Influencing Factors to Choose STEM Areas: The Case of Strongly STEM-Oriented High School Students

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Abstract - **The need to understand better the actors and factors that influence students' perceptions of pursuing an academic and professional future in STEM areas has been studied for over 30 years. In this work, we focus on students who are strongly oriented to science, technology, engineering, and mathematics to investigate what motivates them and who has been cultivating their inclinations to these careers. High school students who attended an international science contest on mathematics, physics, chemistry, biology, and computing (over 600 attendees) were invited to participate in a focus group. Thirteen students attended the call. The session lasted over 90 minutes and was video recorded. All the session was transcribed, and a group of researchers analyzed the data based on an adaptation of the expectancy-value theory. The results indicated that the students did not feel they had the expected support from their schools; instead, their primary support came from their family (particularly their parents). It was interesting to find that among this group of students, their conceptualization of STEM and interest in how science and technology could improve the world (or their world) proved to be a significant factor in keeping them motivated to pursue their goals.**

Index Terms - Educational innovation, Expectancy-value theory, High school, Higher education, Interest in STEM.

INTRODUCTION

Nowadays, most recognize the importance of motivating students to pursue careers in science, technology, engineering, or mathematics (STEM). This is to ensure readiness to face future challenges, maintain economic growth, and foster global competitiveness [1]-[2]. However, several studies have documented that student motivation to pursue STEM careers is not increasing as needed, and several research efforts report changes in teaching methodologies to foster students' interest in STEM and achieve equity [3]-[4]. Furthermore, researchers argue the need to build communities to understand more profoundly how to address this situation [5]-[6].

This study focuses on high school students who are strongly oriented to STEM areas to understand the factors that keep them motivated to succeed in STEM courses in school and eventually pursue STEM careers. Specifically, the research question for this study is, "What are the factors that strongly influence STEM-oriented Mexican students to these areas?"

METHOD

To answer the research question, we conducted a focus group at the end of a science competition for high school students. The science competition had three phases: first, the students took a written test of two STEM subjects; second, the best 20 students were selected for a written test, and third, the best 5 took an oral exam. In the first two phases, knowledge, accuracy, and time management were the main factors evaluated. The students had the option to participate in two contests in areas of Mathematics, Physics, Chemistry, Biology, and Computing.

The participants of this study took the first phase but did not pass to the second evaluation. However, we made them an open invitation to participate in our focus group. Thirteen students attended the session. The names of the participants are kept anonymous for this report. The entire session was transcribed, but the video of it is kept locked.

I. Sample

Thirteen 18-years-old students participated in the focus groups, 5 females and 8 males. In the science contest, most of the participants chose to take the mathematics test, then, in order, chemistry and physics, and last, biology and computer, taking into consideration their first and second choices. Regarding their interests in professional careers, eleven indicated engineering majors, one in medicine and one in digital animation. Within engineering, their preferred areas were bioengineering, computing, and applied sciences. All these students reported having high grade-point averages in high school. Twelve of them were in senior year, and one was in junior year. Eleven attended a private school, and two studied in a public high school.

II. Data collection

Qualitative data were collected by videotaping a focus group interview. This interview was analyzed by four researchers, who first looked for a theory that would shed light on the conversations of the focus group. The researchers also collected quantitative data on the students' interests that will be presented in a separate paper. The motivational model of pathways to STEM careers [7] was chosen because it integrates clearly how both external and internal factors influence some students to follow a STEM career. These factors were adapted to make sense for the Mexican high school student case (Table 1).

TABLE I
ADAPTATION OF THE FACTORS TAKEN FROM THE EXPECTANCY-VALUE THEORY [7]

Factor	Adapted meaning for this study
I. Main factors	
A) Sociocultural factors	
i) Socialization	Social systems
ii) Cultural norms	Stereotypes of activities, culturally established norms
B) Contextual factors	
i) School/Classroom	Relationship with school members, i.e., teachers, coordinators, principal.
ii) Family	Relationship with close family members
iii) Peer	Relationship with classmates or friends
II. Intellectual aptitude and psychological factors	
A) Ability self-concept value	Self-expectations of success
B) Subjective values of tasks	
i) Interest value	Inner motivation or enjoyment to perform a task
ii) Utility value	Task that helps to fulfill a personal goal
iii) Attainment value	Self-recognition of achievement, attainment of goals
iv) Cost value	Anticipated psychological and social costs to the student
III. Actual activities	
A) Academic performance	Student's self-perception of his or her academic achievement
B) Future goals/ Aspirations	Academic goals and professional aspirations
C) Course enrollment	Extracurricular courses such as summer camp
D) Activity engagement	Self-selected activities such as reading, science contests
IV. Career interest	
A) Post-high school choice	Next step after high school
B) Career choice	Career interest

