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INCLUDES TWO INTERVIEWS

The roses project directors

Anna-Karin Westman

Magnus Oscarsson (Linköping University)

Anders Jidesjö (Mid Sweden University)

President of the Catalan Society of Technology (SCT)

Núria Salán

ROSES Project. Importance of science and technology today

What do teenagers think about their science class?

by Maricarmen Albás, Clara Blanch and María Pilar Almajano

According to the PISA 2015[1] report, boys and girls perform very similarly in science tests. It implies that cognitive ability in science is not gendered. However, around 5% of girls' value pursuing a career in science or engineering compared to just over 12% of boys, as shown in Figure 1. In the same report, the majority of students expressed a strong interest in science topics recognising the important role of science in their world. However, only a minority reported participating in science-related activities. In contrast to other large-scale studies such as TIMSS[2] and PISA, the ROSES project suggests that if we want to know what young students want to do in the future, we need to look not only at their cognitive dimension but also at their social and emotional dimensions: these are often the most important determinants of their final choice.

According to Núria Salán, president of the Catalan Society of Technology (SCT) and coordinator of the UPC's Gender Programme, we must bring technology closer to citizens by showing its fundamental role in social progress. The technophobia that, she says, still exists in our society needs to be broken: *Catalonia needs technologists, we want to have more boys and girls who opt for technology studies because the future will be technological or it won't be*. Fighting against gender inequalities in this field is also one of Núria Salán's challenges. For Salán, there is no single cause, and the main reasons could be related to a lack of role models and references. For example, she says, there is a lack of examples of STEM professional women who show themselves naturally in their usual tasks; on the other side, though, there are many examples of STEM boys (see the full interview at the end of the article).

HOW TO MAKE SCIENCE AND TECHNOLOGY MORE ATTRACTIVE TO YOUNG PEOPLE?

Science and technology education plays a key role in modern society as they are the engine of its economy and their relevance from a cultural and democratic point of view. For the OECD, for example, quality science and technology education is essential in a global, knowledge-based economy where technology is ubiquitous. For this reason, when PISA assesses the quality of an education system and the level of preparation of young people to successfully face their future, too, it focuses precisely on science and mathematics, in addition to reading.

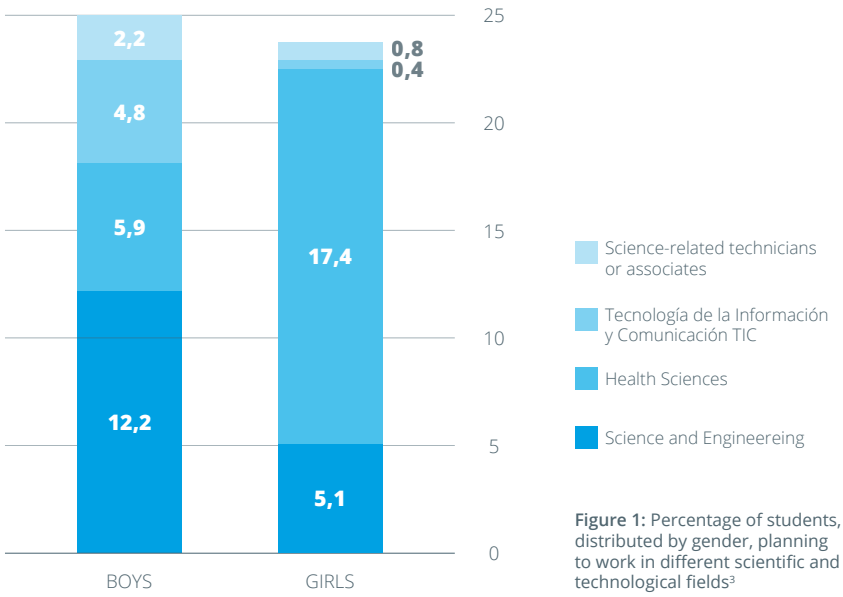

Figure 1: Percentage of students, distributed by gender, planning to work in different scientific and technological fields[3]

