






## PERCEIVED BARRIERS AND BENEFITS TO PROMOTING SCIENCE AND ENGINEERING BY UNIVERSITY LECTURERS THROUGH OUTREACH LECTURES TO SECONDARY SCHOOL STUDENTS

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### Abstract

Lectures on science and technology constitute one of the most noteworthy activities used to promote STEM-related degrees (Science, Technology, Engineering and Mathematics). This research seeks to identify the factors that pose an obstacle to promoting science and engineering via scientific and technical lectures to secondary school students, as well as their positive aspects, based on the experiences of teaching staff who conduct such lectures. An exploratory study consisting of 16 interviews was conducted with lecturers of different ages, qualifications and academic profiles at the University of Castilla-La Mancha (UCLM). The software ATLAS.ti was used to perform the qualitative analysis. The results of the interviews reveal obstacles related to secondary schools, the speakers, and the university environment, mainly focusing on organisational aspects. Similarly, positive aspects have been found with regard to students, speakers, the University and society in general, all of which are geared towards promoting these studies and communicating scientific knowledge. The main conclusion drawn from this study is that science and technology lectures may be a good outreach tool, but they require greater organisational and institutional support.

**Keywords** – Science and technology, STEM, Science outreach, Secondary education, Engineering.

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## 1. Introduction

Society today, which is certainly complex and conflictive with regard to how we use and abuse the advances available to us (Han, 2022), is based on technology and information (Vennix, den Brok &

Taconis, 2018), and its well-being is linked to the continuous progress of scientific knowledge and its applications (FECYT, 2015a). Thus, education has become an essential element within a changing context due to increasing complexity, uncertainty, accelerated globalisation and rivalry (Laguna-Sánchez & Segovia-Pérez, 2023). This is also linked to the growth of countries, being a factor that affects social progress (Martínez-Gil, Oyarvide-Ibarra, Rosales-Cortés & Bustos-Gómez, 2019). Moreover, the technological progress of countries is an essential part of their economic development and advancement, where engineers, technologists and scientists play a fundamental role due to their capacity for innovation (FECYT, 2015a; Ramírez, 2018; Utley, Ivey, Hammack & High, 2019).

For more than a decade, it has been noted that the number of students choosing to pursue STEM (Science, Technology, Engineering and Mathematics) related studies in developed countries, mainly in the European Union and the United States of America, has been decreasing. This raises concerns about the future or already current decrease in the number of scientists and technical professionals trained in these fields (Everis, 2012; Falcone-Lanas, 2016; Hall, Dickerson, Batts, Kauffmann & Bosse, 2011; Lupión-Cobos, Franco-Mariscal & Girón-Gamero, 2019; Ramírez, 2018; Valero-Matas, Valero-Oteo & Coca, 2017; van den Hurk, Meelissen & van Langen, 2019). In Spain, the Confederación de Sociedades Científicas de España (COSCE) report (2011) indicates that pre-university students do not perceive science subjects positively, with insufficient motivation to study science and technology, together with an increasingly low motivation (Valero-Matas & Coca, 2021) and gender-biased (García & Hijón, 2022) to work as scientists or in fields related to science and technology.

Beyond the educational sphere, this situation is affecting competitiveness and the growth of industry and the economy, and negatively impacting the development of research and innovation programmes (FECYT, 2015a; Valero-Matas et al., 2017). It is noteworthy that in a society as technologically-based as the one we live in today, which has achieved high levels of knowledge and education, there is a certain lack of interest in scientific and technical matters (Falcone-Lanas, 2016). This leads us to reflect on whether there may be a certain dissonance between the image that is projected and the reality of these issues, and if so, what actions may mitigate the myths and prejudices that are held regarding this aspect, such as, for example: “that STEM subjects are not for girls” (Martín & Santaolalla, 2020: page 44), or, according to these authors, that we are faced with an education that is far removed from critical and reflective thinking, the hallmarks of a participatory citizen. Nothing could be further from the truth, since the STEM approach may be a good choice in order to explore certain problems and challenges of our century (Tuong, Nam, Hau, Tien, Lavicza & Houghton, 2023).

It has also been noted that students who have completed their secondary education find it difficult to choose between different technical degrees, owing to a lack of knowledge of the specific competences of each, and lack of adequate counselling in secondary education (Poveda, Sánchez-Cambronero, Lozano-Galant, Tarifa, Galán, Porrás et al., 2015). The lack of a common degree map, and the different names of the degrees that provide access to the same professional skills depending on the destination university, further hinder students when making their choice.

Within this context, various activities have been developed in recent years by governments, companies and STEM-based organisations, universities and secondary schools, in order to inform students, to motivate them and thus foster new scientific and technological vocations in STEM fields (Eeds et al., 2014; FECYT, 2015a; Fundación Telefónica, 2014; Jeffers, Safferman & Safferman, 2004; Valero-Matas et al., 2017; Vennix et al., 2018). One such outreach activity is lectures imparted by experts from research institutes (whether public or private) (Vennix, den Brok & Taconis, 2017). It is essential that young people understand what universities can offer them before they enter. For example, in 2019, professors from 13 Spanish universities, together with secondary school teachers, conducted some 50 outreach projects involving more than 1,500 students (Innovaspain, 2019).

The institutional relationship between universities and secondary schools may be found in Bourdieu's (1990) concept of habitus, whereby adaptive practices are established in pursuit of conscious goals. Taking advantage of the socio-economic relations and certain complementary goals, both institutions can

establish collaborations over time (Reay, David & Ball, 2001), based on common goals such as education and knowledge transfer. What's more, the existence of a secondary school institutional culture of collaborating with, or enabling the outreach activities offered by universities in their facilities, can broaden students' horizons when it comes to choosing future university studies (González-Sanzana, 2016).

