

GENDER-BASED UNDERREPRESENTATION IN COMPUTER SCIENCE AND RELATED DISCIPLINES

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Abstract — Traditionally, biological determinism served as a priori explanation for inadequate performance occurring in minority groups. Concurrent with this thinking, women were deemed to be naturally deficient in math and hence their large-scale absence from math-related disciplines. Lacking empirical support for nature-based arguments, current research relies on social determinism to test gender-based disparities in the pursuit of math. Although this latter model seems closer to reality, as evidenced by research results, this paper suggests that future studies must examine the issue from a choice-based paradigm. With work roles no longer based on gender, questions regarding women in math disciplines must be examined within choice-based models rather than those that emphasize environmentally determined criteria. We propose an integrated research model that includes choice as a critical causal variable.

Index Terms — cultural anthropology, education, gender, mathematics, women in engineering

INTRODUCTION

Most cross-country field studies on education and cultural anthropology indicate noticeable inequality in the number of women and men studying mathematics-based subjects such as computer science. Comparatively fewer women enroll for graduate education in these fields; fewer complete them. A corollary question examined in this context is: What factors have caused women's absence from mathematics curricula?

Cultural anthropology offers three broad theoretical reasons for this disparity [30]. The first is embedded in biological determinism: women are biologically incompetent to study mathematics. The second, rooted in social determinism, suggests that women's career and educational pursuits are socially determined; higher mathematics and computer science are not one of them. The third centers on how people actively make choices for themselves and actively voice these choices rather than accepting what is externally determined. By this argument, women's absence from mathematics is either because they choose not to, or they have not been empowered to make such choices for themselves.

While each of these arguments is theoretically convincing, biology-based research has lost currency. Most studies presently concentrate on social factors as the predominant causes of the observed disparity. While findings support this model strongly, not much has been done to examine the issue from the perspective of choice.

The authors of this paper contend that research based on individual choice and purposive behavior should yield more realistic results on the subject and help in building robust frameworks. By empowering women to make independent choices, and by providing facilitative conditions in the execution of such choices [6], enrollment and retention data across fields of study can be realistically examined.

The purpose of this paper is to synthesize and extend our current understanding of factors causing women's absence in math-related education. We start with a review of research that has examined the issue from a biological and then social deterministic perspective. We then propose a scheme, grounded in the notion of choice, as a model for future investigations on the subject. We discuss the importance of our proposal and its implications for theory building and research.

For the purposes of this paper, determinism implies that a person's behavior and preferences are restricted by criteria established by others. Choice implies that behavior and preferences are the product of the idiosyncratic purposive thinking of that person and thus, choice is the bipolar opposite of determinism.

A REVIEW OF LITERATURE IN BIOLOGICAL DETERMINISM

According to the model of biological determinism, women are biologically incompetent to do math and, therefore, do not pursue it. Inherent in this model is the natural selection thinking that certain species are better suited for certain tasks than others because of natural endowment. Although not a sound analogy since women and men are the same species and not competing on the evolutionary scale, it implies that they may have developed complementary attributes to better compete in the evolutionary world. While this argument may be theoretically convincing, empirical evidence does not support it, and often times rejects it. Both intra and inter-cultural studies have found that in cultures where women have an actively sought to study math, they have performed as well as men, and, on occasions, better than men.

Studies of Brain Size

Brain size studies in the early middle of the 20th century were constructed so as to maintain the social norm that white men were more intelligent than African Americans and women. Brain size was assumed to be a good measure of intelligence. To the dismay of scientists, they showed

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African Americans to have a larger cranial capacity. Scientists adjusted their hypothesis, stating that absolute head or cranial size was not representative of intelligence because large people (African Americans were generally larger) would appear to be smarter by virtue of overall somatic growth [14]. A new measurement was taken, that of the left cranial size relative to the height (cranial module vs. height or cephalic module-stature index) as the preferred measure of intelligence. Under this new measurement, women measured considerably higher than men. Social bias was so strong that Hrdlicka added a special variable ad post hoc: women had a lot of air in the brain [15], explaining the larger cranial capacity while maintaining the popular opinion that men are more intelligent than women [3].

