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Staging science with young people: bringing science closer to students through stand-up comedy

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Abstract

Although efforts are being made to bring science closer to secondary school students, science is still mostly perceived within stereotypic frameworks, hindering students' identification with it. In this paper, we claim the role that arts-based approaches can play in science education to break these biased views and understandings and generate a more motivating science learning experience. For that purpose, we analyse research conducted with students from two secondary schools in Barcelona participating in a science education project applying drama-based activities within an inquiry process with early-career researchers. More specifically, we explore students' perceptions of science and their attitudes towards learning science at school and pursuing scientific careers. We then evaluate and discuss how the triad "researchers' interaction - scientific inquiry - artistic creation" can potentially challenge their storylines about science and bring science learning closer to them. Findings suggest that the evaluated approach contributed to progress in this direction through two mechanisms: creating new rapports with science by offering a creative, inclusive and interactive learning experience, and broadening students' perceptions in terms of what implies to do science and who can do it.

Keywords: Drama-based science education, STEM, STEAM, images of science, attitudes towards science

Introduction

In a world currently facing complex and urgent socio-environmental problems (United Nations Environment Programme, 2012), the need for improved scientific culture of the future citizens has been reiteratively highlighted (European Commission [EC], 2015), but its achievement highly depends on how their perceptions and attitudes towards science shape their interest and motivation for scientific learning (DeWitt et al., 2013a, Itzek-Greulich & Vollmer 2017). School science experiences of students, particularly from secondary school, their self-concept in science at the classroom and the images they get from science can influence, positively or negatively, in the development of their attitudes and aspirations towards science learning. Previous research has shown how structural factors such as gender, ethnicity and social class can shape such development. For instance, negative stereotypes about girls' abilities in Mathematics can influence their academic self-efficacy, educational choices and interest in pursuing STEM training and careers (Perry, Boelter & Leukefeld, 2012; Steele & Ambady, 2006). Similarly, youth from low socio-economic backgrounds or ethnic minorities often have unequal access to role models and mentors in science careers, and lack the financial resources to attend college (Oscós-Sánchez, Oscós-Flores & Burge, 2008; Perry et al., 2012). These relationships are necessarily complex and operate differently at different ages (DeWitt et al., 2013b) and at the intersection of multiple social statuses (Perry et al., 2012).

As stated by Kim (2018), science learning, ideally, goes beyond developing the cognitive dimensions of scientific knowledge to include the cultivation of a rich and multi-faceted science identity, including emotional and social aspects. The way such science identities are developed has an important impact on how students position themselves in front of science learning (Kim, 2008). However, secondary school students' identification with science remains scarce as science and scientists are still mostly perceived within stereotypic or narrow frameworks (Archer et al., 2010; Authors, 2018a; Kim, 2018). Furthermore, even when not necessarily negative, narrow perceptions of science held by students might be problematic 'because they may restrict the possibilities for individuals to find a place for themselves within science' (DeWitt et al., 2013a, p.1456), that is, to see science as a suitable option for them (Jenkins & Nelson, 2005).

In this line, developments in science learning theories in the last decades evidenced the need to approach learning holistically and generate meaningful, affective learning experiences, including students' positive emotions, such as enjoyment, and their learning values, both as triggers of interest and motivation (Krapp, 2005). Different methodological approaches to science education have been suggested to translate into practice such a shift, by moving from 'transmission learning' to 'constructivist learning'. Constructivist learning in science education actively involves learners in building meaning through the interaction with science knowledge and theory in contexts that are relevant for their lives (Bell, Urhahne, Schanze & Ploetzner, 2010; Braund & Reiss, 2019; EC, 2015). Pedagogical approaches integrating the arts can be powerful ways of enabling such learning (Braund & Reiss, 2019; McGregor, 2014). Moreover, educational interventions bringing scientists to the classroom can break negative stereotypes students commonly associate to them while increasing their interest in science (Bodzin and Gehringer, 2001; Authors, 2018a). However, more empirical research is needed to assess the effectiveness of these approaches in different contexts (Dawson et al., 2009). In this paper, we analyse a case study in two secondary schools in Barcelona to explore the role that drama-based science education approaches integrating ethical aspects of science can play in supporting students' motivations and positive attitudes towards science and generating a different science learning experience. Specifically, we examine: i) changes in students' perceptions of science and their attitudes towards science learning and pursuing scientific studies after the intervention, and ii) students' reactions to the drama-based science education approach. We take into consideration students' ethnic origin, socio-economic background and gender in our analysis.

