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# Attitudes and self-beliefs of ability towards mathematics and science and their effects on career choices

## A case study with Macao-chinese girls

***Abstract*— *This study explores girls' attitudes and self-assessment of abilities towards mathematics and science and its effects on career preferences.***

***Results from Pisa 2012 stated that Macao girls do as well as boys in mathematics and science. However, less than 0,5% of Macao girls contemplate pursuing a career in mathematics related fields and less than 2% contemplate pursuing a career in science related areas. In this research, which follows a quantitative design and was developed in the academic year of 2013/2014, we studied the female students of Macao secondary schools who also attended a Foreign Language course at Macao Portuguese School. The study is focused on a sample of 45 elements. The "Modified Fennema-Sherman Mathematics and Science Attitude Scales" was adapted to measure students self-beliefs and attitudes towards mathematics and science along four domains, namely (a) confidence, (b) usefulness, (c) mathematics and science as a male domain, and (d) students' perceptions of their teachers' expectations regarding the abilities of male and female students in both subjects.***

***The results suggested that (1) the female students' self-beliefs on abilities in mathematics and science are below average; (2) the female students' attitudes towards mathematics and science are positive; (3) the students attitudes and self-assessment of abilities towards mathematics and science are not significantly related to their intended choice of university degree; (4) the female students do not assume mathematics and science as a male domain; and (5) the female students do not perceive their teachers' expectations regarding girls' mathematics and science skills as lower than boys' mathematics and science skills.***

***Keywords*— *gender gap, Macao, STEM***

## I. *Introduction*

For more than thirty years research findings pointed out that men outnumbered women in Science, Technology, Engineering and Mathematics (STEM) [1], [2], [3], [4], [5], [6], [7], [8], [8]. Improvements have been made with regard to the gender imbalance in the science and mathematics related fields. However, the most recent global indicators still call attention to the underrepresentation of females in STEM programmes. This is puzzling because general IQ tests do not show evidence of gender differences regarding average cognitive scores [9], secondary schools' science classrooms are balanced in what concerns gender, and across nations girls are more likely to complete secondary school and graduate from university [10]. A wide spectrum of factors might be mobilised to explain the reasons why the number of girls and women choosing to pursue careers in STEM areas is much lower than boys and men. Among those factors, situational ones such as self-efficacy beliefs, stereotypes, family and teachers' gendered deep-rooted belief systems, and the socio-cultural and economic environment seem to be more significant than factors based on inborn differences [4], [5], [8]. Research findings from the Programme for International Student Assessment [11] suggested that Macao girls do as well as boys in mathematics. Furthermore, Macao girls outnumber boys at the local universities and tend to be more highly educated than men [12]. However, less than 0.5% of Macao girls contemplate pursuing a career in mathematics-related fields and less than 2% contemplate pursuing a career in science-related fields [13], which indicates that the scenario of girls' avoidance of mathematics and science related careers in Macao not only follows the international tendency but is even more pronounced than elsewhere.

Some authors [12] have suggested that the development of the tourism and gaming industry and the consequent easiness of getting semi-qualified jobs at the casinos, hotels, restaurants and other supporting sectors across the city have been deviating youth from universities and particularly from programmes of greater complexity and length.

As Blickenstaff said [4, pp. 369] there is not a single explanation for the girls' avoidance of scientific fields, but that a "leaky pipeline carrying students from secondary school through university and on to a job in STEM" seems to be in place. He says that the "leaky pipeline" is formed by a mix of internal and external factors, which act cumulatively and persistently throughout the school years to university and work.