As most studies focus on the impact of different outreach and teaching activities on students, in this article we have opted for a different approach by conducting an exploratory study that focuses on the perception of professors of different degree courses at the University of Castilla-La Mancha (UCLM), and who give outreach lectures and talks on science and technology to students of Compulsory Secondary Education, Baccalaureate and Vocational Training Cycles. It should also be remembered that the view provided by this group is not only complementary but also a professional and expert perspective and therefore may be compared to that of students, which is legitimate but also limited and therefore biased, as well as to other professionals involved, such as school teachers themselves, who are usually more at hand when implementing teaching innovations in class, which may well be related to others conducted later at university (Valero, 2022). Having said that, we have taken up this challenge by using a qualitative methodology via structured interviews in order to analyse the perception of university professors involved in giving lectures to disseminate and promote science and engineering among secondary school students, with regard to their usefulness, as well as to identify the factors that pose an obstacle to their development and the positive aspects identified. The following sections include the literature review, methodology, results and discussion, and finally, the conclusions.

## 2. Background

There appears to be some consensus in the literature that pre-university students have a limited view of scientific and technical professions and the tasks performed by professionals in these fields, which may lead them to decide against participating in science (Chen & Cowie, 2014; FECYT, 2015a). Moreover, the concept of engineering is not very clear to many people and, in the case of these students, it is often poor (Hasna & Clark, 2009). Faced with this panorama, a significant step would be to improve the view held by society, and especially pre-university students, of scientists and engineers (Ambrojo, 2015).

There are results that support the hypothesis that knowledge influences interest in and perceptions of science (FECYT, 2015b). In Spain, while technical and scientific professions enjoy a great deal of social prestige (FECYT, 2015b), this positive result does not translate into a willingness on the part of younger generations to make technology their vocation (Becker, 2010). According to Becker (2010), while young people like technology, they do not perceive it as sufficiently attractive when compared to other options.

The situation described above sheds light on the need to develop initiatives to increase general knowledge and interest regarding science in society, and especially among pre-university students (COSCE, 2011). Public outreach activities are important because they can transform public perception of scientists and increase support for scientific research (Poliakoff & Webb, 2007).

In this regard, recent research proposes that the secondary school environment represents a crucial time in which to develop interest in STEM fields (Koomen, Hedenstrom & Moran, 2021) and to help adolescents to learn about potential STEM careers and connect these career choices to their educational decisions (Hall et al., 2011). When students are involved in science, technology and engineering-related activities, it can have a positive impact on their achievement and confidence regarding these disciplines (Oware, Capobianco & Diefes-Dux, 2007; FECYT, 2015a).

People generate interest by means of exposure, which can increase the desire to learn more about a certain topic (Koomen et al., 2021). If a student has never been exposed to a specific area, they cannot develop an interest in it (Hall et al., 2011). According to Dou, Hazari, Dabney, Sonnert and Sadler (2019), exposing young people to science-related experiences that make it easier for them to talk about science, helps them build their STEM identity.

The literature on this subject discusses a wide variety of outreach activities involving science communicators such as public meetings (Besley & Tanner, 2011), discussion forums, exhibitions, science in the media, departmental open days, visiting schools, or media activities (Davies, 2008).

Lectures by guest scientists and researchers at schools can especially, help to bridge the gap between the school curriculum and developments in science and technology (Becker, 2010). Young people also enjoy hearing first-hand accounts of the day-to-day activities and careers of scientists (Chen & Cowie, 2014). Listening to these life stories can help pre-university students to perceive themselves as people who participate and work in STEM or a related field, especially if they feel some kind of connection to the narrator (Chen & Cowie, 2014; Dou et al., 2019).

For an effective process of scientific communication during lectures, Burns, O'Connor and Stocklmayer (2003: page 183) indicate that skills, media, activities and suitable conversation must be used to generate one or more of the following personal responses to science: knowledge, enjoyment, interest, opinion-forming and understanding.

The literature on this topic points out that outreach actions have faced some difficulties in achieving their goals. For example, in case of activities in pre-university schools, it should be remembered that they function in a highly structured manner, with organisational constraints (Falloon & Trewern, 2013). To be more precise, the science communicator must recognise the context in which the communication shall take place, so they may adjust accordingly to the situation and thus avoid any such barriers that may arise (Bray, France & Gilbert, 2012).

It is also important for the speaker to design the lecture or talk so that it has a positive impact on students, encouraging their active participation (FECYT, 2015a) and seeking to detect negative stereotypes in order to anticipate disinterest in science and scientific careers (Ruiz-Mallen & Escalas, 2012).

### **3. Methodology**

This qualitative research consists of an introductory exploration of the phenomena under investigation (Zuliani-Arango, 2010). It frames this research in terms of how, rather than how much, in order to try and understand issues related to the promotion and dissemination of science and engineering by means of outreach lectures, from the perspective of university professors (Pratt, 2009). A considerable amount of detailed information has been obtained, facilitating the understanding and analysis of the questions posed (Bowen, 2005).

#### **3.1. Sample**

The research participants are UCLM lecturers involved in the promotion and dissemination of science, including conducting lectures and workshops for secondary school students (IES). In the Results and Discussion section, the quotes selected from each participant shall be numerically identified, in order to maintain their privacy.

The sample was drawn up using initial convenience sampling (Bryant & Charmaz, 2007), interviewing six lecturers initially at a UCLM centre who were then asked for the contact details of other lecturers at the University who were involved in these actions, applying the snowball technique to draw up the sample (Naderifar, Goli & Ghaljaie, 2017).