The researchers classified the "voices" of the participants based on Table 1. The theoretical model makes it easier to understand the main aspects of the contextual factors of the participants. However, some others needed more discussion and clarification being categorized in the primary model. The path to understanding these aspects required a) to separate ideas tangled in individual interventions, b) to associate each idea with its category, and to contrast the theoretical perspectives with the real participants' voices. Furthermore, there emerged a new subcategory, one in which the students showed themselves to have a subjective conception of science. In the first analysis, it was believed that the new subcategory belonged to intellectual aptitude and psychological factors. After some insights, it turned out to be fundamental. The connection of this to the expectancy-value theory will be discussed in the next section.

PRELIMINARY RESULTS

The process of integrating a Mexican model of trends, patterns, and perceptions that interrelate the meanings provided by the participants is still in progress. However, in this study, we collected, classified, and illustrated with examples the most representative voices of the participants, as follows:

I. Sociocultural factors

According to [7], there are two primary socio-cultural factors: socialization and cultural norms.

Socialization. In the focus group, the students expressed a need for social contact with peers who share their same interests. The students interviewed indicated that one of the reasons why they participated in the contest and other similar events was the need for interaction with people who share their tastes for science.

> "I came to this contest because I like to see what level I am on and how I can improve and continue learning and meet people who like the same as me."

> "We just returned from the National Biology Olympiad... I think that encouraged us a bit to be here because that contest was held a month ago. So many of our friends from the Olympiad were going to come back, so they invited us."

In this category, it is also observed that students felt misunderstood by society in their desire to study science:

> "If you tell people chemistry, they think, 'No, that science always pollutes, right?' I want to study chemistry, and I think they believe it's my fault that we use so much oil, but I have nothing to do with that..."

> "My school supports more sports activities."

Cultural norms. Within the social norms, the willingness to confront that students manifest about the marginalization of women in the scientific areas stands out. They are against the belief that there are specific activities for women and men, but they indicate that in general society, it does happen.

> "So, it's like, a woman in engineering, or a woman specializing in math or physics, it is kind of weird to see it."

> "They are equally important [men and women]. I believe that society creates the difference."

> "Especially in the south, well, we are a little bit more conservative. So, if you see a woman in engineering, a woman specializing in math and physics is a freak."

II. Contextual factors

Factors that are considered contextual include school, family, friends, and peers. This category includes the relationship or interactions of these actors with the students. The participants of the focus group talked about these actors as having a positive influence but also highlighted the cases in which the impact was negative.

School. The relationship with the scholar actors was explained in Table 1. Still, the relevance did not make sense until the positive and negative aspects were identified, and the whole context of the participants could be understood. For example: [What made you interested in a science competition?]

> “It was like a very difficult process because I always hoped that the teacher would give us everything. I hoped that it would be like an eminence that helped us, and partially it is fine, but, uh ... It doesn't push you, right? Sometimes they give us very easy assignments to do…”

School is one of the typical contextual factors of the participants. To feel the institutional support of the school was very important for the students because they noticed how the sports teams were treated as privileged in contrast to the science groups. The participants acknowledged that they had some support from their school, such as giving them extensions to complete their assignments when they were away to participate in a contest. However, they did not identify any other type of institutional support.

Family. Family is a fundamental support for any young student 18-years old or younger. However, a family can be a boost or a detriment. Additionally, the family opinion about a scientific discipline can be a strong voice for a young student in his or her election of a STEM career. For example:

> “... electronics, I like it. My dad is also an electronic engineer, he is like my guide, and that's it.”

> “for me, I've been involved in the food industry, uh ... Because my dad has a business in the oil industry. Then in the summers, he gives me work. I worked with some oil samples, and I liked it.”

This excerpt shows how important it can be for a student not only that his/her family supports engineering but also that they listen to their preferences within this field. The professional practices of the parents strongly influenced the students’ conceptions about that STEM area.

III. Intellectual aptitude and psychological factors

In this section, we focus on the systems of beliefs of the participants. Specifically, we discuss *interest value, utility value, attainment value, and anticipated cost.*

Interest value. This refers to students’ interest and joy in studying a STEM discipline. One of the students mentioned:

> "I'm part of a science team for chemistry and biology, and I was invited [to the competition], but I said, 'I'm going to be in the physics and computing team, especially computing because I like it.’"

Even within the STEM areas, students have preferences. Such was the case of all the participants because they had to choose one primary subject for the competition and a secondary favorite one. In the above example, that a student participated in two disciplines not because he was assigned to those, but because he liked them indicates a broad and robust preference in STEM areas.