Since the last quarter of the 20th century, international initiatives have begun to emerge; they bring together the most diverse *stakeholders* under the same purpose: how can we make learning science and technology more attractive to teenagers, and in particular, how can we encourage them to pursue higher studies related to STEM (Science, Technology, Engineering and Mathematics)? IOSTE (International Organization for Science and Technology Education) is one of the most dynamic proposals. This UNESCO's NGO is recognised to promote science and technology education as a vital part of general education in all countries. Currently, it has participants from nearly eighty countries. It organises a biannual symposium that brings together many high quality, influential research papers and practical proposals from all over the world in each of its editions. Thirty-one countries participated in the last one, which was organised in Korea and held online. It was entitled *Transforming science and technology education to cultivate participatory citizenship*: the main objective was to promote the ability to generate public dialogue and debate and to be willing to take responsible action for sustainable development among young people in a world plagued by unchecked global warming, an energy crisis, health threats, new materials, etc.

In many countries with high PISA and TIMSS scores, interest in and attitudes towards science tend to be very low.

Svein Sjoberg is a professor at the University of Oslo with a PhD in Nuclear Physics and has been an active member of IOSTE since its inception and later its president. He is one of the most influential people in improving science and technology education worldwide. He has been involved in most European projects to improve science education and worked intensively in less favoured contexts such as AFCLIST (*African Forum for Children's Literacy in Science and Technology*). One of his significant achievements has been to bring to science and technology education the scientific rigour of a physicist coupled with an understanding of psychological and social factors. His work includes the social dimension of science education with critical studies on gender, social and cultural differences. One of his major concerns has always been the science education of girls and young women. Professor Sjoberg was one of the first to see that international comparisons of standards such as PISA or TIMSS needed to be integrated with international studies on attitudes towards science and its reactions. He was the first to become involved in global studies on the subject by leading the ROSE (Relevance of Science Education) project: one of the primary studies on the subject. This international research achieved broad participation and valuable results that were a significant step forward in all continents, including Africa and Asia.

In the educational systems of most countries, positive attitudes towards science and technology (S&T) are essential learning objectives, as is valuing science as part of the culture. However, in many countries with high PISA and TIMSS scores, interest in and attitudes towards science tend to be very low. This was of great concern to ROSE promoters who consider affective dimensions in science education as important as academic performance.

RELEVANCE OF SCIENCE EDUCATION. FROM ROSE TO ROSES

ROSE was a cooperative research project aimed primarily at studying how young people relate effectively to S&T. The main objective was to analyse factors influencing students' attitudes and motivations. Its main objective was to analyse the factors influencing students' attitudes and motivations. The study focused on

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a questionnaire for 15-year-olds that could be applied to students from different cultures. It asked them about their experiences with science outside and inside the school, their interest in learning certain content, their views and attitudes towards science and scientists, their future aspirations or their feeling of empowerment concerning the challenges in their environment, etc. Researchers from all continents and nearly 40 countries took part.

The results were of interest to science teachers and researchers, national and international organisations such as UNESCO, the EU and the OECD, and numerous NGOs involved in supporting science education. Svein Sjoberg was invited to participate in numerous European initiatives: *Europe needs more scientists (2004)* provided a basis for the subsequent development of science education policies in Europe; *Eurobarometer* conducted a study on Europeans and their relationship with science and technology, the results of which were compared with ROSE, or *European Round Table of Industrialists (ERT)*, among others, and in the most representative international conferences, such as ECSITE, The Royal Society, ICSU, IOSTE or Eurycide (2010), where he presented the conclusions. Another consequence was the OECD's increased focus on STEM (science, technology, engineering and mathematics) disciplines as critical for development.

The 240 items of the ROSE questionnaire were classified into ten categories, some of which include:

- What I want to learn
- My future work
- Me and environmental challenges
- My science classes
- My views on science and technology
- My informal science experiences
- Me as a scientist

Some of the most striking results were:

1. Young people strongly agree that *S&T is important for society.*
2. In less developed countries, they strongly agree that *S&T make our lives healthier, easier and more comfortable.* In developed countries, they do not agree so much, especially girls.
3. In less developed countries they strongly agree that *new technologies will make work more interesting.* In developed countries, they do not agree so much, especially girls.
4. In less developed countries, they strongly agree that *science at school has shown me how important science is for the way we live.* In developed countries, they don't agree so much.
5. In developed countries, few young people want to be scientists, especially fewer girls.
6. Almost no girls want to work with technology in developed countries, and even boys are ambivalent, especially in Japan.