The sample size consists of 16 participants, which is sufficient for the qualitative research conducted. With regard to the number of respondents, Marshall, Cardon, Poddar and Fontenot (2013) mention that some Grounded Theory research have a sample size of 6 participants. For research projects that seek to understand the common perceptions and experiences of a relatively homogenous group of individuals, 12 interviews may be sufficient (Guest, Bunce & Johnson, 2006).

During the interview analysis, the number of participants was increased in order to reach the theoretical saturation of the sample (Weiss & Willems, 2017). As criteria to establish saturation, it was considered that

it was reached when there was enough information to replicate the study, when the situation of not obtaining additional new information arose, and when coding was not feasible (Chowdhury, 2015, Fusch & Ness, 2015). In addition, it was decided to carry out a triangulation of the data, since the triangulation of the data ensures data saturation (Fusch & Ness, 2015).

A triangulation of researchers was applied in which all authors participated, with the aim of balancing individual subjective influences (Flick, 2004). Thus, multiple observations and conclusions were obtained, providing confirmation of the findings from different perspectives and adding breadth to the phenomenon studied (Carter, Bryant-Lukosius, DiCenso, Blythe & Neville, 2014), also verifying that the indicated saturation criteria were met (Guest et al., 2006).

The sample analysis reports that the 16 participants hold PhD degrees, 15 men and 1 woman, aged between 36 and 63 years. 25, 44, 25 and 6% of the participants are aged under 39, between 40-49, 50-59, and over 60, respectively. They teach at eight UCLM centres in the Albacete, Ciudad Real, Cuenca and Toledo university campuses, and belong to four different departments. In terms of their qualifications, 2 are industrial engineers, 2 are civil engineers, 1 is an IT engineer, 4 are telecommunications engineers, 1 is an industrial organisation engineer, 4 hold degrees in physical sciences, 1 is an architect and 1 is a mining engineer.

Snowball sampling has a selection bias because items are not drawn randomly, but depend on the subjective choices of the respondents who were first contacted and their social network, thus “isolated” cases not connected to any network the researchers have consulted (Atkinson & Flint, 2001; Bailey, 2019) are missed. Sample bias does not allow generalisations to be made in the results (Atkinson & Flint, 2001).

Given the goals of the research, the participants would fall into the group of hard-to-access subjects (Bailey, 2019), owing to the small percentage of professors who are engaged in outreach work. As in the sampling process, the researchers access informants by means of the contact information provided by other informants (Noy, 2008), therefore the sample mainly consists of men. Despite this bias, the sample components offer in-depth and detailed knowledge of the phenomenon under study, providing valuable information that allows research questions to be adequately studied (Martínez-Salgado, 2012).

### **3.2. Data Collection and Analysis**

Structured interviews were used to obtain the information, as this is one of the most frequently used methods in this type of research. In these interviews, the participants share their experiences, perceptions, perspectives and knowledge related to the phenomenon they are questioned about. The wealth and complexity of this form of information gathering is derived from the different interpretations and meanings that people ascribe to similar facts and/or events (Blaxter, Hughes & Tight, 2002; King, Horrocks & Brooks, 2019).

The questions were drafted at the start of the research and a structured interview developed. This interview type is an objective and reliable method, which allows participants to be questioned systematically and allows for simple data classification and analysis (Díaz-Bravo, Torruco-García, Martínez-Hernández & Valera-Ruiz, 2013).

The questions asked in the research are as follows:

1. What barriers do you find in science and technology outreach lectures to secondary school students?
2. Which factors affect the implementation of science and technology outreach lectures in secondary schools?
3. According to you, what are the positive aspects of imparting science and technology outreach lectures to secondary school students?

The interviews were conducted in 2020 either in person or virtually via *Microsoft Teams* (11 interviews) or *Skype* (1 interview). The different procedures used to do interviews were conditioned by the geographical location and availability of the respondents (Baker & Edwards, 2012; Bavaresco, D'Oca, Ghisi & Lamberts, 2020, Denzin & Lincoln, 2011). All interviews were recorded with a digital audio recorder for later analysis.

The audio files of the recordings were transcribed into text documents and analysed with ATLAS.ti 8.1. The first phase of the analysis consisted of data reduction associated with the coding process (Tesch, 1990; Coffey & Atkinson, 1996). In coding, the aim was to separate, reduce, classify and synthesize all the data and manage them more easily (Charmaz, 2006; Jones, 2007). Use of the program helped to analyse, label and group codes into families, in an iterative process.

Using open coding, the concepts and descriptions resulting from the data analysis were labelled and categorised (Flick, 2007). A large number of codes were produced in the coding process, leading to the problem of over-coding (Jones, 2007). By applying constant comparison, similarities in codes were identified and using the Merge Codes option in ATLAS.ti, codes that had different names but essentially the same concept or phenomenon, were merged (Gibbs, 2012; Friese, 2012). The codes were also grouped to form the categories described in the following section (Figure 1).



Figure 1. Networks developed in ATLAS.ti by associating negative factor codes with the main categories

Working on the text files, relevant phenomena were detected by assigning codes (Coffey & Atkinson, 1996), which were suggested by the data itself during the analysis process (Caro-González & Díez-de-Castro, 2005). Using the citations associated with the codes, the data was segmented, decontextualizing them from the original text, to be reorganised in a re-contextualization process (Coffey & Atkinson, 1996). This way, common aspects were identified using the constant comparison method, which facilitated their interpretation, identification of their properties, explore their inter-relationships, and facilitated their description (Tesch, 1990; Charmaz, 2006; Díaz-Bravo et al., 2013; Mathews, Kalfoglou & Hudson, 2005; Penalva-Verdú, Alaminos-Chica, Francés-García & Santacreu-Fernández, 2015).