In the current study, focused on attitudes and self-beliefs of ability towards mathematics and science and their effects on the girls' career choices, we attempted to understand the reasons why so few female students show preference for mathematics or science-related programmes at university entrance level. We seek to shed light over this issue by exploring two dimensions: girls' self-assessment of abilities in mathematics and science; girls' attitudes towards mathematics and science. Within the latter, we focused on two particular factors: girls' perception of mathematics and science as a male domain; girls perceiving their teachers' expectations regarding female students' mathematics and science abilities and skills as lower than boys' mathematics

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and science abilities and skills. The following questions were formulated to steer the research:

1. How do the secondary school girls from this study assess their own abilities in mathematics and science?
2. Are the female students' attitudes regarding mathematics and science positive or negative?
3. Are female students' self-assessment of abilities in mathematics and science related to their intentions to commit themselves to a STEM university degree?
4. Are the female students' attitudes towards mathematics and science related to their intentions to commit themselves to a STEM university degree?
5. Do female students assume mathematics and science as a male domain?
6. Do female students perceive their teachers' attitudes and expectations regarding girls' abilities and skills in mathematics and science as lower than boys' abilities and skills in these subjects?

## II. Review of Literature

Blickenstaff [4] resorts to the "leaky pipeline" metaphor as a means to explain the underrepresentation of girls in STEM areas.

According to the mentioned author, girls often change the path of their studies or career during transitional points such as the moment of completion secondary studies or even after concluding the university degree, but, for Osborne, Simon and Tytler [14], the "leaky pipeline" unfolds between the ages of 10 to 14, much before the stage when it comes to choosing a career.

Blickenstaff [4] views the phenomenon of the gender gap in STEM areas as the result of various factors acting cumulatively. According to the author, schools and teachers are active players in the perpetuation of the gender imbalance in STEM. The lack of meaningful experiences in primary school, an insufficient exposure of girls to female role models in science fields and a selection of class activities commonly designed to motivate boys only are but a few causes that may trigger demotivation of girls towards science during late childhood and adolescence.

Scholars also call attention to a different group of factors, pervasive and yet veiled and rather difficult to address by way of school or classroom interventions: gender stereotypes, which usually favour males over females. Gender stereotypes are enduring social beliefs, which are part of the cultural tissue of societies [6], [15], [16]. Through the traditional lens of gender stereotypes women's primary role is as wife and mother, and there is a limited number of occupations considered suitable for women to work in, usually those associated with health, care and education.

Girl Scouts report [17, pp. 5] acknowledges the effects of gender stereotypes in regards to the STEM areas: "the stereotype that girls are not as good as boys in math can have negative consequences. When girls know or are made aware of this stereotype, they perform much more poorly than boys". Gender stereotypes are particularly present in societies, as in the case of Macao, influenced by Confucian values, where men are the primary authority figure in the family and women are expected to assume a subordinate role in both private and public spheres [18]. Girls Scouts report [17] also points out the positive contribution of self-beliefs in counteracting the impact of gender stereotypes. Holding positive self-beliefs towards mathematics and science learning abilities has been reported as a strong predictor of academic achievement in those areas [19], [11]. According to the two above mentioned studies, students with high self-confidence are able to use cognitive and metacognitive learning strategies in a more effective fashion that those who are not.

Boys have been reported as having systematically more positive self-beliefs than girls even when they have similar performance and, on the contrary, girls underestimate their academic performance and their ability towards mathematics when compared with boys [20], [21], [17]. These findings reinforce the relevance of undertaking research on this matter.

## III. Methodology

A quantitative approach was adopted in this study to examine girls' believes in their ability to learn mathematics and science and their attitudes towards these areas. The data were collected in a survey through a questionnaire administered to a group of female students enrolled in a language course outside their schools. The information collected was described, explained and explored [22] allowing us "to quantify a plurality of data and carry therefore numerous correlation analysis" [23, pp.189). This kind of approach, which is not of an experimental nature because there was no manipulation of variables [24], allowed for collecting data on a single occasion, in an economical and efficient way, and presents several other strengths, such as identification of patterns, provision of data, which could be processed statistically, with an eventual generalization of the findings [25].

*Population and sample*. The study population consists of about 350 secondary school female students of Macao who also have attended the course Portuguese Foreign Language at Portuguese School of Macao taught by one of the researchers. We defined a convenience sample formed by 45 girls attending the said course in 2013/14. They were aged 15 to 19 years, enrolled at Form 4 to Form 6 (the final year of upper secondary education), from 21 public and private secondary schools (out of the 47 existing in Macau).