Integrating the Arts in Science Education

The arts have been recognized as ways of knowing and sensing the world, through the specific qualities of aesthetics, such as appealing to the senses and embodied experience, imagination, resonance and empathy (Eisner, 2002). The multiple languages of the arts (e.g., visual, auditory, kinaesthetic) have the potential to stimulate the exploration of scientific concepts from multiple vantage points while appealing to different learning modalities (Land, 2013). In so doing, artistic languages can break down some communication barriers that students' find hard to cross (Braund & Reiss,

2019). Similarly, the arts provide embodied and empathetic experience, allowing learners 'to absorb a multiplicity of new stimuli, cognitive and visceral, that we can unpack and play with' (Greenwood, 2011, p.51). In doing this, arts-based approaches involve social and emotional dimensions of learning (Eisner, 2002). It is precisely this capacity to bring together multiple learning dimensions –affective, cognitive, embodied- into play that has been claimed for introducing the arts in science education (Braund & Reiss, 2019; Ødegaard, 2003).

The pairing of artistic and academic activities within the science curriculum (i.e. arts-integrated programs) can engage students in cognitive processes (e.g., careful observation, inquiry, analysis or representation) that deepen their learning (Catterall & Waldorf, 1999; Rabkin, 2006). Integrating the arts into school science can provide opportunities for bringing together convergent and divergent skills, both needed to approach today's' multifaceted and complex problems (Land, 2013; McGregor, 2014). For instance, research conducted by Henriksen (2011, 2014) on science teaching practices integrating the arts across the USA showed that the connection between disciplines in creative ways led to more motivated, engaged, and effective learning in science.

Furthermore, previous research has specifically argued and provided evidence about the role of drama-based techniques (e.g., improvisational theatre, role-play, storytelling) in supporting science education. Drama-based activities are known to stimulate empathy and sympathy and provide a meaningful context in which to explore research ideas (Authors, 2014; Dalrymple, 2006; Dawson, Hill, Barlow & Weitkamp, 2009). These activities require participants to externally represent what takes place internally (Schattner & Courtney, 1981). In so doing, they have the potential to make complex and abstract ideas, theories and processes more comprehensible to students (Braund & Reiss, 2019). Drama-based techniques have been proven useful for describing, exploring, or discovering scientific issues within inquiry-based learning projects, going beyond cognitive aspects to include as well procedural, emotional, and motivational dimensions of learning (Authors, 2018b; Dorion, 2009; Metcalfe, Abbott, Bray, Exley & Wisnia, 1984; Ødegaard, 2003). Drama in science education settings has also been effectively applied to relate scientific topics to affective and social contexts (e.g., playing stories of scientists), and to reflect on the role of science in them, producing critical insights of science as a practice and of who does science (Ødegaard, 2003). Similarly, studies in primary and secondary schools have shown how such

embodiment and dramatic enactment of scientific contents and phenomena can foster students' dialogic learning and meaning-making (Dawson et al., 2009; McGregor, 2014; Varelas et al., 2010).

While drama-based educational experiences have been recognised as able to portray the human dimension of science (Braund & Reiss, 2019, Ødegaard, 2003), direct contact between students and scientists has not been reported in these experiences. Rather, in the reviewed experiences scientific knowledge and contents used or gathered by students within the drama-based approach come from the teachers and/or from secondary sources such as text-books, reports and surveys. Our research tries to fill this gap by incorporating early-career researchers into the creation process with secondary-school students to support them in their inquiry. By bringing scientists into the process and linking students with real-life science, we expect to help the pupils get a more realistic vision of scientific practice in different fields of research. Getting to know first-hand, up-to-date and contextualised research experiences of young scientists and reflecting together about science's role in society and the values embedded in research practice, is approached as a way of humanising science while also challenging narrow stereotypes about scientists.