Taking into account the qualitative and exploratory approach of this research, it was possible to understand and interpret those aspects included in this study that are based on the knowledge and opinions derived from professional experience, as close as possible to how interviewees perceive it, but without being able to generalise the results obtained (Blaxter et al., 2002; Pratt, 2009). In this process, meaning has been sought in the data in a rigorous and systematic way (DeCuir-Gunby, Marshall & McCulloch, 2011), establishing relationships between data categories by means of an interpretative analysis, seeking to describe the phenomena studied in order to draw up a theoretical model (Trinidad, Carrero & Soriano, 2006).

## 4. Results and Discussion

### 4.1. Barriers or Difficulties Encountered

On analysing the answers to the first questions, a series of factors were revealed that have a negative impact on the implementation, development and/or maintenance of this type of activities. The factors have been grouped into three categories: secondary schools, speakers, and the university environment.

The factors included in the category of Secondary Schools have been sorted by how many of times different participants mentioned them in their answers. These factors are students' lack of interest, high attendance at lectures or talks, the class or age of the attendees, organisational issues, and inadequate or insufficiently equipped rooms.

Lack of interest among secondary school students is the most important factor in this category. This is a negative effect and, according to participants, it is difficult to reduce or eliminate it. In some cases, it may be related to the subject matter of the lecture, for example, all interviewees who give lectures on robotics state that they can easily overcome this lack of interest due to the attention paid by young people to the applications demonstrated in the presentation. However, other participants, whose topics deal with building or industry, claim that it is difficult to address technologically focused topics in terms that is suited to the students' prior knowledge.

The changes taking place among secondary school pupils are pointed to, as a reason for this lack of interest. In the words of Participant No. 12: "It's a student group with which it is hard to connect and to raise their interest. So, then, there you are, talking about a subject and you can feel that a small percentage of the class is paying attention to you while the rest are thinking of other things. This perception may be partially linked to the "Kids These Days" phenomenon, according to which adults perceive the youth of today as worse than when they were young (Protzko & Schooler, 2022).

It should be noted that research on the effect of new technologies have also revealed some interesting insights. Tanil and Yong (2020) found that smartphone presence and phone conscious thought affects learning and memory recall. Additionally, Kuznekoff and Titsworth (2013) state that students who use their mobile phones during class tend to write down and remember less information than students who refrain from using phones in class.

Moreover, students' perception of science and engineering may not match the image they have or seek to have, of themselves, leading them to avoid these disciplines and consider them unsuitable for them (Woods-Townsend, Christodoulou, Rietdijk, Byrne, Griffiths & Grace, 2016).

Speakers who have been invited by the secondary school to give talks describe a different situation, as they have lectured in classrooms with a small number of students, all of whom were interested in the subject as it is closely related to the subject matter, so they consider the experience to have been highly positive.

Many participants state that a barrier is created when large numbers of students are forced to attend lectures by the secondary school. These decisions in secondary schools contribute to increasing the percentage of students who are not interested in the lecture topic, thus increasing the lack of interest and attention, as well as the percentage of dissatisfied attendees, all of which pose an obstacle to the normal evolution of the outreach activity and thereby negatively affecting knowledge transfer: "We have kids who seem to be going for the sake of going, which complicates your communication with them" (No. 11). The interviewees consider this to be a mistake on the part of the organizers, who believe that an increased number of attendees will lead to a more successful activity, resulting in the opposite effect.

Another variable that appears as a negative factor is the participants' age or their school class. Considering this factor, when imparting lectures to large groups, the older the student or the higher their school class, the more difficult it becomes to disseminate knowledge of science and engineering, due to preconceived notions on subjects such as physics, chemistry or engineering in general: "The higher the class, the greater their fear ..., they have prejudices and it's very difficult to demolish them" (No. 9). Although young students are generally open-minded and interested in many scientific topics, this scientific interest tends to decline with age (Jensen & Sjaastad, 2013; Osborne & Dillon, 2008). Moreover, when participants have given lectures to second-year students of the Spanish Baccalaureate, they note that their main concern are the upcoming university entrance exams.

Organisational problems include the time needed by secondary school teachers to schedule these lectures and meet the administrative requirements imposed on them by their school. This means that speakers

have to be contacted at the beginning of the school year or, when it is the universities that are offering the lectures, they have to publicise the lecture schedule at the start of the school year. The lecture topic must also fit the subject curriculum in order to justify the activity. All of the above would fall under what Fallon and Trewern (2013) call the “pragmatic realities” of schools, where all experiences beyond the classroom must be planned taking into account the subjects, the timetable, the resources available, and all activities that require teachers’ time and energy.

It is considered that there are secondary schools whose institutional culture encompasses a set of common values, attitudes, beliefs and norms that lead them to collaborate with the University in outreach activities (Brown, 2004; González-Sanzana, 2016), but it may be that the regional and national laws governing the organisation and functioning of secondary schools (Ministerio de Educación y Ciencia, 1996; Consejería de Educación, Cultura y Deportes, 2012) have certain prescriptions that hinder, to some extent, this collaborative culture.

Another barrier is created when secondary schools try to schedule the outreach lecture on specific dates that are related to a cultural activity of the school, which clash with the speaker’s previous commitments, creating a scheduling issue.

