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A cross-cultural survey of female undergraduates' aspirations for scientific study and careers

(Uma comparação cultural entre as aspirações de estudantes de graduação pela carreira e pelo estudo de ciências)

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Almost worldwide, females still comprise a minority of degree-holders and employees in the physical sciences. Although a significant amount of research has been done to investigate and improve the underrepresentation of females in science, the problem is far from solved. Since this is still a global issue, this cross-cultural study uses qualitative survey responses completed by approximately hundred Indian, American and Brazilian female college/university science students to identify factors that influenced students to choose scientific majors and plan for future careers. Both differences and common influences between cultures have practical implications for techniques to help attract and retain women in science worldwide.
Keywords: qualitative survey, cross-cultural study, female career.

Em praticamente todo o mundo, mulheres ainda constituem uma minoria entre portadores de diplomas e trabalhadores na física. Embora uma quantidade significativa de pesquisa tenha sido feita para investigar e corrigir a sub-representação das mulheres na ciência, o problema está longe de ser resolvido. Como esse é ainda um problema global, esse estudo comparativo de culturas utiliza respostas a pesquisa qualitativa completada por aproximadamente um cento de estudantes universitárias, nas áreas de ciências exatas, tanto brasileiras quanto indianas e americanas, para identificar os fatores que influenciaram sua escolha de área, bem como seus planos para uma futura carreira. Tanto as diferenças quanto as influencias comuns entre as culturas tem implicações práticas em técnicas para ajudar a atrair e manter as mulheres nas ciências através do mundo.
Palavras-chave: pesquisa qualitativa, comparação entre culturas, carreiras femininas.

"If we're going to out-innovate and out-educate the rest of the world, we've got to open doors for everyone. We need all hands on deck, and that means clearing hurdles for women and girls as they navigate careers in science, technology, engineering, and math".
First Lady Michelle Obama, September 26, 2011 [1].

"Se formos inovar e educar o resto do mundo, precisamos abrir portas para todos. Precisamos de todas as mãos na tarefa, e isso significa retirar os obstáculos para mulheres e meninas quando elas navegam em carreiras em ciência, tecnologia, engenharia e matemática."
Primeira Dama Michelle Obama, Setembro 26, 2011 [1].

1. Background and motivation

Several international studies have been conducted on the underrepresentation of women in science, Technology, Engineering, and Math (STEM) [2-7]. But recent researches tend to focus on STEM employment trends later in life [8,9]. An interesting report [10] says this underrepresentation does not arise because women are less skilled in those areas but because they elect to pursue other opportunities. The present study investigates undergraduate females' perceptions regarding science during a key junction when many students formulize and confirm the direction of their career trajectory.

The cross-cultural nature of this study adds insight to this global issue by comparing populations with different retention patterns and cultural stereotypes. In the United States and Brazil, many females are deterred from science as early as elementary school and the numbers continue to drop after each educational level [11], the so-called "leaky pipeline" effect. In contrast, the "glass ceiling effect" characterizes retention patterns in India [12]where the percentage of women stays relatively high through graduate school then representation in the workforce drops dramatically. Although

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women have earned 37% of all doctorate degrees awarded by Indian institutions, they hold fewer than 15% of science faculty positions. The societal stereotype - "girls aren't good at math and science" that remains relatively widespread in Western countries is increasingly less uncommon in India where females have been outshining their male counterparts in these subjects on national exams over the past decade.

Qualitative analysis helps find patterns in American, Brazilian and Indian undergraduates' survey responses to explore which experiences initiated, encouraged and discouraged interest in scientific fields. Analyzing open-ended questions allows students to identify their most influential life experiences without the restriction of pre-selected multiple-choice options, adding depth and detail that large-scale survey efforts miss. The results of this study are particularly important to teachers and family members who can encourage young women to consider these professions. An increase in the number of females graduating with STEM degrees will create a larger and more diverse applicant pool available to fill job vacancies and promote the economic vitality of their respective countries.

1.1. Study design

1.1.1. Data collection

This study surveyed females from a prestigious women's college in India (30 respondents), a Baptist liberal arts women's college in the United States (28 respondents) and a top ranking co-educational university in Brazil (28 respondents), between 2011 and 2013. Most of the Indian students surveyed were pursuing honors degrees in physics (68%) and chemistry (25%). Since the Baptist Liberal Arts College does not offer physics as a major, approximately 75% of the surveyed students from this population were studying biology, chemistry or a combination of the two, with an assortment of other majors. Essentially all of the surveyed Brazilian students were pursuing degrees in physics. Variations in institutional type and academic major contribute to differences in the surveyed populations that extend beyond culture, but most results are disaggregated into these three student populations.