Thus, we try to contribute to the development of educational drama-based science education approaches while exploring the transformative potential of bringing young researchers' voices, experiences and values as a source of knowledge in dialogue with students' own experiences, emotions and meanings in the creative learning process. Moreover, our research further contributes to the body of evidence on drama and science learning byintegrating humour into the pedagogical approach through stand-up comedy (i.e., a comic style in which a comedian performs in front of a live audience). Although stand-up comedy is being increasingly claimed as an effective science communication approach (Pinto, Marçal & Vaz, 2015; Ruben, 2019; Sverluga, 2019), its use as science education tool within the classroom is still underexplored. We thus analyse a drama-based approach that combines stand-up comedy and theatrical sketches as means to connect with secondary school students and deconstruct stereotypes of science as something boring. Furthermore, in such an approach students are the creators and performers of their own scientific stand-up show and not just spectators. We start from the assumption that integrating rational, emotional and

embodied dimensions of learning in science education through drama-based, participatory techniques using humour can provide a rich source of individual and collective experimentation, exploration and enjoyment, which in turn can affect students' perceptions of science and attitudes toward science learning.

Methods

Context of Study

We present research from the [acronym, anonymized] project, an H2020 European research project that investigated the effects of the use of participatory science education methods based on performing arts in fostering secondary school students' motivations and engagement with science subjects. A series of science education workshops were applied in two secondary public schools in Barcelona city: IES Consell de Cent (henceforth, Consell) and INS Broggi (henceforth, Broggi). We selected both schools to have one with pupils from a low socio-economic background (Consell) and one from a medium socio-economic background (Broggi), according to corresponding district's per capita income (Barcelona City Council, 2017). Both schools also broadly differed regarding students' academic achievement, with a generally lower level in Consell, being a school that faced more challenging dynamics (e.g. high absenteeism among students, integration needs in students coming from abroad, complex family backgrounds).

Thirty-nine students participated in total, aged between 16 and 17 years old, on a voluntary basis. Participant students also differed among schools according to their ethnic origin, for which we considered both students' and their parents' country of birth (see Data Collection section below for a definition of this variable). While in Broggi 15 out of 20 pupils were born in Spain and had Spanish parents, this was only the case for 5 out of 19 pupils in Consell. Regarding gender, while in Consell the group was gender-balanced, participant students in Broggi were mostly girls (see Table 1).

[INSERT Table 1]

Drama-Based Workshops: Design and Implementation

The drama-based approach was implemented in Barcelona between February and March 2018 and was designed and facilitated by two science communicators with experience in theatre and stand-up comedy. Throughout six workshops of two hours each, students engaged in an inquiry learning process in which they collectively created short

monologues to explain scientific contents to an audience through combining story-telling, theatrical sketches and humour.

The workshops were implemented during school time. Each session of the workshops integrated a first reflective activity on different aspects related to the nature of science (e.g. links science/society, ethical issues in research) and a second performance activity in which each group of students worked on their scientific monologue, bringing to the creative work the reflections and contents generated before. Through the reflective activities, students were invited to (a) select a scientific topic for the monologue, (b) think about related research questions, (c) look for reliable information to answer them, and (d) reflect on related ethical and gender issues related to the selected scientific topics. Performance activities, in turn, included different theatrical and creative exercises to train students' performance skills and to support them in developing and rehearsing their science-based artistic piece.

In each school, invited by science communicators, two teachers and five early career researchers (e.g., PhD students and postdoctoral researchers) voluntarily participated in helping students include scientific content in their performances through dialogue, reflection, and discussion. Groups of three to four students were created and one researcher was assigned to each of them, while science communicators and teachers rotated among groups.

Students worked with the researchers and teachers on the development of their script, which they improved and rehearsed with the science communicators. In each school, a 45-minute show was created and performed at the events hall, in front of other students and teachers. Each show combined five to six short sketches (5-10 minutes) about the selected scientific topic each, which in most of the cases were directly related to the scientists' research (see Table S1 in Supplementary Material). Despite being performed by several students and including theatrical representation in some cases, the sketches kept the structure and identity of stand-up comedy, following a particular narrative thread that engaged in conversation with the public and having humour as a core performative element.