Utility value. This value means that the participants saw science as a way to reach some personal goals. As one of the students mentioned:

> “Like, all the science behind how oil is extracted from a seed and then distilled, so in the end, there is a product that you can eat or cook. That, I like it. All the processes they go through to get a product, and then to finish it up for the market, and things like that.”

The way this participant talked about the utility of the scientific method through an everyday product gives us an example of how they can perceive science as a way to reach a goal.

Attainment value. The self-recognition of achievement and personal identity to a STEM area. For example:

> “I understood what computing was about until I was in high school. Before that, I did not like it. For me, it was only the use of Word, Excel, and PowerPoint. In fact, it was funny, because as a child, I did not use to play with Paint, I preferred Excel. So, when they taught me the same, the basics, something that I already knew from a long time ago, I did not enjoy it. Then, I learned how to program, that was really cool!”

This student learned more computational skills and gave him/her attainment value through these activities. The way that the student reached into memory gave us a revelation of how this skill evolved and produced satisfaction.

Anticipated cost (psychological, economic, and social). This subcategory was critically relevant to this study because there was the moment when the participants talked about what they sacrificed for STEM. The way they spoke about the school as a social place that receives little attention from authorities made a strong statement. As they said:

> “In my high school, uh ... The lab is horrible, they do not have, they do not buy equipment. In contrast, there are several soccer fields; those they take good care of with chemicals, and things like that. They buy soccer balls, equipment, and things like that, but they invest very little in the, uh, the academic part.”

IV.. Actual Activities

This involves curricular and extracurricular activities chosen by the students or in which the students are willing to participate. We focused on two sub-categories, namely, future goals or aspirations and activities engagement.

Future goals / Aspirations refer to activities that students would like to do in the future, such as in their professional careers (research, practice, etc.) or academic goals (studying for a doctorate degree, passing a course) or achieving something. All participants had high expectations about their futures and their professional careers. Their aspirations and future goals were as diverse as they were challenging.

> "What I mainly want to do with my studies is create, but to create something that can help people."

They perceived that science would help them to be supportive and proactive citizens.

> "...to find new things and apply scientific knowledge, because there is nothing that I could like more than that, sincerely, to help the world."

Students coincided with an important reason to choose a scientific orientation.

> "… I want to do something for humanity, and that's why I prefer this ..."

These students showed a high sense of helping others; they talked about changing what is known radically or fundamentally, including changing the educational system as we know it today.

> "I am looking for something more, like, from the information that exists, I create. Create something that can revolutionize, and I want to promote a renewal of education ... in terms of technology."

Activity engagement. Another common trend among the participants was their desire and willingness to participate in extracurricular activities that involve science, technology, engineering, or mathematics. They choose to spend their free time studying STEM areas, preparing for more contests, like the one they were participating in at the time of conducting the focus group.

> "Well, I'm here because the school invited me. Eh ... I've always liked science, although chemistry is relatively new to me. Eh ... I have participated in several of these contests. When I was little, and I was in high school, my physics teacher took me to the physics Olympics."

> "Biology being my [favorite] area, I feel that when I get some success in other areas, for example, when I won the physics contest at my school, [her parents recognized those achievements more than when she succeeded in her expected area]."

Even though this experience was relevant for them, social connectivity through STEM contests motivates their attendance because it relates to their social needs to meet students who share their same choices and passions that challenge them.

> "...what I would like to comment is the same; what motivated me is that you really come to meet people with different personal qualities [and similar interests]."

Other activities they engage in are also related to their academic growth, such as reading science books that encourage their self-learning and their independence.

> "...so, at the end of the school year, I said, 'Well, why don't I start reading a book?' And then I grabbed a book ... I started with an easy one that is the Audesirk, and then it goes up a level and little by little. So, I loved that."

> "I no longer like having biology classes anymore because it bores me. I prefer to read a book and review it ... I became an autonomous person... now I don't depend on anyone."

Also, the student talked about how an experience made him like the area of engineering:

> "I've been in the food industry, uh ... Because my dad also has some oil businesses, so like in the summers, he gives me work. And I used to do that, check the oil samples, and so on, then I liked all that."

V. Career interests

This group of students was categorized as strongly oriented to STEM areas, given that they were participating in an international science competition (Mathematics, Physics, Chemistry, Biology, and Computing). Their selection of post-high-school choices and their college majors highlight their confidence in their abilities and sense of value towards STEM-oriented activities. This group talked about their career interests, stating what, why, and for what reason they choose their professional careers.

Post-high school choices. This refers to broad opportunities for professional development, such as research. Research is precisely what more than one student mentioned during the dialogue, for example:

> "I really like to investigate. If I could, I would dedicate myself completely to research and to study on my own [for pleasure]."