Almost a generation has passed since ROSE, and scientific and technological progress has means that the world and society are continuous transformation. There have been social developments, new addictions, new models and trends. How much have students' interests changed? In a world where social networks have changed the way we relationship and inform us, global environmental challenges are highly mediatised (Greta Thunberg) and a world wide pandemic has disrupted all their plans.

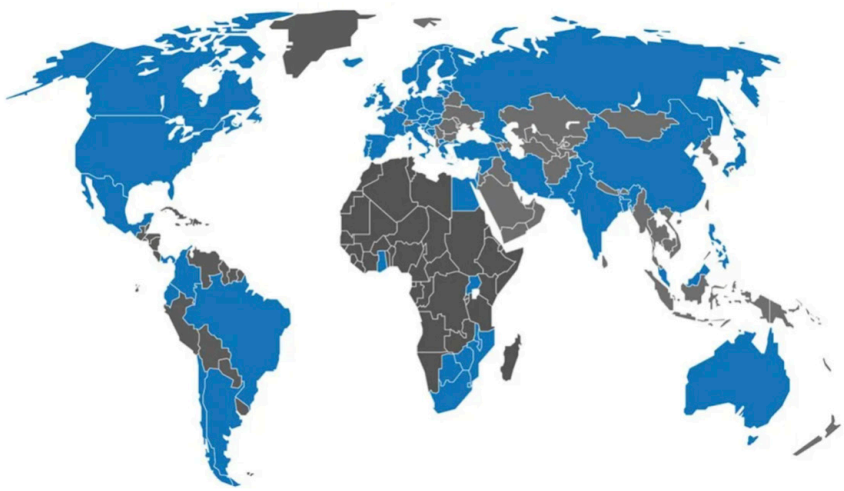

Figure 2: Countries where ROSES-2020 analysed results.

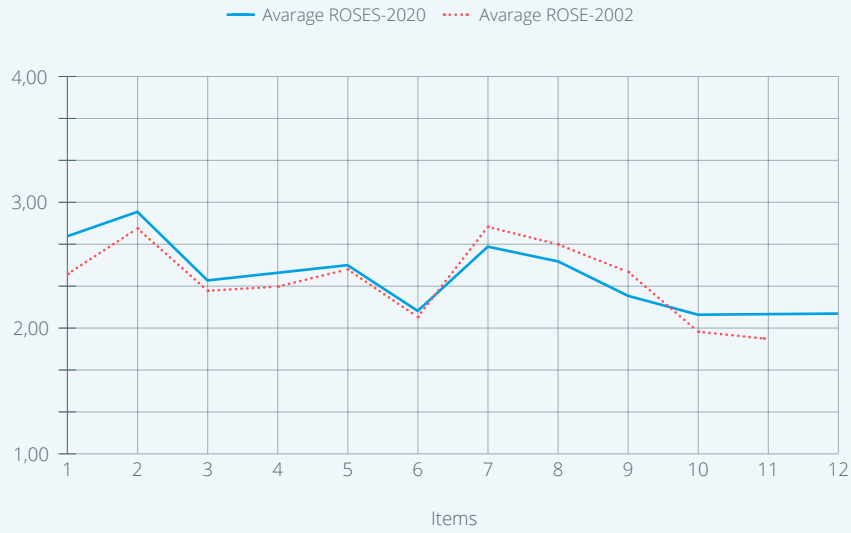

Figura 3: Comparison result of category F of the ROSE-2002 and ROSES-2020 questionnaires.

It is in this new context that ROSE Second (ROSES) is born. This time Professor Sjoberg passes the baton to three Swedish researchers: Magnus Oscarsson (Linköping University), Anna-Karin Westman and Anders Jidesjö (Mid Sweden University).
The number of participants in the new project is growing, as shown in Figure 2, reflecting the situation in April 2021. It continues to grow due to widespread interest. ROSES is intended as a continuation of ROSE. The main objective is to update the empirical evidence in the context of the new situation and to inspire significant improvements. Therefore, most of the questions remain the same. The aim is to study how ROSES results relate to ROSE, to what extent there is a progression or regression, what impact ROSE had and what more could be done to improve S&T education.