Data Collection and Analysis

Data were collected and analysed by the authors of this paper, who specifically focused

on exploring the arts-based educational process and assessing its impacts on participant students. We collected data through a mixed-methods approach (Table 2 and Supplementary Material).

Moreover, to assess whether such intervention might have affected participant students' perceptions of and attitudes towards science, in each school, we also involved in the research another group of pupils as a Control group (n = 26, 9 in Broggi; 17 in Consell). Students in the Control group were in the same school year, but in a different classroom and neither participated in the workshops nor entered into contact with the scientists. We obtained informed consents from all participants, including parental consents from students.

We quantitatively approached changes in students' perceptions and attitudes towards science and science learning before and after the intervention through written surveys delivered to both participant and Control groups. The pre- and post-surveys were delivered several days before the beginning and one week after the end of the project, respectively. They included: i) closed-ended items, about students' socio-demographic characteristics; and ii) Likert-scale items approaching students' perceptions of and attitudes towards science. The post-survey also included one Likert-scale item and two open-ended questions around students' self-assessment of learning outcomes from the workshops and changes in their perceptions of science. Likert-scale questions had four possible answers (1: strongly disagree, 2: disagree, 3: agree, and 4: strongly agree) and were compiled or adapted from other validated survey instruments (Reflection Questionnaire, Kember et al. 1999; PISA, OECD 2009; Attitude Towards Science Inventory, Weinburgh & Steele 2000). The resulting survey was also piloted with a group of students from Broggi school (n=10), within the same school year but not participating in the workshops, to ensure that the items were properly understood by the students (e.g. item reliability).

We also conducted systematic observations during all the workshops that focused on design elements, science communicators' facilitation, and students' reactions to the activities proposed (conducted by the first author). After the intervention, we conducted: i) one reflective session with all participant students in each school, to reflect on their learning throughout the workshops and the drama-based experience; and ii) a focus group with selected students in each school, to further

explore students' answers to pre- and post-surveys. For the specific items and questions included in these instruments, see the Supplementary Material.

We conducted quantitative and qualitative data analysis. First, changes in students' answers to the Likert items before and after the intervention were analysed using Wilcoxon ranking tests (p-value < 0,1) for non-parametric related samples. The same tests were used to analyse whether students' answers in both surveys varied according to their ethnic origin (born in Spain and with Spanish parents, born outside Spain or with foreign-born parents), socio-economic background (lower, higher) and gender (female, male). We did so for both participant and Control groups. Finally, we calculated the variation of students' answers between pre- and post-surveys and explored whether this variation was significantly different between participant and Control groups by running chi-squared tests for each Likert item.

[INSERT Table 2]

Second, we analysed qualitative data from observations, open-ended questions in surveys, focus groups and reflective sessions using a directed approach to content analysis (Hsieh & Shannon, 2005). Content analysis was chosen among the different analysis traditions as it helped us explore students' answers in detail and identify themes, patterns, and meanings related both to their experience of the workshops and their views of science. The analysis was supported by the software Atlas.ti and guided by three categories: i) students' perceptions of science; ii) students' attitudes towards learning science at school and towards pursuing scientific careers; and iii) students' reactions towards the drama-based approach. Our analysis also took into consideration students' socio-economic background, ethnic origin and gender.

Results

Changes in Students' Perceptions of Science After the Drama-Based Workshops

Before the intervention, participant students (hereafter students) in general already perceived science as: connected to real-life issues, holding ethical implications and valuable for them. These perceptions remained globally positive after the workshops (see Table 3). We only found one case with statistically significant changes in this regard: after the intervention, students totally agreeing with the statement '*What I learn*

in science class will help me get a job' increased from 6 out of 39 to 11 out of 36 (p=0.008). However, when assessing the variations in students' answers between both surveys, we did not find that these significantly differ from the ones presented in the Control group (results not showed).