Hrdlicka was a fervent follower of the biological determinism argument. Another more recent follower is Ernie Govier. Govier attributed gender stereotypical school subject choices to be a result of biological differences according to sex rather than the result of societal pressures to be 'masculine' or 'feminine'. He stated that these biological differences resulted in differences at the level of interests and personality. He states in the highly biological determinist book *Why Men Don't Iron* (1998) the following: "Sex typical academic choices ... are in part a result of sex differences in brain structure. These differences in the brain lead to sex differences in abilities, interests, levels of aggression, motives and emotional characteristics and these in turn will influence what boys and girls choose to do in schools" [24].

Studies in the United States

Results of several respectable studies conducted in the United States make the biological determinism model tenuous to accept. Rogers and Kaiser [28] found Hawaiian girls consistently performing mathematics better than boys. There are two explanations for this difference, and both have social origins, not biological. The first attributes the difference to the immigrant girls, explaining that their ease of immigration compared to male students may have caused the inequality. The second blames the school systems, stating that gender difference in achievement may have occurred because of the differential availability of situational rationales for school compliance [4].

Other United States' studies that focus on within-group differences have found that disparity exists in the white population only [5]. Most studies report no difference in the performance of African-American children in the nine-to-sixteen age group. These same studies suggest that the female Hispanic-American student slightly outperforms her male counterpart. The only ethnic group where the male outperformed the women in mathematics was the white student.

Studies in the United Kingdom

In 1980, Geffry Driver studied 2300 secondary-school graduates of both sexes, including white students and

students of West Indian decent, in five multiracial secondary schools in the United Kingdom [5]. In this study, he observed that West Indian girls outperformed West Indian boys markedly in most all subjects including English, mathematics, and science. The white boys outperformed the white girls but on a much smaller scale. The West Indian girls were in fact the highest performers of the four groups - West Indian girls, West Indian boys, white girls, and white boys. The white boys came second after a large gap. The other two groups, West Indian boys and White girls performed equally. Driver attributes the high performance of the West Indian girls to their matriarchal culture, where men often do not work. In Jamaica, women rather than men control the finances and assume responsibility for the family's survival. There, the girls consistently outperform the boys in literacy and mathematics [32]. This characteristic has remained even after immigration to other cultures and it is reflected in the women's superior academic performance.

Studies in India

Studies done in India account for the male-female disparity in mathematics education, as due to social mores [28]. Throughout India, mathematics and education in general is highly valued. Historically however, a girl's education in India has been given a lower priority than that of a boy because a girl must be married and sent away (although this custom has significantly changed in recent times due to India's rapid economic development), while a boy is expected to support the parents in their old age. However, even in this country, in samples of males and females studying math, instances are available where females significantly outperformed males. In most Brahmanical families of India, education is a priority for both sexes. Studies have found in the predominantly Brahmanical belt of Southern India, such as Mangalore, females outperforming males in math [28]. An added reason for the anomaly seen in Mangalore is possibly its matriarchal familial system that promotes women.

Studies in Papua New Guinea

In Papua New Guinea, the society is matrilineal and the women have more social power than men. Girls are treated with respect in the classroom as in society as a whole. Studies in this environment have found both males and females doing equally well in math and no one group significantly outperforming the other [17].

A REVIEW OF LITERATURE IN SOCIAL DETERMINISM

Social determinism is a popular theme today for explaining the presence or absence of women in certain disciplines and professional careers. Underlying this model is the notion that a woman's place in society is determined by the norms, values, and priorities of that society in conjunction with her

own natural traits. Thus, what a woman would pursue educationally, or as a career, is a function of society's needs and how the society perceives her. Most societies perceive a woman as a facilitator and a caregiver, rather than as a leader or analytical expert, and thus expect her in roles that would demand these traits. Because mathematical disciplines require different traits, women are not favored or encouraged in those disciplines and hence their absence from such disciplines. Research performed using male-female traits/behaviors and the roles they play in society significantly supports the social determinism model.

Mathematics Perceived as Masculine

Martin [22] records that most mathematicians are men, and math, like the rest of natural sciences, is perceived to be masculine – a subject for those who are rational, emotionally detached, instrumental and competitive. Masculine subjects seem to be valued more than feminine subjects. Math being a masculine subject further attracts men to the subject. “The high status of mathematics as a discipline may be attributed in part to its image as a masculine area. Mathematical models gain added credibility through the image of mathematics as rational and objective – characteristics associated with masculinity – as opposed to models of reality that are seen as subjective and value-laden” [22].