In relation to the above, cases where the subject matter of the lecture does not match the secondary school’s activities (employment days, fairs, cultural events, etc.) have been reported, when a speaker has noted that the topic to be presented or the talk itself was out of place. In situations such as the one described above, it must be noted that “one-off” interventions alone have little long-term impact on science choices and participation rates (Macdonald, 2014).

An additional factor is that secondary schools may have little time to include this type of activity, as Participant No. 16 states: “It’s a significant constraint and the kids have other things to learn, you can’t organise talks for them because their timetables are full”.

Another factor that hinders the holding of these lectures is the hall or classroom where they are held. In some cases, they are not best suited to the activity, as described by Participant No. 10: “schools have one of these halls that are not very adaptable, a multi-purpose room with chairs scattered all around, the students enter late and when you’re talking, they start moving the chairs, creating these unwanted messes”. They also mention technical issues with the rooms such as poor lighting, low resolution projectors or old classroom computers, leading Participant No. 7 to recommend: “It’s almost better to take your laptop along”, which most of the participants do.

The learning environment in which the lecture is delivered and the educational tools used can have an impact on student motivation (Vennix et al., 2018), affecting the knowledge transfer process and the impression created by the lecture.

There are eight factors in the Speaker category that have a negative effect on conducting these activities. In order of their importance, they are: time available to deliver the lectures, travel and distance to the secondary schools, the unsuitability of the contents of the lecture, choosing the right approach to the lecture, the teaching methodology used, lack of recognition and discouragement. Some of these factors are interlinked and may occur simultaneously.

Several participants report that time constraints are a major factor limiting their ability to deliver more outreach lectures. These activities must be performed in conjunction with their teaching and research work at university: “My first difficulty is time; our work schedule doesn’t let us conduct as many lectures as I personally would like” (No. 16). They must also find a slot in their weekly schedule that is compatible with the date and time proposed by the secondary school for the lecture.

Lack of time is found to be one of the most negative perceptions when participating in public outreach activities (Poliakoff & Webb, 2007; Rennie 2012). Mathews et al. (2005), when researching the views of



US geneticists on science policy-making and public outreach, found that these scientists' lack of time posed a barrier to their participation in outreach activities.

As pointed out by Rennie (2012) in her research, the distance between the lecturer's place of residence or the city where the campus is located, and the town where the secondary school is located, is a very important factor. This geographical separation implies a journey frequently made in the speaker's own vehicle, this journey therefore also consuming time. It should be noted that the Autonomous Community of Castilla-La Mancha is very widespread and the distance to be covered may pose a serious inconvenience.

Occasionally, these above-mentioned factors come together, which means that the speaker has to overcome three difficulties: making time in their agenda, travelling to the venue, and the time consumed in the entire process: "between the commute and everything else, you've lost an entire morning" (No. 16). Also, Falloon and Trewern (2013), in their research on partnerships between schools and scientists in New Zealand to help schools motivate and inspire students to study science, note that issues such as distance, the need for long-term planning, and the demands on scientists' time pose a problem for these outreach actions.

There are other factors that are significant enough for certain participants to pose a difficulty in this type of action. One is tailoring the contents of the talk to the attending student type. They try to find points of similarity with the students' syllabus in order to demonstrate that the contents of the lecture may be of use in their current schooling.

This interest in linking the contents of the talk to the syllabus contents is due to the immediate access to information available to young people today (Álvaro-Martín, 2015; Vázquez & Fernández-Mouján, 2016). If the attendees find nothing in it that may be of use to them now, they are less likely to pay attention, and do not consider the idea that it may be useful in the future: "The main problem I've seen is to convince them that this talk may be of interest to them, that it isn't something completely external ..., rather it's talking of science which may be useful to them in one subject or another." (No. 7)

The other problem is to use a teaching methodology that communicates information that can be understood by the audience. This may be the reason why each speaker uses different tools to facilitate communication, attract attention and increase students' interest (videos, models, robots, etc.). University professors are used to teaching one type of student and although they have developed their teaching method over the years, it may not be the most suitable one for secondary school students: "We know a lot about science, but maybe what we lack is a teaching methodology. I can explain Arduino but I might need to be told how to teach Arduino to a 12-year-old" (No. 7).

In addition to finding the method that best suits the subject matter, they seek to adjust the difficulty level and vocabulary used in the lecture to the participants' level, which poses another difficulty: "you're talking to an audience of secondary school or Baccalaureate students, you have to explain your research to them in words that are as simple as possible and which reach them ..., if you explain it as you would at university, they won't understand anything. You have to go down several steps, several levels, to reach them, using another language that you don't normally use" (No. 8).

These factors: customised content, suitable teaching methodology, and vocabulary level, are closely linked. Each speaker develops a teaching strategy during lectures which lets them avoid these issues or at least minimise their negative impact on the activity.

Another factor that some participants consider to be negative is the lack of institutional recognition for conducting outreach lectures or talks. They contrast the low value that is given by institutions to this activity, with the effort and work involved in performing it, as stated by Participant No. 16: "The worth of outreach activities is poorly acknowledged". They point out that they give lectures more for personal satisfaction than due to any extrinsic motivation. The lack of recognition of outreach activities has been

reported in several research studies as a barrier to their delivery, as they do not figure significantly in the scientific assessment of the speakers (Mathews et al., 2005; Royal Society, 2006).

All the factors mentioned in the Speaker category, whether singly or as a group, have negative effects, discouraging them from continuing their outreach work. Some point to the resulting fatigue, which makes it difficult to continue outreach activities over time: “You’ve spent your energy there, you know you’ve done something very positive but it wasn’t the goal you wanted” (No. 11).

