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WHY WOMEN TEND NOT TO CHOOSE MATHEMATICALLY DEMANDING CAREERS: A SYSTEMATIC REVIEW OF ALL TIME LITERATURE

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More than 30 years of intensive research on women's participation in sciences, technology, engineering and mathematics (STEM careers) have shown how women tend to be severely underrepresented, particularly in mathematically demanding careers. This research has explored reasons of underrepresentation from different perspectives and reached contrasting results. Existing summary reviews have offered useful but non-systematic approaches, presenting difficulties with the identification of emphases and gaps in the literature. This paper presents preliminary results of a comprehensive systematic literature review. By analysing purposes, methods and perspectives from a broad sample of papers, this study aims to explore gaps in the literature and advance a model that allows for integration of dissimilar approaches.

UNDERREPRESENTATION OF WOMEN IN MATHEMATICALLY DEMANDING CAREERS

The problem of the representation of women in mathematically demanding careers has been described as both progressive and persistent: it remains despite several interventions and treatments and becomes more acute in more advanced levels of the academic career (Cronin & Roger, 1999). For example, in Chile, while women in life and social sciences account for over 50% of students in undergraduate programs, in mathematics, engineering and computing they are 34%, 24% and 10% respectively (SIES, 2016). Women in the academic careers are even less represented. For example, in three of the biggest engineering programs in Santiago de Chile women account for only 16-17% of lecturers and professors with more than half-time contracts (number derived from public information in websites of Universidad de Chile, Universidad Católica y Universidad de Santiago).

Promoting female participation in careers with intense mathematical content is important for several reasons. Firstly, more participation of women can strengthen sciences through diversification of the labour force. Several studies have proven than diverse groups of people work better, are more creative and provide better solutions to complex problems (e.g. Smith & Schonfeld, 2000; Woolley et al., 2010). In addition, increasing women's participation in STEM can reduce social inequities produced by their low participation in highly valued careers and the corresponding gender pay gap (Petersen & Morgan, 1995).

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Following the persistence and relevance of the problem, many researchers have attempted to understand the reasons for women's underrepresentation on mathematically demanding careers. 30 years of intensive research have come from different paradigms and theories to explore why women tend not to choose STEM, yielding dissimilar results and emphasizing different facets of the problem. Many researchers have tried to summarize this evidence following their own reviews of the literature. For example, in the process of reviewing the literature I have found at least 20 reviews. Even though these reviews provide valuable information, as a group there are important weaknesses.

Available reviews have either provided atheoretical summaries of reasons why women remain underrepresented in mathematically demanding careers or presented systematic focused reviews on the evidence of one theory as an explanation of this issue. On one hand, the main weakness of the summaries reviewed is that they have not presented a systematic approach in their methodologies. Some examples are Roger and Duffield (2000), Blickenstaff (2005) and Wang and Degol (2013). These reviews provide lists of factors with and without evidence of the impact on women's STEM career choices, but their narrative approach makes it difficult to get a sense of how the research has emphasized different explanations and what areas remain unexplored. On the other hand, systematic reviews have been focused on understanding the literature that has used one particular theoretical model or approach. For example, recently Su and Rounds (2015) and Boucher and colleagues (2017) explored how stereotypic perceptions of STEM as not affording communal goals that influence who enters, stays and excels in engineering, mathematics and computing. These focused reviews allow a more accurate account of the amount of evidence for this particular theory, but do not allow the integration of this evidence with competing theories in the field.

Systematic and integrative analyses of the literature in the understanding of women's mathematically demanding career choices are needed for two main reasons: 1) it can provide a clear sense of what the literature has been focused on and therefore which areas remain unexplored; and 2) it can advance the development of models that could bring together literature coming from diverse paradigms and allowing better integration of evidence. This research addresses these needs by systematically analysing the literature on women's STEM career choice using an identity lens.

USING IDENTITY AS A LENS FOR UNDERSTANDING LITERATURE ON WOMEN'S CHOICE OF MATHEMATICALLY DEMANDING CAREERS

By and large, the literature that has tried to explain women's choice of mathematically demanding careers has presented complex relationships between individual choices and social influences. One relevant concept that can be used to understand these complex processes is the concept of identity. On one hand, identity considers different individual dispositions that have been found related to individual academic decisions, like interest (what I like or enjoy), aspirations and goals (who I would like to become) and perceptions of one's own ability and expectations of

success (what I am capable of), etc. (Eccles, 2009). On the other hand, many authors have suggested that this concept allows for broadening the focus of the interrelated understanding of subjective experiences in mathematical social contexts, including learning activities (a sense of who I am in a particular learning context), belonging to social groups (who I am in relationship with others), and social categories and influences of culture and society (who I am in a group and who we are in society) (e.g. Lerman, 2001).