The data consists of responses to the five short answer questions listed below. The survey was completely voluntary so the respondents would respond honestly to the questions with a valid portrayal of their opinions.

1.1.2. Qualitative Survey Questions:

1. What made you choose your major in college?
2. Was your current major your first choice? Why or why not?
3. Did a teacher or role model inspire you to pursue science? How?
4. If you have made up your mind about further education and long term career plans, what are they?
5. At what age or stage of your schooling did you make this your career choice? Why?

1.1.3. Data reduction

In order to analyze survey responses, answers were transcribed and organized into a spreadsheet. Question responses were split up into segments that contain one primary idea to be coded exclusively within each domain. The codes were developed iteratively, based on both literature and collected data. Specific codes were organized under three independent domains: scientific identity, past experiences and outcome expectations that describe a student's present, past and future influences (respectively). Statements that explicitly mention a positive or negative impact were coded as "encouraging" or "discouraging", respectively.

The "scientific identity" domain in this study was influenced by Hazari's gender study [13] on likelihood for choosing a physics career based on high school experiences. Statements that discuss students' present perception of their interest, performance, competence in science and recognition as a "science person" were coded under the "scientific identity" domain. Past experiences fall under the "outside influence" domain, for example, statements about past advice, influential courses or extracurricular activities (such as a job or research experience). The "outcome expectations" domain includes future plans for specific degrees/ careers, financial goals, yearning for prestige or extraneous goals (such as a flexible career, people-friendly profession, opportunity to travel, etc.).

To establish inter-rater reliability, an independent researcher was trained in the code definitions. After preliminary coding and discussing disagreements, code definitions were refined and the process was repeated for a larger portion of the data. Reliability scores were found to be above benchmark values, suggesting that independent researchers could apply the code definitions consistently and that agreements are unlikely to be coincidental.

1.2. Results

1.2.1. What do undergraduates consider when choosing a course of study and/ or career?

Figure 1 displays the percentage of statements under each domain, by culture. Assuming the frequency of statements is correlated with how much each domain influenced the surveyed students; we can infer something about the domains that influenced each population the

most. All three populations mention influences from all three domains and responses reveal some common themes across culture. However, there are some notable differences, especially within the "outcome expectation" domain.

An interest in science was a primary motivator for students from all cultures. An American explains why biology interests her; "I like that everything (at least the basics) tend to follow rules that can be explained. I like that things are tested (experimentation). I would like to work in a field that is consistently changing/ advancing". An Indian student describes a similar sentiment, "I love physics it helps to understand what is going on in the nature around us, physically as well as mathematically". A curiosity about the natural world initiated interest for several students including a Brazilian who decided to study physics when she "was 9 years old and looked at the stars".

Under the "outside influences" domain, students from all populations mention high school teachers and family members as influential, while several students discuss being primarily self-motivated. An Indian student reflected on her role models and wrote, "to some extent it was my mom, but I myself was so interested from my early stages that no one needed to influence me". Unlike teachers who were almost exclusively mentioned positively, advice from family members deterred some students when "family disapproved of the course". Several Indian students and a Brazilian student (but no American students) mentioned historical scientists as inspiring. For example, "Marie Curie inspired me, as she was a woman researcher in an age when scientific research was dominated by men" and "Albert Einstein. He was a great physicist and I admire his work. His work, discoveries and research inspired me to attempt to get to their level".

Statements in "outside expectations" domain varied noticeably between cultures. Many Americans consciously chose their major with a specific lifestyle in mind, deciding on a practical and interesting career path. An American kept switching majors until she found a field she enjoyed and could imagine a future; "I enjoy puzzles looking at how things fit together and why they work. Biology and then Chemistry turned out to be exactly what I liked.... [With] previous majors... I liked the courses but didn't see myself doing anything with them in the long run." Similar statements from Americans discuss choosing a major that "I thought would prepare me the most for the kind of things I want to do later in my life".

Indian and Brazilian students express more abstract and generic career goals, often listing off educational degrees in preparation for a future in academia. For example, "I plan on doing M.Sc., then Ph.D. in physics. I even want to continue my life with physics" and one student explains making her career decision "after 12^{th}. All said teaching job is better for girls, that's why I chose academics & due to my deep interest in science, I also decided... to go in research also". Brazilian students tend to mention similarly generic career goals, probably because they are less familiar with career options available degree holders in the sciences. One Brazilian admits wanting to work outside of academia but thinks it will be difficult. She states, "I would like to work in industry but they don't encourage it at my University".

