On the impact of STEM sustained actions on the future of young students.

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***Abstract*—This paper presents a preliminary analysis on the impact of Municipal Schools of Young Scientists (MSYS) project on young students' decisions regarding their university studies. MSYS, and the pilot project that preceded it, has been operating in Extremadura for more than six years, and some of the students have already reached the age to access university studies. Although not all of them have attended MSYS all these years, we have performed a preliminary analysis that considers what they are studying, if they do, today.**

This paper presents data about those first years of MSYS that are then compared with the population of young people who have completed compulsory schooling in Spain, and particularly in Extremadura, Spanish region where the project is developed. The data collected shows evidence of a remarkable impact on students interests around STEM areas: an increase of 21 points on the average number of students studying a STEM university degree is reported, when compared with both the population in Spain and Extremadura.

Although data obtained are still preliminary to establish a causal relationship, the correlation shows the interest of the approach, with an improvement on all of the measured values. In any case, we think the analysis of the project reported will be useful to design new sustained STEM actions in the future.

We hope this results will encourage local administrations and families to continue supporting the project in the next decade.

I. Introduction

The importance of STEM education is widely recognized as a means to combat the lack of general interest among young students in science and engineering. Researchers have already shown that early exposure to STEM initiatives and activities has a positive impact on the perceptions of primary school students [1]. Yet, we think that the standard approach developed in many STEM initiatives, which are based on single workshops offered to students, are not the best approach: students do not have the opportunity to progressively develop their skills and interests in the topics to which they are exposed in these single day workshops. Moreover, usually the students have been taken by their teachers so they do not freely choose to attend these types of activities.

During the last few years, we have tried to address this issue by means of the Municipal Schools of Young Scientists (MSYS) project [3], which are nowadays working in 20 cities. The success of the project relies in the involvement of municipalities, whose local governments provide the funding for developing the project along the academic year. MSYS has been working for several years, and we already have data from former students that allows us to analyze the impact that the project may have in their decisions on degrees to be pursued.

This paper analyses the evolution of former young students who attended MSYS during the first years, and have already reach the age for deciding what to study. As we describe below, two different models were applied and we can now analyze results obtained.

The rest of the paper is organized as follows: Section II introduces the situation of STEM initiatives in Spain. Section III describes our methodology, while section IV presents the results. Finally, we draw our conclusions in section V.

II. Studying STEM initiatives' impact

As described above, researchers have already shown that early exposure to STEM initiatives and activities has a positive impact on the perceptions of primary school students [1]. Many papers can be found in the literature trying to analyze "Effects of Exposure on Attitudes Towards Stem Interests" (such as [4]), but few can be found that considers the relationship between STEM programs and students decisions, mainly because STEM activities developed are usually single-day workshops offered to students. Among those, we can refer to [5] where a series of important conclusions are reached, such as: (i) high school course enrollment in STEM classes may be an indicator of STEM-related persistence and STEM degrees obtained by students; (ii) When asked in 12th grade about their plans for a college major, those who indicated a major in a STEM field were more than three times as likely to earn a STEM degree as those who were planning for a different major at that time; (iii) many students make their major decisions before they ever arrive on college and university campuses; (iv) it seems that focusing attention on increasing student interest in science and mathematics and demonstrating to students the utility of these subjects in their current and future roles may pay greater dividends in building the STEM workforce; (v) there is a strong positive association between teachers emphasizing further study in science and discussing science careers and increased levels of student interest in science; (vi) while the difficulty in large-scale data collection is recognized, authors recommend that future researchers collect multiple streams of data.

The above referred considerations are the main motivation for the project and results discussed below. Although many initiatives try to develop STEM actions in Spain and also in the area where we have deployed MSYS, such as those managed by office in charge at the University of Extremadura [1], few of these projects try to analyze how students participating are influenced by these activities.

Among the few attempts to evaluate the impact of STEM actions in the geographic area under study, we may find the project launched by Science and Technology Spanish Foundation that considers single day workshops [2]. Although results are of interests, we think that a deeper analysis is required taking into account more sustained actions along the time, where students have the opportunity to develop their abilities and interests. Similarly as regular education cannot obtain appropriate results in short terms actions, and therefore universal schooling has been adopted world wide, we aim at providing clues on how sustained STEM actions can really have an impact on young students, so that in the future educative authorities may consider including these usually extracurricular activities within the school curriculum. Thus, after several years working developing MSYS, we can for the first time analyze students decisions about degrees to be pursued.

We describe below a summary of MSYS methodology, and their main differences with other available initiatives, and then provide available data collected along the years, discussing possible conclusions that may be drawn.

III. Methodology

The main goal for MSYS is to get the students environment involved in the STEM actions developed. But beyond that, there are important differences that distinguish this project from other STEM actions: (i) profesional STEM teachers hired (instead of volunteer based approach); (ii) activities developed along the year (100 hours of activities, instead of single actions 1-2 hours long) (iii) MSYS involves social groups around young students, with a well established methodology which includes meeting with the mayors of the towns, parents and teachers: teachers disseminating information among students, families encouraging them to participate and local administrations funding the project and coordinating activities within the town. Results obtained along the years regarding towns involved and students participating are included in Table I. Interested readers may refer to [3] for a longer discussion on the methodology applied and the activities developed every academic year.