PRELIMINARY ROSES RESULTS AND FIRST COMPARISONS

Spain is one of the participating countries. In Catalonia, more than 800 students from 11 schools in Barcelona, Girona and Tarragona have already participated. Figure 3 shows a comparison of 12 items belonging to category *My science lessons*, of the ROSES questionnaire. The graph shows that Catalan students better perceive their science classes than the average Spanish data collected in ROSE-2002[4].
On a scale of 1 to 4, students were asked to what extent they agreed with the statements about *My science lessons* are:

1. *Science is a difficult school subject.*
2. *Science is an interesting school subject.*
3. *Science lessons have opened my eyes to new and exciting work.*
4. *Science is more enjoyable than most other school subjects.*
5. *The things I learn in science lessons will be useful in my everyday life.*
6. *Science lessons have made me more critical and sceptical.*
7. *Science lessons have increased my curiosity about things that we cannot yet explain.*
8. *Science lessons have shown me how important science is to the way we live.*
9. *Science lessons have taught me how to take better care of my health.*
10. *I would like to become a scientist.*
11. *I would like to get a job in technology.*
12. *Science lessons have helped me to understand sustainable solutions in my everyday life.*

As can be seen, the results, 18 years apart, follow the same pattern. The highest scores are obtained in 1, 2 and 7: they reflect the difficulty, interest and usefulness of science class. On the other hand, the lowest scores in 6, 10 and 11 reflect the intention to be a scientist or get a job in technology.

Norway pioneered the questionnaire application and presented its results at the IOSTE symposium in Korea in February 2021. Figure 4 shows a comparison of preliminary results from Catalonia and the Nordic country, about 4 items related to attitudes in science classes.

These first results obtained reflect a similar trend in the interest shown in the subject of science (Item F2), close to 70% of adolescents. The trend, therefore, seems to be maintained, despite the changes and efforts made by the education systems.

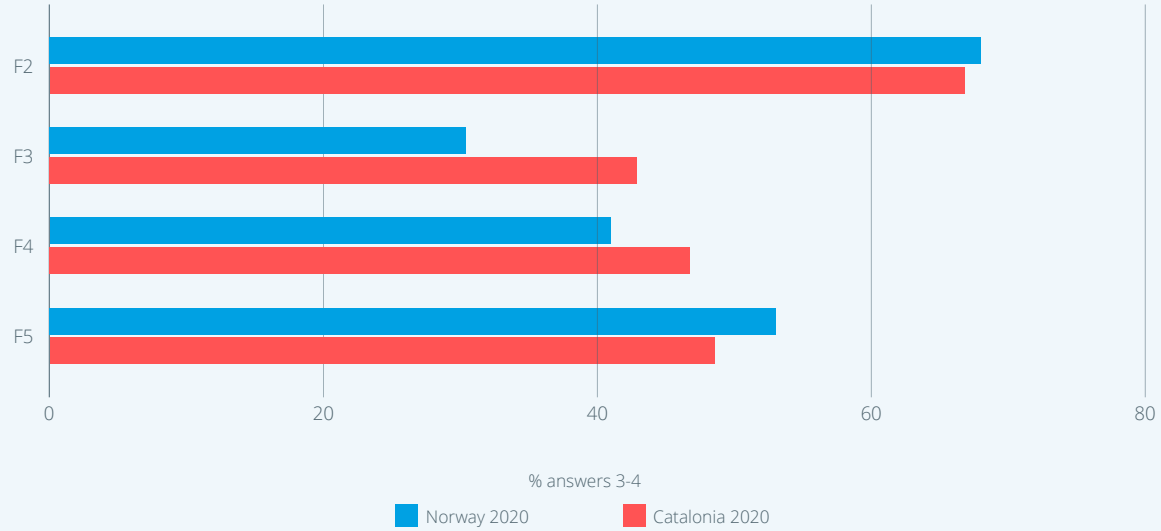

Figure 4: Preliminary comparison between Norway and Catalonia in ROSES-2020.