In the University Environment category, a number of factors that act as barriers to outreach actions have been highlighted. These factors are the lack of a strategic outreach plan by the university itself, competition between different university departments, and the lack of funding.

More than a third of the interviewees consider it necessary for the university itself to develop a general strategy for the promotion and dissemination of science and technology. They also believe it is necessary for different departments, and even the teaching staff, to be more involved: “I think it’s a duty for those of us working in science in one way or another to try and develop these actions” (No. 7). In this regard, Rennie (2012) found that lack of institutional support constitutes a negative factor in outreach actions. The UCLM is currently establishing outreach initiatives (<https://www.uclm.es/misiones/investigacion/uclmdivulga>).

The fact that it is the departments or the professors themselves who conduct these outreach actions when contacted by secondary schools, shows that there are no organisational strategies or common vision. This may create negative impressions of the university within the pre-university educational environment, as described by Participant No. 12: “It looks like we’re fighting and snatching each other’s chances”.

Universities must try and understand how academics involved in outreach and promotional activities view their relations with secondary schools, as well as their accumulated experience in these activities, in order to design strategies for the positive involvement of all involved parties: The university, university departments, secondary schools and lecturers (Mathews et al., 2005). They must also explore means to facilitate the involvement of university faculty members in public engagement for science and engineering (Mathews et al., 2005).

Based on the experience gained in promoting the degree courses at their universities, some interviewees also point to the need to develop information activities for secondary school students in order to explain what is studied and what are the qualifications granted by each degree, as a means of guiding their decision-making process when they must choose between different educational pathways in secondary education.

“There must be a global, coordinated, and overall activity by the University itself, to make visits to secondary school students before they have to start selecting a pathway, there should be informative talks on the different career types available..., but instead of going for 17- and 18-year-olds, who already know what they’re going to do or have almost decided, I think we should go earlier, at the beginning of secondary school, actually” (No. 15).

When universities lack a clear and defined outreach strategy for promoting science and science degrees, individual department activities inadvertently compete with each other and/or with universities in other neighbouring autonomous communities. This competition is exacerbated when multiple university centres offer similar or the same degrees, making some lecturers believe themselves to be doing the work for other centres.

It also risks overloading secondary school students with information that may hinder the process of popularising science itself, as described by Participant No. 12: “They have too much information. Now we’re going to tell them about the benefits of one field of engineering, but last week they had a professor of Industrial Engineering, and the week before that, the professor of Computer Science. So, there’s so many talks and so much information that they’re unable to appreciate this opportunity to listen.

There's also no funding scheme for this work. The costs of lectures given in locations other than the speaker's place of residence or campus location are usually funded by the schools or the speakers' university faculties, however, two exceptions have been found. In one, financial aid is received from an outreach association created by a group of professors from different universities. The other is from outreach project funding granted to the schools. It should be noted that the UCLM has recently implemented a grants programme for outreach activities that meet a series of requirements, in order to receive funding.

Participants who have sought funding by participating in public calls for state support describe a laborious, complex and highly competitive process. According to them, such grants involve a great deal of management and processing, thus creating further responsibilities which discourages department heads from continuing them in subsequent editions. As Participant No. 12 points out: "All national grant schemes are extremely complicated and tedious, i.e. a science outreach project requires a exponentially higher level of detail than a research project". They specifically mention their experience with the calls for grants to promote scientific, technological and innovation culture, awarded by the Spanish Foundation for Science and Technology (FECYT) (FECYT, 2021).

As is the case with the lack of outreach plans, several participants lament the lack of a clear university budget for these actions. In the words of Participant No. 16: "Some funding would be required, and there isn't any for these things".

The lack of sufficient or significant funding for promotion and dissemination activities in STEM and STEM-related degrees becomes a barrier to their development (Mathews et al., 2005), and shows teachers and researchers that it is not a high priority activity for universities (Royal Society, 2006).

Figure 2 provides an overview of the factors that have a negative impact on science and technology outreach lectures, grouped into the three main categories.

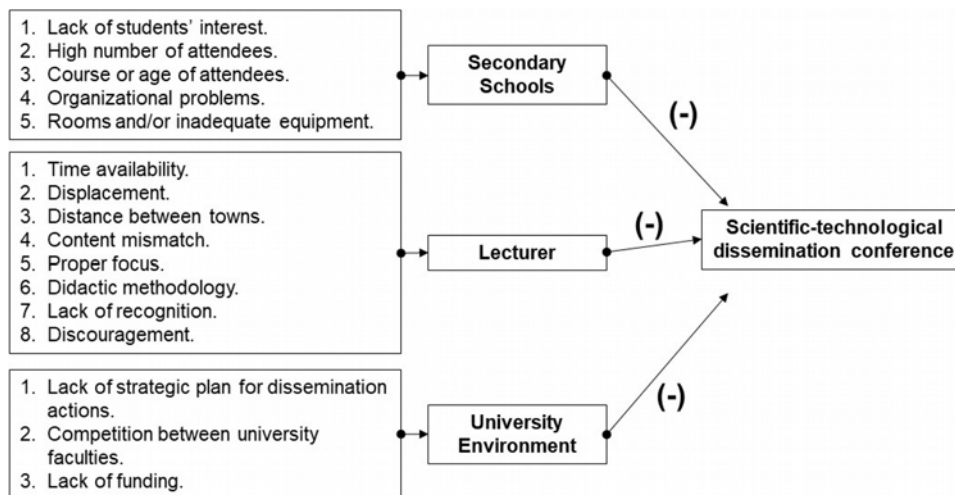


Figure 2. Factors with a negative impact on the implementation of outreach lectures

#### 4.2. Positive Aspects of Outreach Lectures

The positive aspects of outreach conferences are of a holistic nature involving different stakeholders within the educational system such as secondary school students, secondary schools, university departments, teachers and society.

