enjoy and engage in other domains of science, such as chemistry and biochemistry, and from understanding identity formation for girls across various fields of science, technology, and engineering?
- What impact does intervention at the elementary level have on girls' subsequent attitudes, experiences, and career decisions? What does effective elementary teacher education that facilitates these early interventions look like?
- What kinds of informal or extracurricular science education experiences are available to girls in different geographical locations, and how might more effective partnerships be created between schools, universities, and community organizations to provide more of these? How do the impacts of informal programs differ when considering girls of differing identities, and how can extracurricular science experiences support girls in forming scientific identities? What impact do these informal experiences have on girls' science participation in the classroom and future engagement with science? What specific features (e.g., curriculum and pedagogy, nature and culture of science) are used in these programs and can be adopted for teaching school science? What particular features of programs contribute to positive outcomes in the short and long term?

Curriculum and Pedagogy

The studies in this theme work to change curriculum and pedagogy in science classrooms to be more inclusive of the experiences, learning styles, and interests of girls and prompt the following questions related to teacher education, professional development, and curriculum development:

- How can teacher education and professional development programs effectively address teachers' resistance to and lack of information about gender-inclusive practices? How can we incorporate issues of gender equity into teacher education and professional development in ways that are both meaningful and realistic for teachers?
- What impact do gender-inclusive curricula have on students of varying ages in more diverse settings? Do these impacts differ for girls and boys in these diverse settings and, if so, how and why?
- To what extent are issues of bias and sexism a focal point for curriculum developers? How can gender-inclusive curriculum development efforts partner with general science education reform-based curriculum development to enhance both? How might a gender-inclusive curriculum more deeply address issues of the nature and culture of science or identity?

Nature and Culture of Science

The third theme in the recent literature critiques science itself as well as how it is portrayed in schools and argues for a reconstruction of the nature and culture of science in order to engage excluded groups. The studies that deal primarily with the nature and culture of science are largely theoretical discussions or qualitative examinations of attempts to address these ideas with teachers (Bianchini et al., 2003; Capobianco, 2007; Meyer, 1998; Richmond et al., 1998). Given this, some clear questions for further research remain:

- What do curriculum and pedagogy that take into account ideas of the nature and culture of science look like more specifically, and what essential features are embedded in curriculum and pedagogy that view both the nature and culture of science more critically? What is the impact of addressing issues of the nature and culture of science on students' experiences and learning in science?
- How can curriculum materials address or include multiple perspectives and knowledge claims in science? How might perspectives that are not part of the traditional scientific canon be represented in the curriculum to spark student interests, critical science learning, and engagement in science?
- How can teacher education and professional development address the challenges that teachers find to both connect with *and* critique science? (Richmond et al., 1998). How do teachers address this potential challenge with their students, administration, and parents?

Identity

Finally, the fourth theme makes understanding issues of identity central to questions of gender and science and calls for a new approach to these issues. This fairly new line of research implies several directions for future research:

- What do curriculum and pedagogy that take into account ideas of identity look like? How can teachers effectively support their students in forming scientific identities? How does a school's culture impact students' scientific identity formation? How do we involve parents in discussions of scientific identity? What impact do current curriculum reform efforts have on students' scientific identity formation, such as in viewing themselves as the "kind of people" who do science (Brickhouse et al., 2000)? How can we effectively evaluate this on small and large scales?
- How can teacher education and professional development promote productive teacher reflection on "who their students are" and the challenging balance between recognition of students as individuals and recognition of systemic inequities (Bianchini et al., 2000, p. 542)?
- What initial concrete steps might we take toward promoting the recognition that masculinity and femininity are cultural constructs (as described by Gilbert & Calvert [2003]) and that both can reside within males and females? How might a school as a whole or education in other subjects in addition to science play a role in promoting this awareness?

Conclusions

Through the questions just presented, we have attempted to highlight gaps in the research and areas that merit further exploration. In addition, we have attempted to illustrate new questions that arise when applying insights from other themes in the gender and science research, all of which are ongoing in the current literature. We conclude by highlighting two areas that come up repeatedly in the questions outlined and warrant further elaboration and consideration for future research.

