

# Effects of single-gender mathematics classrooms on self-perception of mathematical ability and post secondary engineering paths: an Australian case study

*Deborah Tully<sup>1</sup> and Betty Jacobs<sup>2</sup>*

<sup>1</sup>Faculty of Mathematics, Newton Country Day School, Boston, Massachusetts, U.S.A.,  
debbietully@post.harvard.edu,

<sup>2</sup>Faculty of Engineering, University of Technology, Sydney, New South Wales, Australia,  
betty.jacobs@uts.edu.au

## **ABSTRACT**

This study, undertaken for a Master's Thesis at Harvard University in 2008, focused on a population of female engineering students at the University of Technology, Sydney (UTS) probing the influences of their secondary school experience on their choice to pursue an engineering course of study at university. The motivating question which directed this research is: Do unique opportunities exist in an all-female secondary school mathematics classroom which impact a young woman's self-perception of her mathematics ability as well as promote a positive path towards an engineering based university major?

Utilising both qualitative and quantitative data collection instruments, this study examined a sample of Australian engineering students (N=112) enrolled at UTS. Though the primary focus was on females who attended single-gender high schools, other male and female students were surveyed and interviewed for comparative analysis.

Demographic statistics show that 40% of UTS's female engineering student population attended a single-gender secondary school, indicating a potential influence of school type (single-gender) on engineering enrolment patterns. Female students were primarily motivated to pursue a post secondary engineering path because of a self belief that they are good at mathematics. In contrast, male students were more influenced by positive male role models of family members who are practicing engineers. In measures of self-perception of mathematical skill and ability, female students from single-gender schools outscored their male engineering counterparts ( $p < .01$ ). Additionally, female students seem to benefit from verbal encouragement, contextualisation, same gender problem solving groups, and same gender classroom dynamics.

*Keywords:* women in engineering, secondary school, mathematics self-concept

## **1. Introduction**

### **1.1 Background**

The gender gap in mathematics has been a topic of considerable research over the past several decades. As our world grows even more dependent on technologically driven competencies, women's participation in mathematics affects future career and economic opportunities. Mathematics is perceived as the "critical filter" creating access for women into equitable, higher paying professions such as engineering [<sup>1</sup>]. Over recent decades, women have made increased strides in pursuing mathematically orientated college degrees, yet men outnumber women two to one in quantitative university concentrations [<sup>2</sup>]. In fields such as engineering, women's participation is still below 20%.

The gender imbalance of women's participation in engineering seems striking as the demand for engineers over the next several years is projected to grow between 10% and 20% [<sup>3</sup>]. This equity gap may be related to a woman's prior mathematics experiences and the learning environments which produced her perception of her mathematical self [<sup>4</sup>].

A recent longitudinal study, the *Women's Experience in College Engineering Project* [<sup>5</sup>], surveyed over 15,000 U.S. female engineering students. The type of secondary school attended by these women was 94.3% coeducational and

5.7% single-gender. While approximately 1.0% of all U.S. female secondary students attend a single-gender high school, the percentage of female engineering students from this large study, who attended single-gender high schools (5.7%), is almost 6 times the national average of girls' attendance at a single-gender high school.

Compared to the U.S., Australia has a much higher percentage of secondary students attending single gender schools. Of all female secondary students in the state of New South Wales, approximately 22% attend an all-girls high school [6][7][8].

Females display a similar intelligence and aptitude for quantitatively driven university majors as compared to their male counterparts, yet the self-perception of female students towards their mathematical ability lags, potentially affecting their choice into an engineering course of study [9]. This study probes the impact of single-gender secondary mathematics learning environments of a female population of Australian university engineering students and the contributing factors that influenced their choice to pursue an engineering major. While the research intent is to primarily focus on females who attended single-gender high schools, males and females from both coeducational and single-gender high schools are surveyed and interviewed for comparative analysis. This study explores the following questions in the context of an Australian case-study.

## 1.2 Research Questions

Do unique opportunities exist in an all-female mathematics classroom which impact a young woman's self-perception of her mathematics ability as well as promote a positive path towards an engineering course of study? While this motivating question directs the course of our research, the following guiding questions shape the basis of the research:

- What factors and motivations contribute to a student's choice of an engineering university major? How does this compare between male and female students? How does this compare with attendance at a single-gender secondary school?
- How are measures of self-perception of mathematical ability of students enrolled in an engineering major affected by gender and by attendance at a single-gender secondary school?
- How has secondary school mathematics teaching and learning promoted an entry for women into the engineering pipeline?