INTERVIEW WITH THE ROSES PROJECT DIRECTORS

What impact did ROSE have on the educational systems of the participating countries?
ROSE surprises in several ways, which explains its success. One key result is that students are interested in science and technology, and the interest is linked to specific content. Another result is that students' interest seems to be related to social development, and the trend is international. In general, the more modernised a country is, the less interest students show. The connections with performance are more challenging to understand. There were different reactions in different countries. Each country decided how to make use of this evidence and worked on policies and reforms. For example, in Sweden, we tried to incorporate the affective dimensions in the 2011 curriculum reform. However, it was difficult to make a difference. Beyond the participating countries, I would say that, for example, in PISA, there was a discussion about the importance of measuring *affective attitudes*, a debate that is still going on. Other organisations and NGOs have shown interest in the results, and many stakeholders have used them.

What motivated to the continuation of the ROSE project?
Worldwide colleagues contacted Svein Sjoberg about ROSE and wanted to know more about changes and new research. This led him to propose an expert roundtable at the IOSTE conference in 2016. As a result, we were asked in Sweden to continue the work and create a second ROSE study. Given that many things happen in different societies and globally, such as climate change, conflicts, catastrophes, social networks, etc., together with, for example, science and technology campaigns, several colleagues argued that the results would have changed. It is expected that youth culture, modernity or other situations influence the results. We want to investigate in order to draw conclusions empirically substantiated statements. Since many are interested in this research, we consider it worth a try.

What are the differences between the questionnaires of the two projects?
In ROSE, most countries collected data using paper questionnaires. Although many students found the questionnaire time-consuming, it worked. Today, most countries collect data in a digital mode. In a digital mode, most people interrupt it if they find a questionnaire too long. For these reasons, from many worldwide colleagues expressed the wish to shorten the number of items in the questionnaire. We had several discussions on how to do this, especially in the ROSES advisory board. After methodological considerations, we applied a statistical method that helped us optimise and improve the questionnaire to add some new categories and items.

Could you tell us what trends you observe in this second study?
These are the first results, and they are preliminary. However, a first general impression is that the situation resembles that of the early 2000s. We are now analysing it further and will be able to see some trends, which we will publish and

I call for the visibility of models of proximity, such as alumnae of secondary schools everywhere, who now have a STEM profession, regardless of how they have achieved it.

communicate in the following papers. There will probably be different situations in different countries.

How to make science learning more relevant to girls and young women?
It is essential, but we are not sure about causality and there is a risk that we will not address the real causes of the problems identified. For example, there is much evidence pointing to the importance of early childhood and the primary education, which makes us suspect that projects at the secondary level may be too late and unsuccessful. However, we need more evidence and practical experience before giving recommendations.

The Roses Project Directors:
Anna-Karin Westman
Magnus Oscarsson (Linköping University)
Anders Jidesjö (Mid Sweden University).

INTERVIEW WITH NÚRIA SALÁN

Why do you think so few girls choose to study STEM careers?
There is no single cause, and the importance of each one varies depending on the environment (economic, social, family, ...). The main reasons lie in a lack of role models and references. There is a lack of STEM professional women who show themselves naturally and generally in regular tasks. At the same time, there are examples of STEM boys. There are STEM women who are quickly identified. However, they are usually *impressive* women (Nobel Prize winners: Marie Curie, Margarita Salas or professors: Anna Navarro-Schlegel), and this makes a *normal* girl, with *normal* grades, might feel outpaced from those models. It is crucial to give visibility to women inventors without a university education: it would make clear that having an excellent education is not essential to be creative or inventive. However, it is better if they have it. I call for the visibility of *models of proximity*, such as alumnae of secondary schools everywhere, who now have a STEM profession, regardless of how they have achieved it.

Family environment is another very influential factor. So, it is quite likely that a girl born in a STEM trained family may decide to do a technical university degree after finishing her chosen technological training cycle. Finally, another factor sometimes turns out to be the strongest: the lack of *training/information* of teachers in the technological field and the multiple professions developed from STEM training. For example, very few teachers come from a technological baccalaureate. Not having knowledge or a particular passion for STEM creates clichés and ignores the more human profile of technology (design of medicines, food and medicine preservation systems, robots that make impossible surgeries possible, assistive robotics, ergonomics, comfort, sustainable design...). Therefore, it would be necessary to include technology content in general teacher training.

These three reasons often combine, and when they happen to converge at the same point, we find ourselves with a *STEM black hole*.