Women are not perceived as using logic, a perception common for the time, as the following comment portrays. Dr. O. G. Selfridge critiques the computer science journal paper “Programs with Common Sense” [23]. He states, “Deductive logic is inferred (sic) as much as anything else. Most women have never inferred it, but they get along pretty well, marrying happy husbands, raising happy children, without ever using deductive logic at all.”

According to Tavris, women have developed a better ability to integrate components in the development of solutions [29]. Men have traditionally learned to use anger to combat for survival. Women, as opposed to men, have honed their intuition and the ability to read faces because of their reluctance to use physical force. Today men do not use their intuition as often as women, as it is not as highly developed. Thus, with their heightened intuition, women have excelled at those sciences in which she must integrate, and often by default is assigned to those.

Feminine Tasks

Women receive a lot of cultural pressure to do feminine tasks under which mathematics does not fall. Many women, as are men, are naturally drawn to the study of math [28]. Kaiser describes the appeal of math and the guilt of pursuing it rather than other more expected or acceptable fields: “Mathematics is an addictive occupation, or preoccupation, regardless of gender. Becker has described features of mathematics that draw both women and men to the subject: ‘its logical nature, its problem solving aspects, its objectivity and its creative nature’ (Becker, 1990). In the mid-1960’s when I completed my degree in mathematics, I felt that the

support women who were considering mathematical careers needed most was company in guilt – guilt occasioned by their avoidance of personal and communal social responsibilities. But, securing company in guilt meant being able to find other female mathematicians, and there were fewer around then than there are now” [9].

Many homes do not give women the same support for school as they do for men. Females are expected to do many chores around the house at a young age. The male is expected to study. Women who live on campus and are relieved from their chores do significantly better than their Cinderella counterparts [13]. Women’s work, paid and unpaid, is often described as a double burden [16]. Frigga Haug [12] argues that it is more accurate to say that “women are located in two areas with contradictory logics of time”, the measured time of paid work and the unmeasured time of unpaid work, and therefore unvalued, situations where spending more time is better than rationalization.

Math’s Utility Value

Although men find mathematics very useful, women, even those who are good at it and enjoy it, often do not find it to be a useful subject. Rather, society encourages women to value careers that involve more social interaction. Math in woman’s education is seen as only as stepping-stone that will not play a major role in their final life or job goals. A common phrase heard from females is: “I can do math, and it’s even fun sometimes, but I want to choose a career that will allow me to do something useful with my life. I want to work with/for people” [25]. This statement implies that women feel that a job’s usefulness depends on their social impact within their job. Women feel that math does not allow connection with others, a common misconception about math despite the many applications of math to social concerns. “The teaching of pure mathematics as concepts and techniques separated from human concerns, plus the male-dominated atmosphere of most mathematics research groups, make a career in mathematics less attractive for those more oriented to immediate human concerns, especially women” [22].

The Association of American University Women (AAUW) has done extensive research during the last two decades of the 20th Century [1]. Their published findings include the following points in respect to math and science and gender:

- Math confidence has a stronger link to math achievement than any other variable. As girls grow up, they lose confidence in their ability to do well in math. Studies have shown that girls’ loss of confidence in their math abilities precedes a decline in achievement in the middle grades.
- Girls who do well in math tend to have nontraditional views of gender roles.
- Girls who are highly competent in math and science don’t choose related careers at the same rate as highly competent boys.

- Boys who drop out of math and science courses tend to do so because they can't do the work. Girls who abandon those fields often do so even when they are doing well in the class.

Snob Value of Mathematics

In a study designed to understand what about math is attractive to men and at the same time not attractive to women, Burton [6] asks women and men why they like math. Surprisingly, she found that men preferred to study math because there is a cultural conception that it is difficult, and they enjoyed being part of a group that could understand it. One male student said: "The fact that it was so intellectual and so hard and was so different really appealed to me...to put it bluntly, the snobbery you know, how you felt to people really stupid."

Men, in all but most recent times, were expected to be the breadwinners of the family. Intelligence was seen to be a huge benefit in the ability to support one's family. Men were continuously expected to prove themselves as capable and fit members of the productive society. Society did not have this expectation for women, although today such perceptions are changing rapidly. Studying mathematics gave some of the male students the ability to feel that they were at least, better than their peers who did not understand these concepts. The snob-value, as the student put it, supplied the males with sufficient cultural encouragement for mathematical study.