The complex interrelation of aspects that the identity concept has tried to account for has given rise to multiple identity definitions that differ theoretically and methodologically (for reviews on mathematical identities see Darragh, 2015 and Radovic, Black, Williams & Salas, 2018). In our review, my colleagues and I suggested that these different definitions at least differ in three dimensions: a change/stability, a representational/enacted and a subjective/social dimension (see Radovic et al., 2018). For example, if we apply these dimensions to the study of the underrepresentation of women in mathematically demanding careers, the process can be understood as a development in time or as a choice (change/stability), focusing on the act of choosing or on representations that may influence this act (representational/enacted), and considering individual or/and social circumstances (see examples in Radovic et al., 2018). These different emphases and focuses will have implications on the general understanding of the problem. For example, if the focus is placed on individual characteristics, it can be assumed that there is only one way of doing mathematics (in which I am good or bad) or that there is only one type of mathematician (with which I identify/or not) independent of context. In contrast, if the social construction of individual choices (relationships and identities) is considered, mathematics and gender can become constructed phenomenon, where local and cultural negotiation of meanings and discourses happen.

Following the usefulness of identity as a concept for the understanding of choice and the previous analysis of its different uses for the understanding of individuals' relationships with educational subjects, this review uses this concept for the analysis of literature on women's mathematically demanding career choice. The analysis is focused on answering how this literature has approached the choice process from an identity perspective, considering how individual and subjective aspects of the decision, disciplinary context, relationships with others, gender, and social discourses are considered. This analysis will allow identification of emphases in the literature and a critical analysis of the available evidence.

METHODOLOGY

A systematic search of concepts related to gender (gender OR women OR girl), career choice (career choice OR career interest OR career aspiration) and STEM (stem OR mathematics OR computing OR engineering OR physics OR technology) was carried out in two of the most important databases [Web of Science and Scopus]. These searches yielded 1125 hits after duplicate deletion. As this is a working project, this report will be focused on 400 randomly chosen articles.

Titles and abstracts of the 400 articles were screened to see if they fit the purpose of exploring reasons for the underrepresentation of women in STEM, focusing specifically on women or gendered influenced choices of STEM careers. I excluded 116 articles that were not focused on the process of choosing a STEM career (these were mainly articles that were focused on persistence in STEM academic careers or into work after the process of choosing) and 41 articles that did not present data (reviews, commentaries and projects). After this process 243 articles were selected to be included in this report.

The process of analysis of the 243 papers followed two steps. First, general characteristics of the articles were coded including types of article (study or intervention), area of STEM covered, how categories of women and gender were considered (differences between sexes, focus on women, intersectional, other), in which stage of the career trajectory the sample of the article was focused and methodology. All of this information serves as context for the purpose of the articles and as categories for comparisons. After that I followed a thematic synthesis approach (Thomas & Harden, 2008) in analysing the articles' purposes and focus as described in the abstract and method sections, going from open coding to more abstract categories. I was interested in understanding how each article engaged with the problem, how authors operationalized the decision process and variables that were considered in the analysis. Using theoretical tools derived from the concept of identity, I went from codes highly attached to data to more general descriptions of the approach of the article, considering how the main focus of the article was defined (e.g. interests and aspirations, choice, decision and participation, motivations, identity, etc.) and what intervening variables were considered (individual variables, local contexts, and socio-cultural constructions). Implications from this conceptual approach were explored in relation to how mathematics (and STEM) and how gender (or being a women) was approached.

RESULTS

The first article included in this review was written in 1989. Since then, research on women's decisions to study mathematically demanding careers has grown significantly, with most articles being published in the last 5 years. In relation to specific areas 95 articles focused on STEM careers in general (39%), 49 in computing and information technologies (20%), 34 in engineering (14%), 29 in science (12%), 21 in mathematics and physics (9%) and 15 in other STEM careers or did not specified (6%). Initially, articles were categorized into two main groups: articles that presented interventions (including or not its evaluation) (38%, n= 92) and articles that presented studies (62%, n= 151).

Articles focused on Interventions

The big number of articles that present interventions shows how increasing representation of women (and other minorities) in STEM careers has been a matter of concern and a focus of initiatives aimed at solving this problem. Most interventions

(55) where explicitly designed and implemented with a focus on women or girls. 15 were open for boy/men and girls/women, but had an explicit focus on girls/women, and 18 were focused on students in general (9 of them on minority students), with mentions of gender and other diversities represented but not with an explicit focus on them. Only 4 intervention programs had an intersectional approach, focusing their design and implementation on specific problems of girls from ethnic minorities (e.g. appalachian girls, hawaian girls). Most interventions were focused on school students, with 7 focused in elementary school, 32 in middle school, 29 in high school and 8 in general K-12.

The vast majority of articles that presented interventions aimed at increasing girls (and other minorities) interests and motivation to pursue a mathematically demanding career by offering different programs of "engaging" activities. In this sense, these interventions used an understanding of the individual choice and the commitment with a STEM identity as determined by how the social activity of doing STEM is presented and experienced by students. Examples were after school activities, summer programs, elective courses and workshops with hands-on experiences, focused on problem solving, students' (and girls) interests and some considered mentoring and communication with role models.