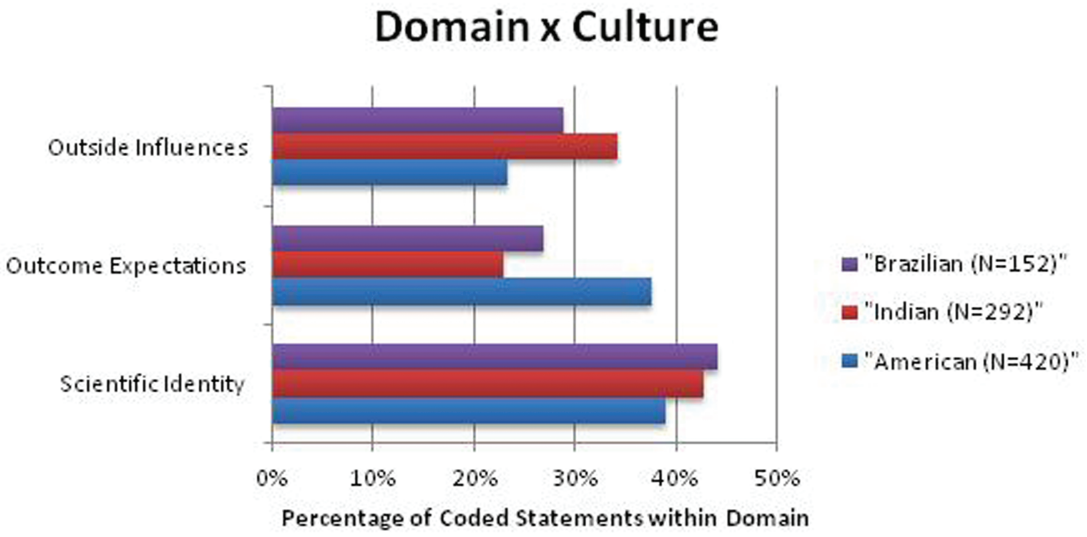

Figura 1 - Percentage of segments that fall under each influence code, by culture. N denotes the number of total coded statements for each population.

1.2.2. What factors encourage female undergraduates to pursue scientific study and/ or careers? Are there differences in which factors encourage students from different cultures?

Figure 2 displays the percentage of statements coded as having an encouraging impact across each of the domains for each student population.

Indian students mention encouraging extracurricular experiences (often research) about twice as often as their American counterparts. An Indian student writes, "I actually got highly affected during my project... Theories can be learnt anytime, anywhere but it's really important that how one can apply his brain practically.... so it helped me a lot in solving my doubts about some basic concepts....". Other Indian students echo the importance of research enhancing content mastery while increasing their appreciation for the scientific process, "these projects and mini projects somehow make learning much easier and provides a creative way to deal with it". Since the institution surveyed in this study has a research project requirement (which is atypical for other colleges in India), these experiences are probably less common for other students in India. However, research projects allowed these students deepen conceptual insights and gain an appreciation for experimentation so expanding similar opportunities could help others enjoy multi-faceted benefits.

These past research experiences often inspire Indian students' outcome expectations. An Indian student discusses hopes of attaining a prestigious career in research because "the vastness of applications, practicality, power and importance of chemistry today made me choose this course that... will give me a sound foundation for research ahead." An Indian student explains how she decided to forgo study in mathematics so she could pursue a Ph.D. "in some experimental field for which I can have better options in physics and establish my own lab with new equipment". No statements like these were found in the American or Brazilian student responses collected in this survey. This is not surprising for the surveyed Americans since research opportunities were limited at their small liberal arts college. The lack of positive research experiences for Brazilian students is slightly more unexpected, since the students attend a university with a graduate program.

Brazilian students have an even higher percentage of statements in the outside expectation domain, often under the "mentor" code, describing experiences when teachers, parents or friends encouraged them to pursue science. For example, one Brazilian said that her father and high school teachers "inspired me to study physics because I earned the best grades". Perhaps the Latin American emphasis on family and community contribute to the higher frequency of these statements.

1.2.3. What discouraging experiences cause females to change their initial course/ career plans? Are there differences in discouraging influences for these three different populations?

Figure 3 displays the percentage of statements coded as having a discouraging impact across each of the domains for each student population.

There were interesting and significant differences in what caused students to switch paths, with Indian students often deterred by low examination results while American students shy away from uninteresting subjects or unappealing job prospects.