By focusing on secondary school students, these lectures can help to popularise science and technology among them, motivate or increase their interest in engineering, and change their perception of engineering-related degrees, as well as their perception of university education. It must be emphasised that motivation is a key function of outreach activities (Vennix et al., 2018).

These lectures bring science and technology closer to the students, and give them a different perception to the one prevalent in their courses. The exposure of secondary school students to STEM activities, both inside and outside the school environment, enhances their interest in STEM studies in higher education (Mitsopoulou & Pavlatou, 2021). Thus, encouraging students to pursue these fields can meet the targets of increasing enrolment in engineering, developing pre-university students and their STEM identities, as well as diversifying engineering fields, covering some goals that are pursued both at university and in STEM companies and organisations (Chachashvili-Bolotin, Milner-Bolotin & Lissitsa, 2016; Dou et al., 2019; Jeffers et al., 2004).

Some participants recommend avoiding the mistake of approaching these lectures as a means of marketing science and engineering. Nor do they recommend excessively compartmentalising the information conveyed, without establishing appropriate links with the students' environment. In order to avoid this problem, Participant No. 5 recommends: "Raising awareness of how different social challenges are addressed from a scientific or technical perspective".

Another aspect that may be pursued, in lectures that include some sort of focused practical activity, is to establish connections between what students study in their subjects and the applications and technological developments associated with engineering.

Activities that seek to facilitate the understanding of science and to provide new insights into science and scientists, contribute to a positive perception of the learning environment (Vennix et al., 2018). Moreover, students with positive experiences in science and STEM subjects are more likely to choose STEM-related careers (Chachashvili-Bolotin et al., 2016).

Secondary school students can change their perception of universities, and especially of engineering, through contact with university professors, discussing their subjects of expertise. These professors can provide ideas, demonstrate new scientific advances and developments, as well as provide different professional perspectives on different fields of engineering. Additionally, an engineering professor may attempt to solve the problem of explaining to non-engineers, the difference between engineering studies and science education (Hasna & Clark, 2009).

For some participants, their main objective during the lecture is to try and change student perception, especially with regard to engineering, due to their negative view of engineering at this age: "Students have a negative view of engineering, of engineering fields in general, because they are difficult, and in many cases they have no idea of their practical applications..., with the exception of school children who have some direct connection to these disciplines, they are not aware of the ramifications and benefits of industrial engineering" (No. 15).

Many young people are unaware of career opportunities in STEM education, therefore providing information on potential STEM careers is one way to increase participation in STEM disciplines (Jensen & Sjaastad, 2013). In this sense, it may be noted that in Spain, science and engineering degrees have greater employment possibilities, since they have the highest employability (Valero-Matas et al., 2017). Also, during lectures, students have the opportunity to question STEM professionals and thus bridge the gap between the perceived and real images of STEM professionals (Woods-Townsend et al., 2016).

Career counselling is a part of the career-related decision-making process. Providing information on STEM careers has an impact on the motivation of secondary school students with regard to these disciplines (Lupi3n-Cobos et al., 2019), helping them to explore their own traits via the nature of these studies, and preventing them from making a premature, ill-informed decision regarding university education (Cantrell & Ewing-Taylor, 2009). This approach to outreach lectures may alleviate the problem identified by Hall et al. (2011), where they found that career counsellors and teachers in pre-university schools had reduced knowledge and experience of STEM careers. In Spain, research by the FECYT (2015a) also highlights that students receive insufficient career counselling in schools.

Additionally, when lecturers explain new scientific ideas to the students and demonstrate their practical applications, they contribute to the expansion of science topics at school and expose students to another way of working in class, which in turn boosts learning in the learning environment (Vennix et al., 2017, 2018).

Other advantages appear from the point of view of the universities, their departments and the teaching staff who give the lectures. One of the main advantages is that these activities may serve as a publicity tool to make the centres known to many students within the course of a single activity. At the same time, the university is presented to a group of people who may be future students there.

Also, when the activity is well implemented, communication is established with teachers from different secondary schools, which makes it possible to enhance the effect of the promotion and demand for lectures and bridge existing gaps between secondary schools and universities (Jeffers et al., 2004). In any case, the institutional school culture of organising these outreach activities with universities can expand available options for prospective university students (González-Sanzana, 2016).

They also create the opportunity to build relationships between secondary schools and universities, and between the teaching staff. For some participants, this relationship with secondary school teachers constitutes a source of information that enables them to remain up to date with ongoing changes at this educational level and to prepare for when these pupils reach university.

It also allows them to keep in touch with pre-university students and to obtain information directly from them regarding their levels of knowledge and to analyse what may be demanded, since, as Participant No. 16 states: “these are the people we shall be working with”.

In the responses on the benefits of this type of activity, more than half of the interviewees include words and phrases such as “I enjoy” (No. 7), “very rewarding” (No. 13), “I’m very excited to” (No. 8). Several participants especially recognise that it is a source of personal satisfaction for them. Personal satisfaction is an intrinsic motivational factor that leads people to perform the activities that generate this feeling, as has been found in other research on activities related to science communication (Martín-Sempere, Garzón-García & Rey-Rocha, 2008; Torres-Albero, Fernández-Esquinas, Rey-Rocha & Martín-Sempere, 2011). “When you see people starting to ..., I mean, you don’t exactly start spreading the word because of how well known it is (muses ironically), it’s because you want to see people’s eyes light up and hear them say: Wow!” (No. 9).