*Instruments*. The questionnaire comprises two parts. Part 1 accounts for demographic data, namely (a) age, (b) grade, (c) current study area at high school, (d) intended area of study at university, and (em) self-assessment of abilities in mathematics; and (es) in science. The answers to (a) and (b) were numeric and to (c) and (d) were nominal. The field of study at the secondary school was grouped into five categories: a) arts; b) economy and commerce; c) political sciences, geography and history; d) humanities and languages; e) STEM. The intended area of study at university was grouped into eight subcategories, which derived from the above-mentioned secondary level categories. For the self-assessment of abilities, the answers

were given on a Likert scale of 4 levels, from A (weak) to D (excellent).

Part 2 consists of 94 questions about the attitude of each one towards mathematics and science, whose answers are given on a Likert scale of 5 levels, from A (totally agree) to E (totally disagree), adapted from the Fennema-Sherman Attitude Scale, "The Modified Fennema-Sherman Mathematics and Science Attitude Scales". This scale measure the students' attitudes towards mathematics and science in 8 (4x2) domains, namely: (fm) confidence in the abilities to understand and use mathematics and (fs) science; (gm) practical importance and usefulness of mathematics and (gs) science in the life of the student; (hm) mathematics and (hs) science understood as exclusive sphere of the male universe; (im) attitudes and expectations of teachers regarding the mathematical and (is) scientific abilities and skills of girls.

*Procedure*. For the statistical data analysis, SPSS programme was used. For the inference analysis a significance level $\alpha$=5 was considered, and either parametric or non-parametric tests were used depending on the characteristics of the variables. Since the same set of 45 individuals answered all the questions, the variables, when compared to each other, were paired. Therefore, in the tests, we treat them as such.

To analyse the questionnaire, 110 variables were set, corresponding to parts one and two: a) 6 variables from Part 1; and b) 104 variables from Part 2. The 6 variables of Part 1 correspond, each one, to the characteristics (a) to (e) (see table of Fig. 1).

FIG. 1. QUESTIONNAIRE VARIABLES – PART 1 AND 2

| Part | Variables and their meaning |
|---|---|
| 1 | (a) age of each student when she fills the questionnaire |
| | (b) grade attended by each student |
| | (c) current study area that each student attends at high school |
| | (d) study area that each student wish to attend at the university |
| | (em) assessment that each student makes regarding her own performance in mathematics |
| | (es) assessment that each student makes regarding her own performance in science |
| 2 | (fm) confidence in the abilities to understand and use mathematics |
| | (fm) practical importance and usefulness of mathematics in the life of the student |
| | (gm) mathematics understood as exclusive sphere (or not) of the male universe |
| | (gm) attitude and expectations of teachers regarding the mathematical abilities and skills of girls |
| | (hs) confidence in the abilities to understand and use science |
| | (hs) practical importance and usefulness of science in the life of the student |
| | (is) science understood as exclusive sphere (or not) of the male universe |
| | (is) attitude and expectations of teachers regarding the scientific abilities and skills of girls |
| | (jm) global attitude of the students towards mathematics |
| | (js) global attitude of the students towards science |

For Part 2, 104 variables were defined. Among these, 94 (47 for each subject) reflect the attitude of each student towards mathematics and science and are related to the 4 domains named above: (f) to (i).

These 94 variables were the basis for the remaining 10 variables, which were analysed and compared with each other and with the 6 variables of the Part 1. Eight of these 10 variables refer to the 8 (4x2) domains: (f) to (i).

The last 2 variables correspond to girls' global attitude towards (jm) mathematics and (js) science and resulted from adding the scores of each of the corresponding four variables. The table of Fig. 1 displays these 10 variables too.

## IV. Results

Part 1 of the questionnaire shows that 18 out of the 45 students (two-fifths) of the sample were pursuing secondary studies in STEM areas, and 7 had chosen to enrol in the stream of Economy and Commerce, in which mathematics is an important academic subject. In total 25 out of 45 students were pursuing secondary level studies in a STEM related area (see table of Fig. 2). Although more than half of the students attended areas where mathematics is a core academic subject, none of the respondents wished to attend STEM degrees at the university.