## 2. Review of the Literature

In society, it is widely believed that boys are better at maths than girls. However, current achievement data does not support this commonly held assumption. High school females enrol in difficult mathematics courses (precalculus and calculus) at the same rate as male students [10].

When secondary school mathematics achievement is assessed through performance on curricular tasks, female students consistently outperform male students [11]. This pattern is also found at the university level by measuring specific mathematics subject grades [12][13]. While male students typically outperform female students on standardized tests, females display greater mathematical achievement when curriculum specific tests are used to measure knowledge and understanding. Standardized university entrance exam (SAT) scores under-predicted the mathematics achievement of females at the university level [14].

Research on single-gender education and the impact on mathematics achievement is contradictory and inconclusive. In a cross-cultural comparison, mathematics achievement for New Zealand female students from single-gender and coeducational schools was not statistically different, while female students from Thai single gender schools consistently outperformed those from coeducational schools [15]. Controlling for student background and school resources, a Nigerian study confirmed the increased performance in mathematics achievement of female students from public single gender schools. However, male students from single-gender schools underperformed in comparison to male students from a coeducational environment [16].

Synthesizing the recent literature on gender and mathematics, Mael [17] asserts that there is some academic benefit to support the improved mathematics outcomes of girls in single-gender schools. While the research does not overwhelmingly confirm significant increases in mathematics achievement for females from single-gender schools, it indicates that girls find that the absence of males in the educational environment provides an atmosphere more

conducive to learning. As well, young women in single-gender environments report a greater confidence in their maths ability which in turn affects achievement [18].

Mathematics self-efficacy can be defined as an individual's perception of their ability to successfully complete a specific mathematics problem. In contrast, domain specific academic self-concept, such as mathematics self-concept, can be described as an individual's perception of their competence or ability relative to mathematics. Marsh [19] suggests that "reciprocal pathways" between increased self-perception of ability and increased achievement exist. His studies indicate that self-perception of ability in mathematics (**mathematics self-concept**) is positively correlated to **mathematics achievement** and is more closely related to it than to any other academic domain. In a study of self-efficacy and mathematics, Pajares and Miller [20] determined that students' belief of their ability to solve different maths problems (**mathematics self-efficacy**) was actually an indicator of their success in solving those problems. Students need to believe that they will be successful before they can be successful. This finding is important for educators who desire to work toward increasing academic success as well as opening a window of opportunity for women into more mathematically based careers such as engineering.

Although mathematics achievement between genders is not significantly different, male students consistently display increased self-efficacy and self-perception of abilities when compared to their equally competent female counterparts [21][22]. Even when females exhibited higher mathematics achievement, their self-perception of ability lagged behind less competent males [22].

Mathematics self-concept affects motivation and is seen as critical for perseverance [23]. Self-perception of ability influences secondary students' course selections which in turn can affect future post secondary academic paths [9]. If women are to pursue mathematically driven postsecondary courses of study, such as engineering, they need to ascertain not only an accurate assessment of their mathematical ability, but to see themselves as skilled and competent.

Women in particular desire to experience a connection of classroom mathematics to the world around them [24]. An overview of teaching mathematics in Europe showed that maths courses that emphasized group work were successful in attracting female students [25]. However, in a coeducational environment, teachers often organize learning activities that favour male participation and learning and teachers openly give more attention to male students [26]. Male students tend to thrive in a competitive classroom atmosphere [27], whereas female students often benefit from higher levels of cooperative activities and open encouragement [28].

Gender issues are often neglected by teachers in their classroom practice [29]. However, teachers whose style promotes mathematical inquiry, and who also serve as models and mentors, have influenced a young woman's career choice towards a mathematical path [30].

Research confirms that for women, mathematics learning experiences can affect the selection of an engineering university concentration. Participation in a female, single-gender mathematics classroom increases confidence which in turn increases continued participation in upper level secondary mathematics courses [18]. Research studies also confirm that the number of mathematics courses taken in high school directly influences a young woman's selection of a quantitative undergraduate major [31]. If a female student enrolls in a high school calculus course, "the odds more than double" of her later declaring a maths or science concentration in college [32, p. 470].