Although MSYS were officially launched in 2014-2015, a pilot project was set up and launched in a couple of small towns (population under 5000 people) in 2012, which are the main focus of the analysis presented in this paper.

We would have liked to work with the random set of young students in Extremadura, but unfortunately, given that the project is offered outside the school environment, and that students attend the activities along the year (up to 100 hours per year) it is not possible to enforce randomly selected students to participate, which oppositely is quite easy for single-day workshops developed at schools [2].

Actually, the same happens with standard musical education in Spain (an any other education area offered as an extra-curricular activity): when students enter Music Conservatories an initial predisposition or interest towards music subject is present in students and families, and they are never randomly selected to enter and stay for several years. Yet, different education models can be tried, tested and analysed to understand differences they may provide.

We thus think the information collected about students interests and activities deserves the analysis and will be useful for future research on other sustained STEM actions.

A. Models analysed

When this project was launched in 2012, two towns were involved, and each of them decided the model to be applied, depending on the fundings available. One of them provided all of the fundings, and thus decided to make the activity free and only invited best students from the high school, while the second town decided a different approach. It was a smaller town with an just a primary school and no fundings available (see table II).

While in the second town an invitation was sent to families of all of the young sixth grade students, explaining how the activity would work and the registration fee they have established for students, in the first one, the high school principal only sent the invitation to the families of the best students as the activity would be free, and only 30 students could register. He explained in the letter the interest of the activity and how the students' grades have allowed them to be *invited*. Therefore, parents felt the interest and *push* all the students selected to attend the activity.

As described before, MSYS pilot project was launched in 2012, and most of the students in secondary school then, have already reached the age of deciding what to study in college, while those who were then in the sixth grade of elementary school have now reached the time for deciding whether to get involved in science when they enroll in high school. The data shown below, have been obtained by phone call to past students, asking them if they have reached the job market, or instead are still studying at High school or University. On the other hand, Regional Government and University office in charge of statistical data were asked so that the information required for comparison are provided below.

IV. Results

As stated above, MSYS has been operating in Extremadura for more than six years. Yet, we focus on students participating in the activities in the first couple of years, 2012-2014. Unfortunately, although more than 60 students ever attended the activity in two towns selected that years, one per model, because of data protection laws, only 3 students

[1]University of Extremadura, Dissemination of Science Office: http://culturacientifica.unex.es

TABLE I
EVOLUTION OF YSLS ALONG THREE YEARS

Year	Towns invited	New YSLS	Number of YSLS	Students
2014	10	8	8	150
2015	25	11	15	200
2016	21	9	19	270
2017	15	3	21	402

TABLE II
STUDENTS PARTICIPATION: TWO MODELS EVALUATED

Model applied	Invitation sent to	Free activity
everybody-pays	all sixth grade students in town	No
best-free	first secondary school best students only	Yes

TABLE III
STUDENTS WHO EVER ATTENDED MSYS 2012-2014, AND THOSE WHO PROVIDED INFORMATION AFTER THE YEARS.

Model	students participating	data collected
everybody-pays	46	31
best-free	55	33

from the second model -any student can register paying a fee- were contacted and provided data required. We had thus to enlarge the number of towns involved in this study, to include more towns that joined the project afterwards (table I shows evolution of MSYS along the years), so that the number of students with available data allowed the analysis we were interested in. Therefore, we finally included more of 100 students from 10 towns following the *everybody-pays* model, although only 64 students answered the questions we were interested in (see table III):

- Are you studying any degree today?
- If positive answer, which one?

As we show below, not all of the students who answered were already studying a college degree; some of them were still in high school or have entered the job market, but this informations was also useful for the analysis.

Table IV includes data from those students who answered the questions posed. The first thing we can notice is the big difference among the two models applied. For instance, if we focus in the students that are currently studying for a university degree, only 20% (2 out of 10) are enrolled in STEM areas for the *best-free* model, and 54% (12 out of 22) are pursuing a degree. On the other hand, the percentage in STEM areas dramatically increase in the case of *everybody-pays* up to 75% (6 out of 8) although the percentage attending University degrees decrease, 46% (20 out of 43). Globally, 48% of the students that attended MSYS, with the age study a degree, have reached university campuses, and among them 47% have chosen STEM degrees.

Secondly, if we focus on those students still at high-school (see table V), we see again differences among the models. For the first one, only 1 out of 9 have chosen science-technology (11%), while in the second case they amount to 90%. Looking at the overall data available for MSYS, we see that 52,6% have chosen STEM related paths in secondary school.

If we leave out students who still are at high-school, and focus only on those who decided whether continuing their studies after this step (information available in table IV), we see that globally, those who went to professional degrees were 12; 9 directly went to the job market, while 20 decided to continue their education at university; therefore 49% are attending university. Of course this is partial information, given that students who are still at high-school have not decided what to do after that step, but this numbers allows to discuss the interest of MSYS.