FIG. 2. SECONDARY SCHOOL CHOICE OF FIELD OF STUDY

| Field of study at secondary school | Number of students |
|---|---|
| Economy and commerce | 7 |
| Political sciences, geography and history | 5 |
| STEM | 18 |
| Humanities and languages | 13 |
| Arts | 2 |
| Total | 45 |

None of the variables which represent age, grade, current study area, and desired study area at university is related to any of the two variables which reflect the girls' assessment of performance towards mathematics or science (chi-square test with Monte Carlo simulation). It should be noted that not even the current area of study and the area they intend to enrol at university are related to self-assessment of performance in both subjects. This means that there is no evidence of self-assessment of mathematics and science abilities being influential to the intended choice of a university degree.

We also found out that the averages of variables reflecting the girls' assessment of own performance in mathematics and science, respectively 2.11 and 2.22, are below the average (2.5) of the scale used (t-test: p=0.002 and 0.008, respectively). The tables of Fig. 3 display the outputs of SPSS with the statistical values of these variables and test results. These results mean that girls perceive that their own skills towards these two subjects as low and eventually lower their skills in other areas.

FIG 3. T-TEST COMPARISON OF SELF-BELIEFS IN MATHEMATICS AND SCIENCE ABILITIES WITH SCALE AVERAGE

| One-Sample Statistics | | | | |
|---|---|---|---|---|
| | N | Mean | Std. Deviation | Std. Error Mean |
| performance in mathematics | 45 | 2.11 | .775 | .116 |
| performance in science | 45 | 2.22 | .670 | .100 |

| One-Sample Test | | | | | | |
|---|---|---|---|---|---|---|
| | Test Value = 2.5 | | | | | |
| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference | |
| | | | | | Lower | Upper |
| performance in mathematics | -3.365 | 44 | .002 | -.389 | -.62 | -.16 |
| performance in science | -2.779 | 44 | .008 | -.278 | -.48 | -.08 |

The analysis of Part 2 variables led to the following general conclusions: a) the average of each variable that reflect the students' attitudes in the domains (f) confidence in the abilities to understand and use, and (g) practical importance and usefulness, both in mathematics and science, is equal to the average of the scale (t-test: $p \geq 0.194$); b) the average of each variable that reflects the students' attitudes in the domains (h) mathematics and science understood as exclusive sphere (or not) of the male universe and (i) attitude and expectations of teachers regarding the mathematical and science and skills of girls is higher than the scale average (t-test: $p \leq 0.014$); c) the average of each variable that reflects the global attitude of the students towards mathematics (159.78) and science (153.91) are significantly higher than the average (141.0) of the scale (t-test: p=0.000 for mathematics and p=0.002 for science). The tables of Fig. 4 display the outputs of SPSS with the results of the latter two tests. The findings suggest that the girls' attitudes are globally positive towards both academic subjects and, at least, no negative for each one of the 4 analysed domains

FIG 4. T-TEST COMPARISON OF GLOBAL ATTITUDE TOWARDS MATHEMATICS AND SCIENCE WITH SCALE AVERAGE

| One-Sample Statistics | | | | |
|---|---|---|---|---|
| | N | Mean | Std. Deviation | Std. Error Mean |
| COMPUTE global attitude towards mathematics | 45 | 159.78 | 29.247 | 4.360 |
| COMPUTE global attitude towards science | 45 | 153.91 | 26.516 | 3.953 |

| One-Sample Test | | | | | | |
|---|---|---|---|---|---|---|
| | Test Value = 141 | | | | | |
| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference | |
| | | | | | Lower | Upper |
| COMPUTE global attitude towards mathematics | 4.307 | 44 | .000 | 18.778 | 9.99 | 27.56 |
| COMPUTE global attitude towards science | 3.266 | 44 | .002 | 12.911 | 4.94 | 20.88 |