Another participant shared how she visualizes science as a tool to avoid suffering in more families:

> "Uhm, from family experiences, my grandfather had cancer, and two of my brothers also had cancer. So, I would like to save families from suffering, and well, to extend the life of the children who are just beginning."

College major. One trend observed in our participants was their wish to pursue a career in research. They allowed us to know their reasons for possibly studying this career:

> "I want to be a child oncologist: cancer, medicine, to cure cancer. ..."

In this other opinion, a student showed how important her family background was in her inclination toward STEM.

Another point of view reminded us that science is fun, or it may seem entertaining for many people.

> "I am not sure what I am going to study. I want to study science, physics, or chemistry. I think so because those are easier for me, and I have fun learning or seeing how

far I can go, and how much I can learn. It [science] entertains me...."

How all these voices and meanings were combined allowed us to think about young scientific thought, selective of its influences, and critical of its circumstances. Additionally, the desire to help the world is no longer only a philanthropic desire, but a utility that the participants found interesting in science.

FINDINGS

It was a challenge to connect these findings based on a framework [7] in the light of our culture. The interpretation of each category made us reformulate the categories and resize the meanings collected in this work. These young students showed their value systems and their perspectives on the applicability of science.

One finding of this study was how the participants made decisions based on their own value systems. The categorization established by [7] argues that STEM-oriented students think or express their subjective task values. This categorization allowed us to discuss what interests interest them, the sense of utility that they saw in some activities related to science and technology, the activities that provoked their feelings of achievement, and the costs to their lifestyles of a STEM vs. non-STEM orientation.

Another finding was a concept of science that complements [7], namely, science as a versatile and transformative tool for humanity. This conception of science revealed three aspects that were elicited in the focus group discussion: 1) science as beneficial, 2) science as a very relevant area of knowledge, and 3) science as a transforming tool for humanity. An idealistic and proactive stance of what science is was evidenced. The participants had their own philosophical views of science.

One characteristic shared by the participants was their determination to come to the contest and to challenge themselves. Analyzing their speeches, along with their reasons, made us understand that, regardless of their contexts, they lived similar stories and that within themselves, they might have difficulties that they would overcome as a challenge. Their challenges have sensitized them to some needs of humanity that they want to address through science.

An expected inclination for the type of population selected in this study is participation in science competitions. However, it was surprising that their involvement was not only motivated by the challenge of the contest itself but also by knowing and sharing with people who have the same STEM interests. Some of them expressed having some support from their school (managers, teachers, and classmates) to attend science competitions. Still, most of the time, the students felt that school is an environment with little challenging activities for them.

As established by the work of [8], recognizing the need for help is a distinctive activity of highly STEM-oriented students. Our research has a similar point of view; the participants expressed that need at some point in their development, but later they became autonomous. About expectancy-value theory, [9] explained that under this lens, teachers play a critical role in students' development, especially for non-STEM oriented students. On the other hand, the participants of this study discussed how they improved self-regulation without guidance from their teachers. This fact could be a reason for the autonomy of strongly STEM-oriented students.

CONCLUSION

The main goal of this research was to understand the factors that influence the motivation of strongly STEM-oriented high school students that let them to cultivate their inclinations to STEM careers. This paper showed that strongly STEM-oriented students have a mindset in which STEM is both a lens through which to see and appreciate the world and a toolbox to help fix some problems in the world or make contributions like advances in medicine. Furthermore, other significant findings of this research are that school, family, subjective task values, and science conceptualization can be auxiliary themes in comprehending what influences STEM-oriented students to take one of these paths. This study helps to deepen the understanding of some factors that strongly influence STEM-oriented students to make their career selections.

Something that caught the attention of the authors was how similar the stories/experiences of women were to those of men, showing no gender differences in their perceptions about the influencing factors on their career choices. However, they recognized the gender imbalance in society in general. The authors think that this research offers a more profound insight into gender differences [10, 11], bringing to light the voices of students strongly oriented towards STEM areas and their gender perspectives. The voices of these students provide a more in-depth understanding of new tendencies or cues that can emerge from their points of view.

The perception of science manifested by this group helped us to characterize their sense of science, which is more directed toward humanity, and to know their reasons for studying it and enjoying it. Observing how these students justified their vocations through the practical sense of science makes us think that perhaps we can add other nuances in future research, to continue knowing the opinions and profiles of these students.

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The authors have no conflicts of interest to declare regarding the submitted manuscript or the research presented in it. Participants were treated following the ethical code of conduct of the American Psychological Association (APA 2017). Specifically, before they gave consent to participate, they were informed that participation was voluntary, that their answers were anonymous, and that they could quit and withdraw the data already provided at any point in the session. The rewards (or chances to win them) were also made transparent in the call.

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