In a study examining the effect of single-gender secondary schools on the selection of traditionally male and female college majors, Thompson [33] concluded that students who attended a female, single-gender high school were more likely to major in sex-integrated fields versus highly female fields when compared to students from coeducational high schools. Thompson suggested that the culture within female, single-gender secondary schools shapes girls' perceptions and attitudes towards gender roles, directly affecting post secondary curricular paths. Consistent with this claim, Lee and Marks [34] determined that girls who attended single-gender schools carried less gender-based stereotypical views with them into their university years. Gender beliefs can influence a student's identity and act as a mediator in career based choices.

Unlike other studies of gender and mathematics, our research focused on a population of female students currently experiencing a mathematically challenging major, specifically engineering. Examined were these students' motivations for selecting an engineering major, with an emphasis of focusing on the impact and contribution of secondary school mathematics learning experience towards self-perception of maths ability as well as prior pedagogical influences.

### 3. Research Methods

#### 3.1 Participants

This study was conducted in Australia within the Faculty of Engineering at the University of Technology, Sydney (UTS). The 2007 student undergraduate engineering population was approximately 2800 students, with females comprising 13%. Enrolment data revealed that 40% of all women engineering students at UTS who attended secondary school in Australia, attended a single-gender high school. All participants in this study (N = 112; female = 39, male = 73) were enrolled as engineering majors.

#### 3.2 Research Design and Instruments

Survey and a semi-structured interview formats were utilized for data collection.

The **survey** format has four distinct components.

- I. Background demographic including school background, highest level of high school maths class taken and university major.
- II. Attribution chart of twelve choices where the participants rank their reasons for selecting their major.
- III. Probes learning and teaching styles by asking participants to rank their preferred ways of learning when presented with newer mathematics concepts.
- IV. Uses a published instrument that measures academic self-concept. The *Self Description Questionnaire III*, [35][36], has been used extensively and validated in prior research [37]. Part IV contains a modified version of the SDQ III with specific focus on mathematics self-concept, which measures a student's self rating of their mathematical skill and ability. This quantitative instrument allows for comparison between females and males as well as type of secondary school attended.

The semi-structured interview format allowed us to identify factors from the student's secondary education which affected self-perception of mathematics ability as well as the choice to pursue an engineering major.

Students participating in this research were recruited through the Engineering Outreach program at UTS. Twenty three students completed the online version of the survey and 89 students completed a paper copy. Eighteen students were interviewed. Each interview was audio recorded and fully transcribed from the audio recording, then coded for emergent common themes.

### 4. Results

#### 4.1 Factors and Motivations Contributing to a Student's Choice of a Quantitative Based University Major

Data from both the surveys and interviews were analysed to determine the contributing factors which influenced a student's choice to pursue their engineering course of study. In the survey students were asked to rank their reasons for choosing to study engineering. The summary of responses is noted in Table 1.

| Female (FSG)                          | Female (FC)                           | Female                          | Male (MSG)                                      | Male (MC)                                       | Male  |
|---------------------------------------|---------------------------------------|---------------------------------|---|---|---|
| Single-Gender Secondary School (n=10) | Coeducational Secondary School (n=14) | Overall (n=29)*                 | Single-Gender Secondary School(n=16)            | Coeducational Secondary School (n=29)           | Overall (n=52)*                                 |
| 1. I am good at Maths                 | 1. Exciting Career Opportunities      | 1.Exciting Career Opportunities | 1. Exciting Career Opportunities                | 1. Exciting Career Opportunities                | 1. Exciting Career Opportunities                |
| 2. Exciting Career Opportunities      | 2. Good Fit for my Academic Gifts     | 2. I am good at Maths           | 2. This is something that I always wanted to do | 2. This is something that I always wanted to do | 2. This is something that I always wanted to do |
| 3. Encouraged by my Parents           | 3. Academic Prestige                  | 3. Encouraged by my Parents     | 3. Good fit for my academic gifts               | 3. Good fit for my academic gifts               | 3. Good fit for my academic gifts               |

(\*Note: some students did not indicate type of secondary school on survey)

**Table 1. Top Three Reasons for Selecting Engineering Course of Study**

Based on responses from the interviews, female students developed a more clearly defined understanding of the quantitative path of engineering only after they had undertaken personal career research in the final years of secondary school. These young women were primarily motivated to pursue engineering because of their prior

maths achievement and their perception that they are good at maths. Excerpts from the interviews highlight this finding.