An interesting finding regarding interventions was that most of the interventions were designed as out of school activities, where students visited universities, colleges or private companies (65 articles, 71%). Only 20 articles (22%) described interventions to school science and mathematics. These interventions offered elective courses and workshops, usually designed by academics or experts in the field and implemented by school teachers or embedded new approaches to school science and mathematics by offering professional development to school teachers in curricular or teaching innovations.

Research Studies

In relation to research studies, a huge emphasis on quantitative data and methodologies was found (n= 115, 76%). Only 24 articles used in-depth exploration and qualitative data (16%) and 12 attempted to mix different sources, mainly by using interview data (qualitative) to explore more detailed survey data (quantitative) (8%).

When analysing how the problem of underrepresentation was approached by research studies, it was found that **all of them** considered subjective experiences and/or individual characteristics as explaining factors. Students' interests and motivations, beliefs about their abilities (self-efficacy and self-concept), confidence, and even some personality traits (competitiveness, perfectionism and orientation towards people or things) were considered. An interesting result regarding how studies explored women's underrepresentation was that a third of the reviewed articles (50) only considered these individual level variables, leaving any social influence unexplored.

In the majority of studies the individual experience of choosing a STEM career was analysed in relation to social variables and considered social contexts. On the one hand, 71 studies (47%) considered proximal contexts influencing individual choices, including background characteristics and the beliefs of parents and teachers (20, 13%), perceived support (29, 19%), how mathematics, science and general STEM is presented in local practice (including teaching and controlled manipulation of environment) (24, 16%), experiences of advanced science/mathematics courses (9, 6%), school characteristics (type, socioeconomic status of school) (6, 4%), and in a smaller number, relationships and interactions with peers (3, 2%).

On the other hand, 46 studies (31%) considered more distal, macro social variables in their inquiries, including institutional distribution of privilege (through for example access to courses), cultural differences in equity indexes between countries, and stereotypes, public images and cultural discourses about mathematics, STEM and gender roles in society. Only a very few (15, 10%) explored macro variables and local variables at the same time, with about half of them exploring how social discourses and institutional constraints are expressed in support and characteristics of socializers, and half on how STEM and mathematics is presented in the classroom/school.

CONCLUSION AND DISCUSSION

This preliminary analysis of articles aimed at understanding women's choice of mathematically demanding careers offers interesting insights regarding the emphasis of the literature in the field. Interventions worked with the idea that individual attitudes and dispositions were intrinsically related with the local experience of doing mathematics and STEM activities. By working with meanings and practices related with STEM, interventions were aimed at changing these individual dispositions. An interesting result regarding these interventions was how most of them were designed as out of school activities. This suggests that activities were offered as independent form regular students' learning activities, contributing to the disconnection between school mathematics/sciences and university/professional STEM careers.

In contrast, research studies showed a big emphasis on individual attitudes, with many of them exploring these individual dispositions in relation to social variables. One interesting result in this regard is how the construction of general discourses in local practices is a neglected topic of research. There is an established literature about mathematics and STEM gendered stereotypes, and this study surveyed some of them (e.g. Cheryan et al., 2013; Leslie et al., 2015). Only very few articles explored how local practices constructed mathematics and STEM as masculine/feminine, for example, through lack of support for women and through particular practices (e.g. non communal).

Although these preliminary results are encouraging about the value of this analysis in advancing the understanding of women's (lack of) participation in mathematically demanding careers, this is only the first step. More detailed explorations are needed.

For example, in interventions there is a clear emphasis on STEM constructions and local activities and how these may affect individual dispositions and identities, but the current analysis does not allow for the exploration of how these local practices relate to gender. Are activities designed as more engaging by, for example, being more similar to "real" STEM (what STEM professionals do in their professional lives or what STEM students do in their careers in HE) or by being closer to "women's/girls'" needs (making STEM more female friendly)?

A more detailed analysis of how gender is considered in research studies can also strengthen the results that were presented in this report. For example, Risman (2004) has argued that gender can also act simultaneously on different levels, influencing individual choices, social practices (expectations, bias and interactions), and institutions and institutional constraints. Again, on these different levels gender (and gendered identities) can be conceptualized as a sex category that is stable and given or can be understood as a social construction, where individuals are required to perform in certain ways that are culturally determined. Although in this preliminary analysis, a strong emphasis on gender as differential and therefore as sex category was observed, further analyses are needed to explore in which cases more detailed constructions of gender are explored.

In summary, this article suggests that there are concerning disconnections between literature and between approaches for the understanding and intervention of the problem of women's underrepresentation in STEM and mathematically demanding careers. Developing different analysis from the entire literature and testing different models of understanding, their approaches and evidences are needed for advancing in this integration. This study will be an attempt towards this direction.

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