What would you say to our young people (boys and girls) to encourage them to choose STEM disciplines?
I would tell them that this present 21st century is the one of science and technology; the coming decades' professions in demand have not yet been written but will be STEM-related professions, and unless they develop a minimum of competencies in this field, they will remain spectators and will not be designing their own future. I would also tell them that the *bad reputation* that precedes STEM is not accurate. Mathematics is not complicated but exciting: it only needs to be well explained. Although it may be perceived as a little more complicated than other disciplines, it is not unattainable training. The gratification that comes with having the training to keep up to date is priceless.

What do you think are students' attitudes and perceptions related to science?
They may believe science is for intelligent people, excellent grades, with a socio-economic profile far removed from low incomes. However, none of these three is strictly true. Throughout the history of humanity, science has helped us understand the reason for everything and justify surrounding phenomena. From this understanding and knowledge, we have designed remedies, improvements and solutions to live better. If nobody had dedicated themselves to STEM, we would not have mobile phones, laptops, wifi, vaccines, or dehydrated food... All the surrounding comfort is, to a

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With a STEM profile, one can participate first-hand in the development and construction of a better world.

large extent, the result of good STEM actions. What remains to be designed and built is in the minds of the rising generations.

What factors can significantly affect science learning?

Teachers should have a positive and assertive view of science. If they have science internalised, they will pass it on with passion.

We are *selling* the students successful role models who succeeded in STEM professions. However, offering a vision of the self-taught genius like Steve Jobs does not help, nor does the *pressure* about what to study or the right time to finish studies in order not to be a failure; there are young people who need a different pace.

There are options for gamification or learning based on actual problems, which help a lot to incorporate science from its application examples to see its usefulness. The teaching staff's complicity and passion are necessary.

What factors can significantly affect science education and STEM vocations?

Examples of *complex* technologies that make our lives easier and more comfortable could help. From these examples, and going backwards, unravel the necessary knowledge for developing these technologies and, by doing so, identify the skills the people who developed them had.

Moreover, examples of sectorisation of technology application could also be used: advances in mechanics are easily directly related to powerful, fast cars; other aspects have also been significant (safety, comfort, ergonomics, energy-saving) considered as *second-class achievements*. The power of a car attracts boys, but girls feel more empathy for its energy efficiency. The same example, with different nuances...

It is often said that with a STEM degree, one will not be short of work. Furthermore, it is true. With a STEM profile, one can participate first-hand in the development and construction of a better world. So are you going to miss it?

Clara Blanch Ricart holds a degree in Civil Engineering from the Polytechnic University of Catalonia (UPC). She studied a Master's degree in teacher training in Mathematics and Computer Science at the Valencian International University (VIU). Since then, she has worked as a mathematics teacher in secondary and international baccalaureate. She has been part of the Impuls Educació research team since July 2020. Currently, she is a PhD student in Engineering, Science and Technology Education at the UPC and co-directed by the University of the Balearic Islands (UIB). She is coordinator in Catalonia of the ROSES-2020 Project together with Maricarmen Albás.

Mari Carmen Albás Bollit is a Telecommunications Engineer from the Polytechnic University of Catalonia (UPC). She is currently a PhD student in Engineering, Science and Technology Education at the UPC and co-directed by the UIB. She has been a teacher of Mathematics and Technical Drawing at the Vall School (Institució Familiar d'Educació) since 1996. She has been part of the research team of Impuls Educació since June 2020. She implemented the international e-Twinning programme, the use of the moodle platform in the school and was a pioneer in the use of mobile devices in the classroom.

María Pilar Almajano Pablos holds a PhD in Chemistry. She has worked in secondary education for 12 years. She has been at the UPC for more than 20 years, where she is currently working. She has two active lines of research: natural antioxidants and the improvement of student learning (both at secondary school and university). A regular collaborator of the ICE of the UPC since the beginning of her professional career, she currently teaches subjects and workshops to UPC teachers and future secondary school teachers (specialising in technology).

Notes

[1] The PISA (Programme for International Student Assessment) report is the OECD's global study of academic performance in mathematics, science and reading.

[2] TIMSS (Trends in International Mathematics and Science Study) international assessment of mathematics and science literacy of fourth and eighth-grade worldwide students.

[3] Source: *First Class Building a Quality School for the 21st Century*
https://doi.org/10.1787/9788468050126-es

[4] *The Relevance of Science Education II: The voices of Catalan students in their science classes. Preliminary results*