Amy (FSG):

*When I had to put my preferences down, I had no idea what engineering was. It was sort of a bit of a whim. A career advisor said to me once, “you are good at maths and science, give it a go.”... So I thought why not just give it a try, and then I did, and I love it, it’s perfect for me.*

Jasmine (FSG):

*I went to a school with 120 girls in my class and I know only two other girls from my grade that are in engineering. It felt like we were going against the grain. Back in high school nobody knew what engineering was. We had to find out facts from friends and relatives...I really enjoyed maths in senior school and it was because of that feeling that I am good at maths, that was a huge motivating factor for me to do engineering. I knew that engineering would be very maths intensive and you would have to ask yourself the question: am I good enough to do it? But if you have that feeling of achievement, it does influence you.*

In contrast to the female students, almost all of the males interviewed had a well formed understanding of engineering and a clearly defined vision for pursuing engineering. For several of the male students interviewed, close family members were also engineers. Excerpts from the interviews highlight these findings.

Paul (MSG):

*I am not one of those people that said that I wanted to do engineering because I was good at maths. When I was in high school, I always thought I wanted to be an engineer. My dad is also an engineer.*

Rob (MSG):

*When I was growing up, I was always inventing things. I knew that I was going to become an engineer. My dad’s an engineer and my grandfather is an engineer.*

For female students, being “good at maths” was heavily cited in interview responses as well as survey responses. However, for males, being “good at maths” ranked ninth out of the 12 survey attributes for choosing an engineering major.

#### 4.2 Quantitative Measures of Self-Perception of Mathematical Ability

Quantitative measures of mathematics self-concept were determined through the SDQ III instrument. Results for “mathematics self-concept” are categorized by gender and school type and summarized in Table 2.

|           | Female Single-gender (FSG) | Female Coed (FC) | Female: Total Sample | Male Single-gender (MSG) | Male Coed (MC) | Male: Total Sample |
|-----------|----------------------------|------------------|----------------------|--------------------------|----------------|--------------------|
| $\bar{x}$ | 38.4                       | 36.2             | 36.3                 | 35.4                     | 34.4           | 34.8               |
| $Sx$      | 4.2                        | 4.8              | 5.5                  | 5.7                      | 6.4            | 6.1                |
| N         | 14                         | 19               | 39                   | 20                       | 42             | 73                 |

Possible rating scores range from 10-50, with 10 representing lowest mathematical self concept and 50 representing the highest mathematical self concept. A rating of 30 would be considered average. Note: some students did not report specific type of secondary school on survey.

**Table 2**  
**Mathematics Self-Concept:**  
**Rating of Self-Perception of Mathematical Skill and Ability**

All population segments scored above the instrument’s average rating of 30. Female students from single-gender secondary schools scored highest, while males from coeducational secondary schools scored lowest. The null hypothesis tested in each case was the equality of means. The most statistically significant finding in the comparison

of means was the higher rating of mathematics self-concept of female students who attended a single-gender secondary school when compared to the total male sample ( $p < .01$ ).

### 4.3 Factors in Classroom Teaching and Learning that Contribute to Increasing Self-Concept and Self-Efficacy

Coding the interviews produced key themes which are highlighted in Table 3.

|                 |  |
|-----------------|--|
| Male and Female | Relaxed, interactive, collegial classroom atmosphere increased enjoyment and facilitated learning  |
| Male and Female | Classroom experience that consistently dedicated 50% of class time for group problem solving activities positively impacted self-efficacy            |
| Male and Female | Small group dialogue promoted effective collaboration and increased understanding in problem solving activities                                      |
| Male and Female | Teacher withholding the answers to the more difficult classroom problems encouraged persistence and promoted self-efficacy                           |
| Female          | Female students prefer to work with other females  |
| Female          | Teacher that was approachable, yet held students to a high standard, improved student motivation and persistence                                     |
| Female          | Verbal encouragement from the teacher improved confidence and mathematical self-concept  |
| Female          | Students had a greater understanding of the mathematics when appropriate context and application were offered by the teacher                         |
| Female          | Female students from single-gender schools learned to speak up for themselves in the learning process  |
| Female          | Female students from single-gender schools noted the highly competitive academic atmosphere at their school and the expectation to attend university |

**Table 3: Key Interview Themes**

Excerpts from the interviews highlight the positive correlation between classroom environment and learning.