First, as might be expected, there seems to be enormous potential for overlap between curriculum and pedagogy and the remaining three themes of this recent literature review (i.e., equity and access, the nature and culture of science, and identity). For example, as the questions suggest, it seems to us that researchers pursuing investigation into potential curricular and pedagogical reforms that address issues of gender would benefit from examining their curricula for the extent to which they address issues of the nature and culture of science as well as identity. In addition, researchers pursuing work on identity and the nature and culture of science would benefit from outlining what their important ideas look like when translated into concrete teaching practices through curriculum. In these ways, they open up opportunity for equity and access for all students to engage in science.

Furthermore, beyond increased overlap between researchers exploring curriculum development within the field of gender with the other ongoing themes, we believe the field of science education in general would benefit from more of a partnership between identity and curriculum research. More specifically, both Brickhouse's work on identity and many current curricular reform efforts draw upon ideas of situated cognition in their underlying assumptions about student learning. In particular, the social constructivist curriculum work that has led to a proliferation of "cognitively oriented curricular innovations" (Fishman & Krajcik, 2003, p. 566) (which are in line with the recommendations of the *National Science Education Standards* [NRC, 1996] as well as Project 2061 [AAAS, 1993]) draw upon the situated cognition learning model to highlight the ways in which learning is a contextual process of enculturation into communities of practice (Blumenfeld, Marx, Patrick, Krajcik, & Soloway, 1997). However, by using a situated cognition framework (Wenger, 1998) to highlight the fact that entrance into a community of practice means forming a certain *identity*, Brickhouse (2001) more centrally acknowledged the potential complexity of entrance into communities of practice because of a variety of institutional, societal, cultural, and personal factors. Thus, it follows from this identity work that current curriculum reform efforts, by their *own* standards of what it means to learn, cannot achieve their goal that ''all students should develop a deep understanding of science'' (Fishman & Krajcik, 2003, p. 564) without taking into account issues of identity—and thus, in turn, the issues of marginalization that prohibit students' entrance into scientific communities of practice. As Brickhouse argued, adopting a situated cognition perspective necessitates the role of gender and other factors that contribute to identity (and often to marginalization) in science *learning*.

Not only does it seem necessary for curriculum developers to begin to think more deeply about issues of identity to achieve what they themselves have set out to do, but it seems equally necessary for researchers of identity issues to think more concretely about how to apply their work to curriculum, as curriculum development is an area seeking actively to impact large numbers of students by making reform efforts ''scalable'' and ''sustainable'' (Fishman & Krajcik, 2003, p. 565). Moreover, a finding that surfaces across the themes in this review is that teachers resist addressing issues of equity and diversity in the face of more pressing concerns about student achievement and curriculum planning (Bullock, 1997; McGinnis & Pearsall, 1998; Plucker, 1996; Richmond et al., 1998; Zohar & Bronshtein, 2005); this issue might begin to be addressed by better integrating novel approaches to curriculum with issues of identity, diversity, and equity in teacher education (Moore, 2006, 2007). Therefore, we believe more of a partnership between curriculum and identity research would be mutually beneficial for the aims of both research areas.

The second and final point we highlight is that a consideration of questions relating to gender and science on the level of the school as a whole is largely absent from the articles reviewed in this study. Although some studies alluded to the role of school type (Jones & Young, 1995; Jones et al., 1996; McEwen et al., 1997; Panizzon & Levins, 1997) or schoolwide policies, such as tracking (Muller et al., 2001) and course selection processes (Roger & Duffield, 2000), no studies focused centrally on the contribution of a school's overall culture or administration in impacting the situation for girls in science, a potentially crucial level of analysis. For example, although several studies examined teachers' views in relation to gender equity and inclusive pedagogy, none examined the views or policies of school principals or other administrators and how these may impact the experiences of teachers and students. Also, although multiple studies commented on the potentially powerful parental influences on gender issues (Andre et al., 1999; Chinn, 2002; Ford et al., 2006; Labudde et al., 2000; van Langen et al., 2006), none examined schoolwide structures that might enhance parent involvement and education in relation to gender (Ford et al. mentioned their current work with mother–daughter book clubs, and future reports on their findings will be a valuable contribution). Brickhouse et al. (2000) and Brickhouse and Potter (2001) began to implicate school values and norms in the process of students' scientific identity formation, but a more thorough and direct examination of these factors is needed.