A. Discussion

All in all, this summary can be compared with the Spanish average for university degrees [2], and also with the average in Extremadura [3] [4]. Table VI provides a comparison among MSYS and the average for tertiary studies.

The first value that can be compared is the population with university degrees, both in Spain and Extremadura, with former MSYS students old enough to attend a college. Although this is not exactly the same information, it is the only one we can compare now. For the Spanish population, we see that 40% hold a degree; this value drops to a mere 20% for Extremadura, while the value for MSYS former students is 48% the best of all. Although this value may decrease if not all of the students reach the degree, we feel confident that the percentage will not decrease significantly, given the interest that students display for getting a STEM degree, and will outperform for sure the average in Extremadura.

On the other hand, focusing in those students that are still pursuing a degree, the Spanish percentage in STEM areas is 26%, the same as the data provided by the University of Extremadura for 2017-2018 academic year, 26%, while for MSYS the value increase up to 47%. We thus notice a big and positive difference for MSYS. The main goal for any STEM project is to increase vocations to science, and increasing 21 points is a great success.

Finally, we can see that from those students that are still at high school, 52% are in science-technology path for MSYS, while only 41% went to that area in the case of the Spanish population and 45% in Extremadura. Again, the rate grows 11 and 7 points when MSYS compares to both Spanish and Extremadura's students respectively.

Moreover, if we only focus on the model that provided best results for MSYS, the case when everybody can attend paying a registration fee, we see that above referred values dramatically increase to 90% in STEM areas at high school, 75% in STEM degrees. Although this data are still preliminary,

[2]Information available at Spanish National Institute for Statistics: http://www.ine.es

[3]Extremadura Regional Government - http://estadisticaeducativa.educarex.es/

[4]Quality and Evaluation Technical Department, University of Extremadura https://www.unex.es/organizacion/servicios-universitarios/unidades/utec

TABLE IV
TOTAL (SCIENCE/HUMANITIES) AT UNIVERSITY AGES.

Model	College	Prof. Deg.	other	total
Best-free	12 (2/10)	7	3	22
Everybody-pays	8 (6/2)	5	6	19
Total	20 (8/12)	12	9	41

TABLE V
TOTAL (SCIENCE/HUMANITIES) AT HIGH SCHOOL AGES

Model	High S. decision taken	no decision yet	total
Best-free	9 (1/8)	0	9
Everybody-pays	10 (9/1)	4	14
Total	19 (10/9)	4	23

TABLE VI
PERCENTAGE OF POPULATION WITH (OR PURSUING) COLLEGE DEGREES

Where	University	STEM degrees	STEM at H.S.
Spain	40%	26%	41%
Extremadura	20%	26%	45%
MSYS average	48%	47%	57%
MSYS everybody-pays	47%	75%	90%

given the number of students included, we think that the general trend is extremely positive, and we hope to confirm this trend in the coming years.

Although it is not easy to find cause-and-effect relationships, and we are still awaiting to have a larger amount of data that will be available in the coming years, when more students have the opportunity to take decisions, we think that results are very encouraging.

In any case, and although this careful analysis have been performed in 2018, we previously had some hints on how each of the models were working, and nowadays only the *everybody-pays* model is being applied in all the towns where MSYS is working in Extremadura, while the *best-free* have been discarded.

Finally, and as we have described in the introduction, we pay special attention to the actions, studies and reports prepared by the Spanish Foundation for Science and Technology, given its role as a leader in efforts to awaken the general interest in science and technology in society. We would like thus to mention the last report they have published: Extremadura, the region where we have been working in the last decade and the one of the poorest in Spain GDP, is the second with the largest increase in its population of general interest for science and technology [7]. Whether this important increase, that has been reported once MSYS is running, is related or not with the effort deployed by MSYS will be the subject of future studies.

V. CONCLUSIONS

This paper analyses for the first time the impact of a STEM action sustained over the years in Spain. Although other analysis had been reported for single workshop actions, to the best of our knowledge this is the first time that a long term activity is analyzed to see how it affects students decision over university STEM degrees they may follow.

The analysis has allowed us to see that the number of former MSYS students attending university degrees are larger than the standard in Spain, with an increase of 8 points, and notably larger when we compare with population in Extremadura, with an increase of 28 points. Moreover, among those already attending university degrees, 47% are in STEM areas, while the Spanish average for those holding a degree is just 26%. Therefore a remarkable increase of 21 points has been documented.

On the other hand, two different models have been analyzed. The most successful one allows to enter MSYS any interested student, and a small fee must be paid by their families to the town hall. For this specific model, which is the only one that we are applying nowadays, 75% of students already in the university are studying a STEM degree.

Although a longer period of time is needed to collect a larger amount of data that allows to perform a deeper analysis, we think an important trend has already been shown, which encourage us to continue the effort with MSYS, and could be useful for designing similar long-term initiatives for promoting STEM vocations among young students.

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