The responses display the interviewees’ commitment to science outreach, despite the lack of adequate recognition of this activity in Spain (Torres-Albero et al., 2011). This commitment to science outreach is related to respondents’ level of motivation (Canrinus, Helms-Lorenz, Beijaard, Buitink & Hofman, 2012) and their responsibility to conduct public outreach (Mathews et al., 2005), which may justify both their participation in these activities and their continuation over time.

Finally, some interviewees consider that, through the outreach work carried out by its teaching staff, the university demonstrates its commitment to Society, returning part of what is expected of it by training secondary and/or primary school students. It is a way of displaying the work of universities, as Participant No. 12 states: “It’s not just about research, it’s also about communicating what we do, it’s something we have to do”.

Thus, outreach lectures serve to make science and technology more accessible to the public and create opportunities for high school students to interact with university professors and scientists (Woods-Townsend et al., 2016). The need to communicate scientific findings to the public is fulfilled in the secondary school environment, in an effort to achieve greater awareness and understanding of science and technology, boosting the younger generation’s support for scientific research (Mathews et al., 2005).

Figure 3 provides an overview of the factors that have a positive impact on science and technology outreach lectures, grouped into the four main categories.

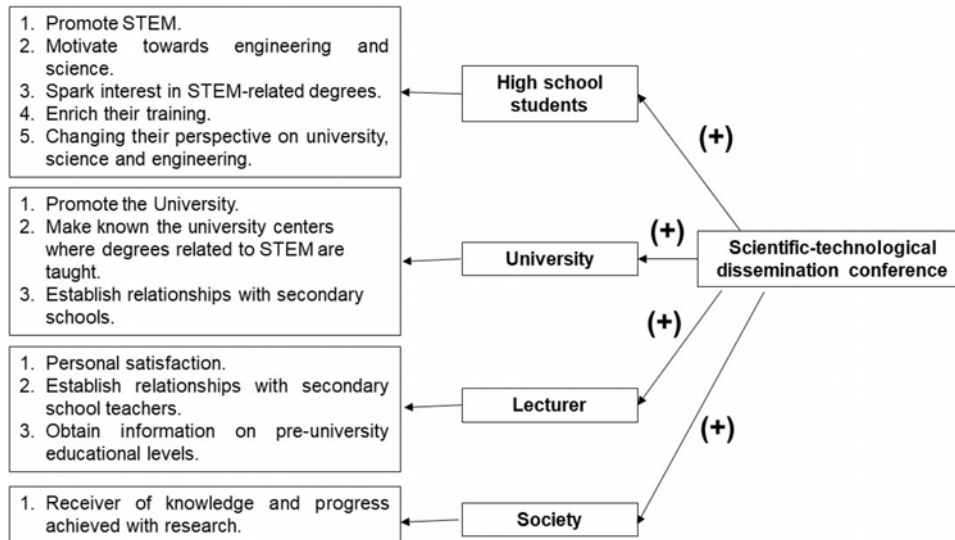


Figure 3. Positive aspects of science and technology outreach lectures

## 5. Conclusions

The need to publicise STEM careers is justified by the decreasing number of students enrolled in these careers in recent years in spite of good job prospects, a reality that is compatible with bridging the gender gap in professions, a fact that is compared and demonstrated is the research sample of this article itself, which is none other than the same reality from which we work and improve. To this must be included the difficulties faced by Spanish Baccalaureate students when choosing between different technical qualifications, due to a lack of knowledge regarding the skills and career opportunities of each.

As mentioned at the beginning, this article focuses on the perception of the professors involved in science and engineering outreach and promotion. To this end, 16 interviews were conducted with professors of varying ages, qualifications and academic profiles who regularly perform this task. This is where the originality of this work lies, in addition to the importance of adding to the body of work that normally focuses on student perception, from a different perspective, one that is professional and external to the school itself. The vision thus provided by the participants enriches other activities which are also required for a better understanding of the promotion of STEM fields.

Among the factors that pose an obstacle to these lectures, it is worth highlighting those related to secondary schools (students' lack of interest, high number of attendees, organisational problems, etc.), the speakers (availability of time, travel, choice of content and methodology, etc.) and the university environment (lack of a common strategic plan and competition between universities).

Knowing the factors that have a negative impact on outreach activities allows three of the parties involved, namely the universities, the speakers and the secondary schools, to consider them and attempt to take measures to reduce their impact.

According to participants, these outreach actions can also have positive impacts, not only on students (motivation and interest in STEM careers, educational enrichment, ...) and speakers (personal satisfaction and relationship with pre-university institutions), but also on universities (publicising its degrees and developing relations with secondary schools) and society in general (knowledge of advances in research).

Therefore, based on the assessment of the professors who give these talks, we may conclude that science and technology outreach lectures are a suitable tool to disseminate scientific knowledge, enabling secondary school students to get closer to STEM and science and technology degrees, but they require organisational and institutional support for their proper implementation, and to achieve the objectives for which they have been designed.

The main limitation of this study is that it focuses on a single university and on professors who teach mainly engineering degrees. It also does not record the perceptions of students who attend these lectures, nor those of secondary school teachers, which may be another future line of enquiry. In this regard, it would be interesting to explore, for example, the level of preparation and attitudes of STEM teachers at pre-university levels, as well as those of university teaching staff.

Finally, it should also be noted that another limiting factor is that at the time the interviews were conducted, the UCLM did not have a specific plan that took into account the dissemination and outreach actions conducted by its departments and faculties. The new strategies that have been developed may have influenced the perception of the teachers who conduct outreach lectures.

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