Haley (FSG)

*Maths was my best subject...Mr. H was the most effective teacher in the school. He was patient and he also made the classes as very relaxed as he could. He was willing to support us and speak to us whenever we needed. Overall, he was very friendly and made us feel as equals. He made sure everyone was comfortable where they were at. He put confidence in us.*

Most students recalled that the length of their maths lessons was 60 minutes with approximately 30 minutes for group or individual practice. Both male and female students noted benefits from the verbal interaction of mathematical discourse. Female students often would prefer to work with other female students. Several students comment:

Faith (FSG):

*I like to work with someone else. It's kind of a group motivator, it makes you sit down and do your work properly. I do like working with girls, because girls are more serious about their school work.*

Heather (FC):

*In class you would form your own little groups and the teacher would come around and help. He was good at communicating with students. The groups ended up with girls in one group and boys in another. I find it's easier in mathematics to have small groups.*

Both male and female students commented on the teacher's role during problem solving activities. While walking around checking on student progress, the teacher may have guided, but rarely gave the answer to the students. In this role, the teacher acted as a facilitator and not the authority, increasing persistence and self-efficacy of the student.

Karen (FSG):

*When we were working on problems, the teacher would walk around and he would come up next to you and look at what you were doing. He would let you know if you were on the right track. If he didn't say anything and gave you a look, you knew there was something wrong. He wouldn't tell you. He would give you a chance to self-evaluate your work. If you still couldn't get it, he would finally comment. He made maths interesting and enjoyable. The teacher was willing to establish a rapport with the class. It was a light atmosphere. Even if you had a problem with the maths, you knew you would be confident enough to work it out in the end.*

While male students rarely spoke of verbal encouragement from their maths teachers, female students remembered the praise from their maths teachers and cited the personal impact it had on them.

Haley (FSG):

*My maths teacher, he gave me confidence in my mathematics. He would encourage me and tell me that I am a very talented maths student and that I should be able to pursue something mathematically at university.*

Each young woman who attended a single-gender secondary school spoke of the highly competitive academic environment and the expectation to attend university. If the individual school promoted a post secondary curricular path, it was more often skewed towards the humanities or law. Females from single-gender schools spoke favourably about their secondary school mathematics classroom learning environments. These young women spoke of the ease with which their classmates verbally participated in class, particularly in comparison to the highly male environment which they now experience at university.

Claire (FSG):

*In a girls school, I could not know something and it was okay. Everyone sort of knew that there were things people didn't know, and you weren't shy to say hold up, I don't get it, try it again. That is a supportive feeling to know that you don't understand, someone else is going, oh my god, me too. I come from an environment where it is okay to ask questions and not to know things.*

Haley (FSG):

*A lot of girls can be discouraged in terms of confidence in maths. They do have their ability to be very skilled in mathematics. It's just, they probably need a little bit more work and encouragement than boys. So I'd say, in a girl's school, girls can speak up with their peers more effectively.*

In an open response prompt that asked students to share their best or favourite maths learning experience in high school, many male and female students (approximately half) indicated that working in small groups within the context of an interactive class was overwhelmingly their best experience.

## **5. Discussion**

### **5.1 Impact of School Type on a Female's Selection of an Engineering Major**

The engineering student body (not including overseas students) at UTS, is comprised primarily of students who attended secondary school in New South Wales (NSW). Approximately 22% of all female secondary students in NSW attend a single-gender secondary school. At UTS, approximately 40% of female engineering majors attended a single-gender secondary school. This is a striking comparison; the single-gender female participation in engineering is almost twice the average of female attendance at single-gender secondary schools.

Yet, none of the interviewed students who attended a female single-gender school believe that their school culture explicitly promoted a quantitative career path. In contrast, if a path was promoted, it appeared to be more directed towards the humanities. The culture of a single-gender school may provide a unique socialization process which allows a young woman the freedom to reach beyond stereotypical career expectations [38]. The academically competitive nature of these single-gender secondary schools may also increase efficacy beliefs through solid academic preparation, instilling in these young women the confidence to choose a less-travelled, male dominated engineering academic path.