This said, the statistical analysis conducted did show some significant differences in students' responses before the workshops according to their socio-economic profile, ethnic origin and gender that were not found afterwards, as well as significant differences in this regard after the workshops that were not previously found. Firstly, before the workshops, students from the school with a comparatively higher socio-economic background (Broggi) seemed to perceive science more positively than their peers in the school with a lower socio-economic background (Consell). For instance, all students in Broggi agreed with the statement '*Science will help me understand more about global issues*' while only four students in Consell did so (100% vs 21% of agreement, p=0.01). Similarly, while all students in Broggi disagreed with '*Science has nothing to do with real-life problems*', four students in Consell agreed with it (0% vs 21% of agreement, p=0.09). Furthermore, 12 students in Broggi agreed with '*What I learn in science class will help me get a job*', while 16 students in Consell did so (60% vs 84,2%, p=0.01). Interestingly, after the workshops, we did not find significant differences between students' responses in the two schools, except for the item '*Science has nothing to do with real-life problems',* which did not change (100% of disagreement in Broggi vs 88% in Consell, p=0.05).

Secondly, and regarding our variable referring to students' ethnic origin, prior to the drama-based workshops students born outside Spain or with foreign parents agreed more than their peers with the statements: '*I do not expect to use science much when I get out of school'* (42% vs 10%, p=0.01) and '*Good scientists do not fail when doing science'* (26% vs 5%, p=0.08). By contrast, the former disagreed more with *'Science will help me understand more about global issues*' (16% of disagreement vs 5%, p=0.009) than those whose parents and themselves were born in Spain. As mentioned above, after the workshops, we did not find statistically significant differences regarding students' ethnic origin in these items.

Thirdly, and regarding the gender variable, before the workshops seven girls disagreed with the item '*The production of scientific knowledge involves creativity*',

whereas all the boys agreed with it (28% of disagreement among girls vs 0% among boys, p=0.01). After our intervention, this significant difference disappeared.

[INSERT Table 3]

Interestingly, when directly asked about the impact of the workshops in their perceptions of science, students in both schools provided an overwhelmingly positive response. For instance, 35 out of 39 students (91% of the sample) considered that '*the workshops helped* (them) *think differently about things they previously believed to be right or true in science*'. Moreover, when further inquired through the open-ended questions of the survey and focus groups about what had specifically changed, students' answers pointed to the enlargement of their understanding of the nature of science by discovering science as a practice. In this regard, pupils reported the discovery of a wide range of scientific applications and research developments in real life that they did not know prior to the workshops. Focus groups students in both schools acknowledged being able to identify a much broader field of topics within science after the workshops, and having more knowledge about what it means to do research. In Broggi, students mentioned that participating in the drama-based workshops had refined their views to science thanks to the thematic research involved in the creation of their monologues and the conversations with participant early career researchers about their studies and jobs. As a result of these discussions and reflections, they realized that science could be practised outside a lab (e.g. fieldwork), and got to know real-world applications of different disciplines, including the social sciences. Students in both schools also expressed discovering new scientific branches related to the involved researchers and different career pathways in science. Similarly, in the post-survey, students reported they acquired new knowledge about the job of a scientist and about the social implications of research. See, for instance:

> I have noticed that there is a large variety of professions which has helped open my mind.
>
> Girl, students' survey, Broggi

Particularly, the presence and interaction of the researchers in such a creative learning environment seemed to be perceived by students as changing their perceptions of scientists and, in some cases, their relationship with science (for instance, identifying more with science). In the focus groups, students acknowledged that researchers offered a different role model that helped deconstruct their stereotyped images of scientists in

terms of: i) scientists' personality: showing that scientists can also be warm, close, and funny people; ii) scientists' skills: by portraying a humbler image of scientists ('scientists do not know everything', being 'super-brainy' is not a must) and emphasizing, instead, the relevance of passion, perseverance, and motivation for being a scientist; iii) scientists' gender: by bringing real female references for young girls at school to make more visible the presence of women in research. In both schools, most researchers were women, and girls recognized they were inspired by their presence. See for instance:

> Girl: (Before the workshops) when I used to imagine scientists, what would come to my mind is a very hard-working person who always had excellent grades (at school) and so on… So, I've been inspired, (the workshops) have inspired me quite a lot.
>
> Interviewer: Inspired because…?
>
> Girl: Because when I see a person who has reached their target, or even better, the target we have in common, I say to myself "if she could reach it, I can do it too".
>
> Girl, FG excerpt Consell

Changes in Students' Attitudes towards Learning Science at School and Pursuing Scientific Careers

In both schools, participant students were oriented towards scientific studies, as they were enrolled in the science-oriented pathway at secondary school, studying optional subjects such as Biology and Geology, Physics and Chemistry or Technology. In general, their attitudes toward science learning did not vary significantly before and after the drama-based intervention. For instance, most students reported enjoying learning science and feeling comfortable in science classes, both before and after the workshops (Table 3).

Statistically significant differences in their responses existed, however, according to the variables related to the ethnic origin and socio-economic background before the workshops, which were not significant afterwards. Four students of foreign origin versus only one Spanish student disagreed with the item '*I enjoy acquiring new knowledge about science at school*' (21% vs 5%, p=0.06 to the Wilcoxon ranking test). *'It often stresses me to take a science class'* was more reported by students from a lower

socio-economic background than by their peers from a higher one (42% vs 20%, p=0.09) and by students of foreign ethnic origin than by Spanish ones (42% vs 20%, p=0.05). Moreover, 13 students of foreign ethnic origin disagreed with the item *'Science is easy for me*', while only seven students of Spanish origin did so (68% vs 35%, p=0.08). Similarly, and in relation to students' perceived self-competence in science, students of foreign ethnic origin disagreed significantly more than their Spanish peers with '*I am able to come up with research questions'* and with "*I feel able to talk about scientific issues*" in the pre-survey (63% vs 30% in both items, p=0.05). None of these differences was found afterwards. In turn, students' agreement to the first item about research questions significantly increased from 22 to 26 pupils after the workshops (56% vs 72%, p=0.006).

When specifically asked about educational expectations, students' responses to their willingness to study a scientific career changed significantly towards more agreement after the workshops (Table 3). While before the intervention students' responses were more diverse and slightly less than a half of them did not think about studying a career related to science (18 students out of 39), after the intervention this number dropped to nine students (p= 0.079). Most importantly, in contrast with the pre-survey, no significant differences existed anymore between students from different socioeconomic level after the workshops. Moreover, significant differences remained in the Control group for this item before and after the workshops (p=0.01) suggesting a positive impact of our intervention in changing students' attitudes towards pursuing scientific careers in a positive way.

During Broggi's focus group, several students further explained that the drama-based workshops were also helpful in their career choice, by making them reflect about and overcoming stereotyped views of science. One of them explicitly expressed that the intervention helped him realize that he wants to study a scientific career, which was also reported in the formative evaluation and in the post-survey by another boy and one girl. See, for instance:

> (I learnt that) Having a scientific career is not just about maths and physics and that makes me very happy, because I'm not very good at that, but nevertheless (now I know that) I will be able to study something that motivates me a lot.
>
> Girl, students' survey, Broggi

When asked about other elements that influence their career choice, Consell students mentioned facing challenges related to family support and the school environment. In this regard, some of them mentioned that the difficulties they experienced to get support from their families (mostly in terms of emotional support) and the lack of a focused learning environment among their peers affected them negatively in their pursuit of scientific careers. See, for instance:

Boy: Since I was a kid I've been told not to study science, to study something else (…). When I told my parents I wanted to study Astrophysics they told me 'study something else, you are not gonna make it…" (…).

Researcher: Did something similar happen to any of you?

Girl: With my dad, yes, at the beginning. He said "no, it's better that you choose an easier path, because later in life you will have (family) responsibilities and you won't have time for your personal tasks"

Excerpt from FG, Consell

Students reactions to the drama-based approach: experiencing learning as something fun

Our observations showed that students were generally actively engaged during the workshops, even if they showed diverse degrees of motivation depending on the activities proposed. Students' previous experiences and knowledge were used as a starting point of theatrical improvisations. They seemed to be comfortable with such an approach: students intervened in quite spontaneous ways, engaging in conversation-like interactions with researchers and science communicators, and showing an eagerness both to share and know more about them.