It is notable that women did not appreciate the snob value of mathematics. It is less acceptable for a woman to be smart than for a man to be smart. In high school, women often act less intelligent than they are in order to avoid the possible social stigma attached to being too smart. Smart women may be viewed as a competitive threat to the men, whereas those who hide their intelligence are encouraged by positive rather than hostile attention from the men as well as help from the men. The men enjoy helping the women as it lets them feel useful and smart, encouraging the Cinderella syndrome [21]. Women become trained that rather than act out their intelligence aggressively as men do, they should be quiet and patient.

The media's embrace of the recent technology boom has given popular social status in conjunction to their monetary gain to people with technical skills but relatively little social and personality skills. From this change in perceived value of intelligence, we have found more young men and women embracing their intelligence.

Classroom Experience

There are several things that affect a woman's success in the classroom. The teacher plays a large effect in the success of women. Many teachers assume that a woman will fail in math, whereas a male will not. Several studies performed in 1983 tested the performance of students when they participated in distance learning [19]. Distance learning is a type of learning in which the teacher was separated from the

pupil; students often submit assignments through the mail. These studies show girls' performance in mathematics equal to boys', implying that the setting in which information is learned affects the relative performance of men and women.

Many studies have been done examining women in the classroom setting. In society, women are often not encouraged to speak out. This trait/expectation usually follows into the classroom where women usually sit silent in class and don't take part in class participation as much as their male counterparts. Teachers are known to call on males more than females in class, reducing the participation of women and their voice, producing negative effects. Vygotsky relates speaking to action, and this inactivity from women severely limits learning possibilities [31]. Vygotsky found that "(1) A child's speech is as important as the role of action in attaining the goal. Children not only speak about what they are doing; their speech and action are part of one and the same psychological function, directed toward the solution of the problem at hand. (2) The more complex the action demanded by the situation and the less direct the solution, the greater the importance played by speech in the operation as a whole. Sometimes speech becomes of such vital importance that, if not permitted to use it, young children cannot accomplish the given task". This said, it seems obvious how a woman may have a more difficult time learning math if she is encouraged not to speak up [10].

Single sex learning has relieved many of the pressures of the teacher effect within the classroom. It was found in Nigeria and Malawi that single sex learning was best for girls [13]. In Malawi, girls entering college from single sex schools did substantially better in mathematics. The staff of a coed school expected less of the girls, thus the girls did not do as well.

CHOICE: A PARADIGM FOR FUTURE RESEARCH

The concept of choice occupies a central position in the social science literature. Human beings are believed to have goals that are idiosyncratic, and satisfying them is critical to their well-being. Human behavior is thus purposive, resulting from the autonomous decisions that people make to satisfy their unique goals. Any externally imposed condition that is perceived to alter the goal or restrict the means to satisfy it has been found to cause frustration, resulting in apathy. Viewed in this vein, women's absence from math is because they do not perceive to have autonomy in choice making and thus resign themselves to socially determined careers.

Although choice-based propositions have been advanced in cultural anthropology and scholars have argued how absence of choice could restrict women's pursuit of math, field investigations that would verify it have been spotty, tangential, and unimpressive. Definitional and measurement problems plague the literature. Most studies are largely exploratory, while causal and corollary research is almost non-existent.

Field Investigations On Choice

To explore how women make job choices, Reed and Dahlquist [27] asked men and women to rank order the importance of the following job factors: safe and healthy working environment, people orientation, pleasant working conditions, opportunities for promotion, task variety, ability to “do the things you do best”, and opportunities to develop close friendships. They discovered that only the last two items significantly affected job quitting. Developing close friendships at work is more important to men than women, whereas women value more to have jobs in their competitive awareness. These findings are interesting since they belie the myth that women prefer safe, people oriented jobs with pleasant surroundings. The authors found no evidence that women differentially favor those job characteristics commonly associated with ‘women’s work’.