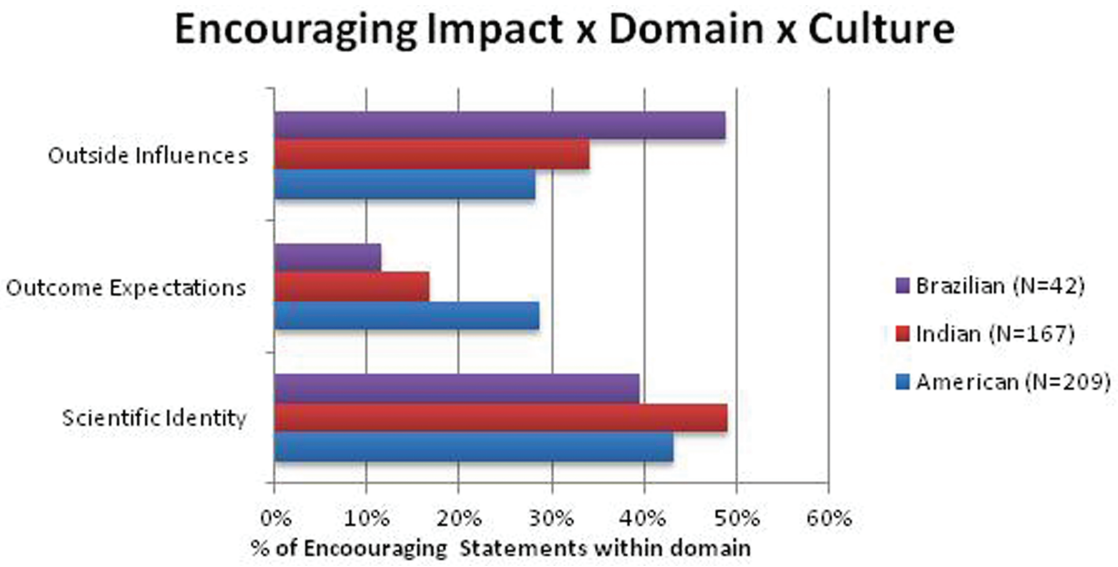

Figura 2 - Percentage of statements coded as having an encouraging impact that fall across each of the domains, by culture. N denotes the number of total coded statements for each population.

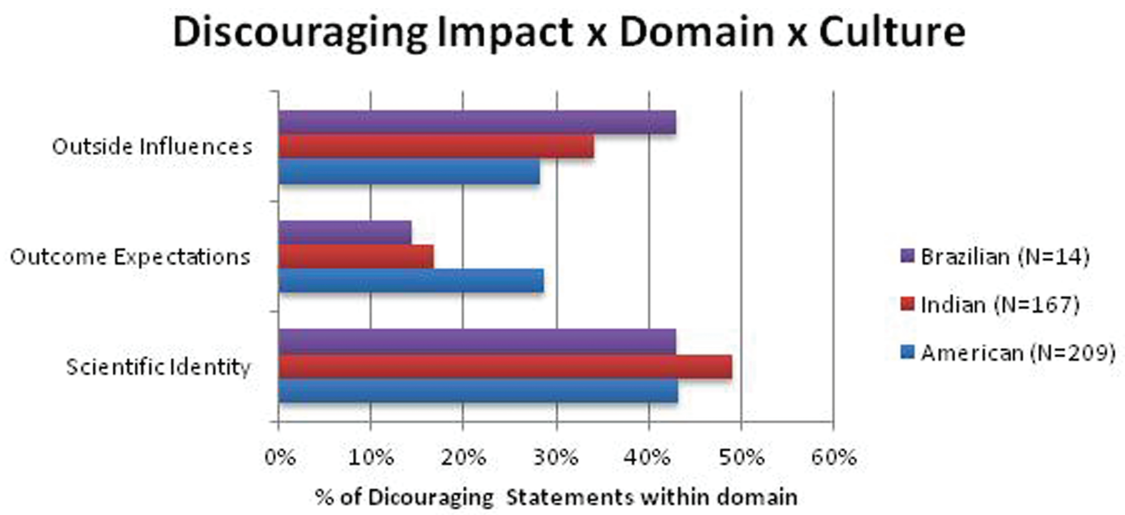

Figura 3 - Percentage of statements coded as having a discouraging impact that fall across each of the domains, by culture. N denotes the number of total coded statements for each population.

The relatively large percentage of Indian negative experiences under performance code is not surprising considering India's countrywide examinations whose inflexible cutoffs limits which colleges and courses a student can pursue. Interestingly, performance and interest tend to be tightly linked for Indian students. One states, business "was top choice, I was not selected in any of the entrance and also of the realizing myself if weak in the practical work that must be conducted during the course, I lose my interest." Similarly, a low rank on an engineering exam makes another Indian student "rethink about my previous decision of making career as an aeronautic engineer then I realized astronomy is my true interest and I decided to make a career as an astronomer." This apparent link between performance and interest casts some doubt on whether Indian students' self-reported "interest" in science really comes from an intrinsic enjoyment of the subject or whether good grades have initiated this "interest". This would be an interesting issue to investigate with in-depth interviews that can probe this issue more deeply and distinguish between an authentic and an externally instilled "interest".