During the reflective session and the focus group, students discussed about the specific characteristics of the drama-based approach that facilitated such engagement. According to them, exploring and communicating a scientific topic through the monologues format helped them connect more easily with the contents and better understand them. They identified the prominent role of creativity and humour as key to this, by drawing their attention towards science and creating a playful and relaxed learning environment. Students perceived this playful environment not only as motivating to get involved but also as an invitation to do so without feeling judged; that is, to freely explore and play:

> Girl: I consider it to be very important that they managed to normalize the fact that if you make a mistake it doesn't matter. Actually, making mistakes was more valuable than being right because that way you could learn. (…)
>
> Boy: I think that the games were very helpful to enter into the class more, it's like you lost shyness… And that was helpful in participating (…). That was very cool, the social cohesion among the whole class.
>
> FG excerpt, Broggi

Similarly, during the workshops, we observed that the diversity of activities proposed by science communicators (e.g. collective warm-ups, small group performative activities, plenary discussions) engaged with a larger portion of students' personalities and learning styles. The drama-based workshops managed to include both those more animated and confident, and those more reserved and quiet, as well as pupils with different sociocultural profiles and degrees of interest towards science. For instance, in Consell school, while boys initially dominated the spaces of plenary discussion (particularly over girls born outside Spain), girls' participation increased throughout the workshops. One of these girls, who also had low academic achievement and interest in science class, was by the end of the workshops, one of the most participative students. In her own words:

> Thanks to the workshops, I've seen many more (scientific) topics and they have captured my attention more... I've noticed that I like science, I enjoy it. I think (the project) is a way of teaching that captures students' attention.
>
> Girl, FG excerpt, Consell

Interestingly, in both schools, students generally showed a greater autonomy and interest to participate in learning activities involving the body and/or dynamic exchanges of ideas (e.g. the creation of a theatrical sketch) than in those activities sitting and focused on scientific reflection, in which they needed more external guidance. This said, when provided with spaces to share their feelings about the drama-based activities (e.g. through small group conversations in the workshops), some students expressed feeling anxiety related to performing the monologue or talking in public (Consell) or to the quality of the final outcome (Broggi). In these cases, the science communicators encouraged the students and invited them to participate in ways they could feel comfortable. In the end, all students voluntarily performed in the final show.

Students also pointed to the importance of the dynamic and participatory character of the drama-based approach and the demand of students' active contribution. Students appreciated that they could choose their scientific topics and develop the content of their monologues -instead of 'just listening and copying', as they admitted to often doing in science class. Furthermore, students especially appreciated the help and support of the researchers, who were an inspiring reference and allowed them to discover new aspects of science, while sharing personal examples from their daily lives. Crucial to this was also the approach emphasis on collaborative work among all participants, as students acknowledged that working together with science communicators and researchers in such a unique way generated a sense of cooperation and trust. Furthermore, Broggi students also appreciated the work on training communication skills and their self-confidence to be able to go up in the stage.

Nevertheless, students also identified challenges related to the drama-based methodology. In Consell, some pupils were particularly critical during the reflective session with the need to train them more on theatrical skills. They acknowledged that body expression was hard for some of them and that they missed having more time dedicated to performance rehearsal. Similarly, in Broggi, three students identified the lack of time to properly develop their scientific monologue as the least enjoyable aspect of the workshops.

Summarising: two mechanisms offering inclusive learning experiences

Overall, students' perceptions of science were globally positive already before the intervention and did not seem to change significantly at the global level. However, students did report that they discovered science as a practice, enlarging their understanding of the nature of science, and improved their perceptions about science learning, by experiencing a different way of learning linked to the performative approach. Similarly, our quantitative results did show that students significantly increased their perceived personal value of science, self-competence in science and willingness to study a scientific career after the workshops. All these aspects can be connected with students' experiences of science learning and how such experiences place students in relation to science. Even if our quantitative data do not allow us to

conclude that such significant differences were only due to the intervention, the qualitative insights gathered with the students provide evidence of a positive impact in their attitudes towards science learning. After the workshops, students reported an increased self-confidence and motivation in science learning. They also expressed an eagerness for more practical, emotional and active science learning approaches.