Similarly, studies that have looked at policy issues beyond the level of the school are also infrequent. Although some authors highlighted the influence of science standards and high-stakes testing on gender issues (Bianchini et al., 2003; Kahle, 2004; Scantlebury & Baker, 2007; Von Secker & Lissitz, 1999), only two studies in this review centrally addressed issues of policy (Harding & Parker, 1995; Rodriguez, 1997). The fact that these school-level and policy-level issues are largely absent from the dialogue on gender and science in the widely read science education journals reviewed herein demands attention in itself; however, a preliminary search of the literature indicates that these issues are not prominently addressed in more narrowly focused journals that explicitly address policy and school leadership either.[6]

Studies in this review clearly illustrate the complex and deep-rooted issues that underlie questions of gender and science. These underlying issues deal with intricate and varied individual identities, with societal inequities, and with long-standing cultural ideas about what it means to be a female or a male, a woman or a man, a girl or a boy. These issues warrant new approaches and questions that somehow integrate, expand, and challenge our understandings of equity and access, curriculum and pedagogy, the nature and culture of science, and identity in science education research. Furthermore, given the magnitude of these issues, the current literature indicates that we must attempt to address them from broader perspectives than is being done currently in the field of science education. In addition to continuing to examine these issues as they play out for students, teachers, and classes, we need a wider lens that examines questions of gender on all levels—including the school and policy levels. If we are to increase girls' and boys' engagement in science, we need to work toward impacting the education that students receive both inside and outside of the science classroom. We must not ignore both contextual and societal issues involved in understanding, teaching, and learning science.

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Notes

[1]Due to space limitations, we present summaries of five representative studies from each theme in Tables 1 through 4; however, the complete list of all 107 studies reviewed can be accessed at: http://www.tc.columbia.edu/faculty/?facid=fm2140. In this complete list, each study is presented as part of only one theme, although it may be relevant to more than one theme and is therefore cited in the discussion of multiple themes in the text.

[2]More precisely, we searched using the phrase ''scien,'' and therefore our search picked up articles using words such as ''scientist'' and ''scientific'' as well as the word ''science.'' This also applies to the mention of the use of ''science'' as a search term later in this paragraph.

[3]Themes 3 and 4 are the least prevalent in the science education literature between 1995 and 2006. Although our review includes 50 studies in Theme 1 and 30 studies in Theme 2, there are only 15 and 12 studies that address Themes 3 and 4, respectively. As noted earlier, from 1990 through 1994, there are only two studies related to Theme 3 and none related to Theme 4, whereas there are approximately 36 studies related to Theme 1 and approximately 20 studies related to Theme 2 published between 1990 and 1994.

[4]Some theorists argue that our understandings of sex, in addition to gender, are socially constructed, and that the binary categories of female and male have also been constructed by a culturally and socially embedded science (Gilbert, 2001).

[5]We read and included this study as the ''early view'' presented online in 2006, which is why it is incorporated here, although it was officially published in January 2007.

[6]We did a preliminary search of the literature between 1995 and 2006 in the following publications that address issues of policy and school leadership: *Educational Evaluation and Policy Analysis* (*EEPA*), *Educational Leadership*, *The School Administrator*, and *Phi Delta Kappan*. With the exception of *Educational Leadership*, all of these journals contained between zero and three articles related to gender and science, none of which addressed the school- or policy-level gaps discussed earlier. *Educational Leadership* contained 16 articles related to gender and science issues; however, only one of these addressed one of the gaps mentioned earlier, in that it described a schoolwide program that involved parents in issues related to gender and science (Adenika-Morrow, 1996).

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