Some of the students who changed their initial career plans because of exam results have found satisfaction but others seem even more likely to pursue their original non-scientific careers despite studying science in college. For example, one Indian student who studied physics because she did not get into business school voices disillusionment with a lack of creativity in science, which affirms her desire to work in non-scientific fields. "I want to pursue MBA or a job as probationary officer in bank [sense] I realized that in India, core sciences are only limited to studying only books and not really going for something innovative. Even the experiments performed in the labs are crammed up." She mentions a lack of academic freedom in India where "families don't really allow you to go outside your restricted area for research, and colleges don't provide enough liberty to perform the experiments."

In contrast to Indian students with performance-limited options, multiple American students chose an enjoyable subject over one where they naturally excel. One student recalls how she chose biology even though "this major was not my first choice. My first choice was mathematics and I discovered that I enjoyed biology a lot more. I am better at math but I enjoy science more." Another student chose psychiatry for similar reasons "I am good at science but it is more of a hobby...I like psychiatry better." American students have more freedom to select majors based on their own interest, which often results in choosing "the path that would make me happiest". In addition disinterest in the subject itself, some Americans find scientific jobs unappealing; "other career opportunities seem more desirable to me". Other deterrents include a lack of exposure, "I don't even know what type of careers in physics are out there", the perception that science careers limit interactions with people "I love working closely with people (not in a lab)" and aspects of the work environment "it is a tough area to get a job, only the best ones are successful and it is a male dominant field".

Several Indian and Brazilian students anticipate gender may negatively impact acceptance in the field. "I feel science society is male dominant and women is always confined to home" and fears that a "job in good companies or MNC's (multinational companies) is not safe or convenient for women due to late timings". Harsh treatment from a professor deterred a Brazilian student from studying in the field. "I stopped working in the discipline for this factor. I was struggling in phy-

sics and instead of helping me with my difficulties, a professor said I should learn about make-up and not learn physics". No other Brazilian students mention specific instances like this but one acknowledges she feels "I would not say discriminated, but underestimated. Because I'm what they call a beautiful woman, I'm usually not expected to be intelligent." Another Brazilian student, who teaches physics, suffers from a similar lack of recognition; "Often many people doubt I know physics... when I say, 'I'm the teacher', they look at me without conviction, not believing I know physics". It appears that there are still substantial socio-cultural barriers to overcome for Indian and Brazilian students before they can feel comfortable in the scientific workforce.

2. Discussion

By surveying undergraduates from three different countries, this survey successfully identified important commonalities and illuminated differences about how females chose scientific studies and plan for their careers. Although differences between populations cannot be exclusively attributed to culture, common themes across populations have immediate, practical implications for a wide variety of women since the respondents represent a range of ability levels and socio-cultural backgrounds. Students from all cultures value advice from mentors (especially teachers and family) and an interest in science. Many students mention research as a particularly positively influence (if they were given the opportunity), helping them to decide whether to pursue futures in academia.

Many of the Indian students discussed research experiences while American students often had more outcome-oriented motivations. Brazilian students commonly mentioned "outside influences", especially mentorship. As far as discouraging experiences, performance on national exams affected the decisions of several Indian students since admittance to a major requires surpassing benchmark scores. In contrast, natural ability in a subject area is less important to American students since several chose a major based on intrinsic interest over natural aptitude.

Ensuring females are exposed to a wide variety of scientific career options (beyond academia) can encourage students from all countries to get excited about futures in science. Many American students mention motivation from specific career goals whereas many Brazilian and Indian students listed very generic employment aspirations. This could indicate a lack of exposure to options outside academia especially since most of today's undergraduates in developing countries will out-educate their parents. Studying a subject without focusing on career implications could contribute to Indian women leaving science (instead of working) after they complete their studies, an issue that deserves more investigation. Exposing students to what it is like to work in these fields might help students find jobs where they will be interested and successful.

Connecting high school students or undergraduates to female scientists could simultaneously address many of the suggestions in this study. Female scientists could provide mentorship, quiet concerns about working in a male-dominated environment and give tangible examples of working in science careers outside of academia. Hopefully, suggestions from this study can address these issues at early stages in decision-making to increase the representation of females studying and working in technical fields.

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