DeLeire and Levy [8] examined male and female job preference in terms of job safety. They found that the top ten occupations with the highest risk of death are all predominately filled with men, whereas those with the lowest risk of death were predominantly filled with women. There are two exceptions: College and university teachers are only 38.6% female and the third safest profession. Math and computer science jobs are the sixth safest and with only 26.7% female. So, even if women do prefer safer jobs, this does not explain why they are not in computer science and math fields. DeLeire and Levy admit that this survey does not answer the question of whether women choose safer jobs or are socially constrained to choose safer jobs.

There is an age-old argument that students from secondary school and beyond do choose their classes, their majors, and their careers. Unfortunately, these choices are driven by sociological concerns [7]. For instance, Lage [18] found that 14-15 year olds perceive girls’ involvement with computers as due to loneliness or lack of femininity. Also, even if women are better at math and computer science than men, they perceive it to be much more difficult. The social environment coerces these choices and perceptions. This becomes clear when we compare subject selections of boys and girls in coed and single-sex schools [26]. In the former, boys primarily select math and physical science, whereas girls select English and French. In the latter, girls primarily select Physics, whereas boys prefer French.

Difficulties in Measuring Choice

Regarding why choice-based research is sparse, some researchers have begged the question by arguing that there is no such thing as empowered choice; choices are made based on our social, and individual referents [2]. Career choices are meaningful only within the context of a person’s entire social experiences, and much of a person’s life is channeled towards a particular goal by social constructs.

Lightbody and Durndell [20] express further difficulties for measuring choice: not only does society construct social stereotypes, but students often self-stereotype their own

abilities and preferences to be in accordance with society’s stereotypes. The authors’ proposed solution is to identify and target potential women candidates in engineering and revise course content to encourage women students. Gottfredson describes how men and women both have a “self-defined social space” and a “zone of acceptable alternatives” within which an individual is more likely to consider vocational alternatives, and how these are markedly different for women and men [11].

A Proposed Framework for Choice-based Research

Mainstream research on the role of choice in women’s career selection is still sparse. One reason for this deficiency is that social determinism is still a convenient model to undertake on the subject. A second reason pertains to the confusion surrounding the definition of choice itself: it is culturally constructed or idiosyncratically determined? A third reason is that causal and well-integrated models that would test choice along with other competing arguments are missing. The importance of such models for theory building and accumulation of generalizable research data cannot be underestimated. They could possibly indicate that women are absent from math because: (a) they lack the autonomy to make independent choices; (b) they have the power to choose but they are alienated from mathematics because cultural taboos are still fresh in their mind; (c) their absence from math is an aberration – it is a statistical artifact.

To provide the initial groundwork needed for investigating choice along the above lines, this paper defines choice as a behavioral outcome emerging from the idiosyncratic, deliberate, and purposive thinking of individuals. Inherent in this definition is the notion that individuals will make educational or career choices in a way that effectively uses their innate aptitudes and preferences toward fulfilling their life goals. Following the social science traditions, this definition assumes a “high-low” dimension in the condition surrounding choice making. Thus, in a high choice situation, the choice maker perceives total autonomy and has further exercised this autonomy by selecting a course or career according to her innate preferences. In a low choice situation, the choice maker perceives limited or lack of autonomy and has chosen a course or career according to someone else’s preferences a low choice condition would indicate a passive and externally determined selection. In statistical terms, the correlation between personal preferences and what is selected will be high in the former and low in the latter.

The above framework assumes that the effect of exogenous variables, such as culture, on both the perception and exercise of choice will be neutral because subjects for a study of this kind will generally emerge from homogenous social groups only. Questionnaire items to measure choice should therefore focus on endogenous variables only such as individual preferences, aptitudes, needs and goals, family expectations, perception of autonomy in choice selection, satisfaction with the choices made, and curricular

performance. Data on the latter mentioned variables are especially critical since they would indicate the extent to which choices were made autonomously. In other words, satisfaction and performance will be high in instances where choices were made based on one's preferences compared to those that were externally determined. By using both men and women in sample construction, and by operationalizing the framework across different social settings, realistic results can be obtained.

CONCLUSION

Traditional research relied on biological determinism to test women's absence from mathematics. Current investigations use socially determined criteria for this purpose. A third causal factor discussed in the literature, choice, has received very little research attention due to a lack of appropriate analytical frameworks. The authors of this paper contend that realistic data on the subject can be obtained only by examining choice side by side with other causal variables and offer an integrated model for the purpose.

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