We also crossed the variables of Part 1 with the variables of Part 2. Comparing, through the Pearson correlation coefficient, the variables that reflects the girls' assessments of their own performance towards mathematics or science with the variables of Part 2, we found that the girls' assessments of their own abilities in mathematics and science were positively correlated with those variables that reflect their attitudes, globally and in each of the four domains, towards both subjects ($p \leq 0.025$). One exception was found, namely the variable related to the practical importance and usefulness of science in the life of the student (p=0.078). These results suggest that girls' self-assessments of abilities towards mathematics and science are strongly related to their attitudes regarding mathematics and science (except the practical importance and usefulness of the latter). These results also show consistency in the girls' answers to the two parts of the questionnaire, which reassures the reliability of the research [26]. As a natural consequence of this correlation, the crosstabs between the intended choice of university degree and each of the two variables concerning the attitudes towards mathematics and science dismissed a relationship between the first and the latter (chi-square test with Monte Carlo simulation: p=0.487 for mathematics and p=0.549 for science). We can not say that girls' attitudes in respect to mathematics and science have influence on the choice of the programme they wish to attend at university, what is a similar result to that we achieved with their self-assessments of performance.

The comparison between girls' self-assessment of abilities towards mathematics and science and the comparison between their attitudes regarding these two subjects led to the following results: a) there is a positive linear correlation (Pearson's correlation coefficient: p=0.027), between the self-assessment of performance towards mathematics and the self-assessment of performance towards science; these variables are mutually dependent (chi-square test with Monte Carlo simulation: p=0.018) and there are no differences between the total scores of both of them (t-test: p=0.354); b) there is a strong positive linear correlation, globally and in each domain (Pearson's correlation coefficient: p=0.000 in all cases) between the attitudes towards mathematics and the attitudes towards science; c) there is no difference between the average of attitudes towards mathematics and science, globally and in each domain, except with regard to the teachers' attitudes and expectations regarding the girls' abilities and skills of girls; in this case, the attitude regarding mathematics is better than regarding science (t-test: p=0.019). These results show no evidence supporting a differentiated self-assessment of abilities and skills towards mathematics or science and no evidence of differentiated attitudes towards either mathematics or science.

Results from Pisa 2012 stated that Macao girls do as well as boys in mathematics and science. However, less than 0,5% of Macao girls contemplate pursuing a career in mathematics related fields and less than 2% contemplate pursuing a career in science related areas.

## *V.* *Conclusions*

The findings of the current study are consistent with previous research on the gender gap in STEM areas. Similarly to the findings from the American Association of University Women [6], stating that the girls underestimate their performance and skills in mathematics and science, the

female students from this study expressed low confidence in their own abilities in mathematics and science, although they have a positive attitude with regard to both academic subjects. These two conclusions are correlated and are not mutually incompatible.

Regarding the third and fourth questions, there is no evidence in the current study that self-assessment of mathematics and science abilities or attitudes towards those academic subjects exerts influence on the intended choice of university degree. Other environmental factors might need to be examined, such as family, school, community or culture, as to explain the girls' avoidance of STEM university degrees, rather than the ones included in the study.

Considering the results related to the specific domains of attitudes, we can answer to the fifth and sixth issues: a) girls don't assume mathematics and science as a male domain; b) girls do not consider that teachers' attitudes and expectations regarding mathematics and science abilities are gendered. However, if in one hand the female students seem to believe that choosing a STEM field at university degree is not related to being a boy or a girl, on the other hand none of them have plans to follow a STEM degree at university.

This fact seems to confirm the "leaky pipeline" that carries the female students from secondary school through university [4] and the results of Marques and Correia [12] who declared that, in Macao, the gender gap concerning the interest to pursuit a STEM career is more pronounced than elsewhere

At last and comparing again our findings with studies carried out in other countries [6], [15], [16], perhaps the social beliefs, in particular the Confucian values [18], are stronger reasons for the perpetuation of the gender imbalance in STEM that affects Macao society [4]. Perhaps the obstacles preventing girls from pursuing studies at university level in STEM shall be looked for at the ages of 10 to 14 as suggested by Osborne, Simon and Tytler [14], i.e., much earlier than the moment they apply to university. As advocated Marques and Correia [12] perhaps the foreseeability of obtaining well-paid jobs in the gaming and tourism industry eclipses the advantages of pursuing a career in STEM.

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