## 5.2 Student Reasons for Selecting an Engineering Course of Study

Apart from “exciting career opportunities,” male and female students cite different motivations for pursuing an engineering course of study. Positive role modelling dramatically impacted male students as many of their fathers were also engineers. The tendency of sons to follow in the occupational footsteps of their fathers is not uncommon [39]. However, females had very few models from which to motivate this academic choice. Maple and Stage [2, p. 42] assert that the “decision to pursue a quantitative based major may largely be determined early in a high school career.” While this was affirmed in the men, this statement was not true for the women examined in this study.

For many of these young women, their specific path to engineering was not determined until later in their high school career. The lack of explicit models was overcome through counselling with career advisors, teachers and parents. But one may wonder how many other young talented women did not consider an engineering path because of lack of supportive counselling or positive models?

## 5.3 Female Gains in Mathematics Self-Concept

Females rated higher than males in the measure of mathematics self-concept. This result conflicts with previously published research which shows that boys consistently display higher levels of mathematics self-concept than girls even when achievement levels are equivalent or when female students demonstrate greater mathematical competency. In our study, female students from single-gender secondary schools scored highest in mathematics self-concept which measures a student's self-perception of their mathematics ability ( $p < .01$ ). This finding complements the primary reason why these female students from single-gender schools selected engineering. These women believe that they are good at maths! Pajares [22] asserts that a girl observing a woman demonstrating mathematical excellence helps to potentially raise that girl's self-efficacy. Perhaps this effect occurs in an all-female environment as girls learn from each other. These women also speak highly of their classroom environments in which their teachers not only provided authentic learning experiences, but encouraged them to persist and excel. This type of learning environment allows for the development of increased self-concept and self-efficacy [40].

## 5.4 Classroom Experience: The Unfolding of Teaching and Learning

The personal attributes of the teachers, most notably their encouragement, care and availability, appeared to motivate these female students from single-gender schools to excel. Stage and Maple [24] assert that without focused encouragement and support, most women will avoid mathematics-related academic paths. The affective qualities that mathematics educators display in their classrooms impact the mathematics learning experience for students. For women, these mathematics learning experiences can have an important impact on whether or not a mathematics-related major is chosen [32]. Female single-gender classrooms can often display the most gender-equitable learning environment when compared to coeducational classrooms [41] and may pave a way for increased options for young women into future engineering paths.

## 6. Summary of Key Findings

This study investigated the opportunities that exist in an all-female mathematics classroom which impact a young woman's self-perception of her mathematics ability as well as promote a positive path towards an undergraduate engineering course of study. Through the implementation and analysis of a mixed-methods research study, the following key findings were determined:

- Secondary school type (single-gender) influenced enrolment patterns for women entering engineering. In New South Wales, girl's enrolment at single-gender secondary schools is approximately 22%. Enrolment data from UTS indicates that 40% of the women enrolled in the school of engineering attended a single-gender high school.
- Women are more likely to choose engineering because they believe that they are good at maths. This finding is more pronounced for women from single-gender schools as they cited “being good at maths” as a top reason for selecting an engineering major. In comparison, men are more impacted by male role models and displayed long-held beliefs in their desire to pursue engineering.
- Women who attended single-gender secondary schools displayed the highest self-perception of mathematics ability. They rated higher than females from co-ed secondary schools, and higher than all male students as well ( $p < .01$ ).

- Classrooms that were interactive, relaxed, and collegial, and where 50% of class time was regularly devoted to problem solving activities, positively impacted students' academic self-concept and self-efficacy. Female students in particular benefited from teacher encouragement and contextual applications of mathematics problems. Female students from single gender-secondary schools felt more empowered in the single-gender environment.
- When learning new mathematics material, both male and female students preferred learning maths in an interactive environment between students and teachers. However, female students indicated less of a need for teacher involvement in small group interactions when approaching new mathematics material.

## 7. Conclusion

In this study, young women from single-gender learning environments appear to possess increased levels of mathematics self-concept. Shaping curriculum, pedagogical practices, and classroom culture at the secondary school level to facilitate greater academic gains for young women in mathematics may promote enhanced levels of self-perception of mathematical abilities, which in turn may facilitate increased participation of women in engineering career paths.

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