Furthermore, the drama-based approach seemed to have a notable impact in reducing differences in students' responses in terms of their ethnic origin and socio-economic background. Before the intervention, participant students of foreign ethnic origin and/or low socio-economic background reported feeling stressed during science classes, not enjoying science learning or finding science difficult more often than their peers born in Spain and from a higher socio-economic background. After the workshops, these differences were not found. Although our sample is small and does not allow for multi-variable statistical analysis, these quantitative results are in line with the qualitative findings. Similarly, students of the lower socio-economic background school significantly increased their motivation to study a scientific career after the intervention. Also, in this school, a progression was observed among girls of foreign ethnic origin towards higher participation throughout the workshops.

All in all, throughout the project, participant students were actively immersed in a research process that was mediated through an artistic practice (i.e. stand-up comedy combined with improvisational theatre) and involved researchers that helped students navigate their inquiry. While examining our findings, we have found that this triad - '*researchers' interaction - scientific inquiry - artistic creation*', is key to generate inclusive learning experiences engaging different profiles of students in science learning. We use the metaphor of the triad to highlight the interconnectedness of these three elements, being present throughout all the process. Inclusivity in learning was fostered through two main mechanisms: i) creating new rapports with science through humour, by offering a creative and interactive learning experience, and ii) broadening students' perceptions in terms of what implies to do science and who can do it, by fostering their interaction with researchers within an artistic context. These mechanisms are introduced and discussed in the following section.

Discussion

In this section, we discuss how our case study brings relevant insights into the capacity of drama-based science education approaches integrating researchers to generate inclusive learning experiences and enrich students' storylines about learning science and scientific practice.

The links between sociodemographic/structural factors and students' perceptions of and attitudes towards science learning are complex and difficult to reduce to a given pattern. However, previous research suggests that students experiences of science in marginalized or minority groups often operate against their embracing science as something 'for them' (DeWitt et al., 2013b). While offering inclusive ways of engaging diverse profiles of students and a supportive science learning experience (and especially to those struggling with science), our research points to the potential of drama-based approaches integrating researchers to tackle barriers associated to socio-economic, ethnic and gender factors. As mentioned above, we identify two mechanisms fostering inclusivity, both in the educational design and in the projected image of science. We discuss them in what follows.

Learning Through Humour: Facilitating Creative Learning Experiences

In terms of design, the methodological approach facilitated students' active immersion in an inquiry-based learning process in science education that was mediated through artistic practice. After the intervention, many students acknowledged discovering that science learning can be fun and 'for them'. The humoristic approach within stand-up comedy was key to this. As Pinto and colleagues (2105, p.11) argue 'laughing is a simple, seductive and universal way to communicate' and stand-up comedy has the potential to establish 'a close relationship with the audiences, which may be explained by the use of humour, informal language and generally talking to the audience as equals' (Pinto et al. 2015, p.15). By applying stand-up comedy as a pedagogical approach, these features were expanded to the learning process with students. Indeed, results suggest that the humoristic and theatrical approach propitiated a relaxed and supportive learning atmosphere that fostered a sense of connection among participants and minimized competition. Both aspects favoured the collaboration needed to produce

and perform the scientific monologues collectively.

Furthermore, theatrical exercises and performance creation framed students' explorations of scientific topics and connected them to their previous knowledge and experience, making them able to find the most appropriate ways to approach the topics constructively (Ulger, 2016). In doing this, the workshops brought scientific topics closer to students while providing socio-cultural contexts and affective links to otherwise abstract or distant issues (James, 2017). Students could 'enter into the world of science' by linking it to their everyday world and making sense out of it (Mutonyi, 2016, p. 949). Such an approach recognized students' diverse funds of knowledge (e.g. their experiences, every-day knowledge, Barton & Tan 2009) as legitimate science classroom resources for the creation of scientific monologues, encouraging the participation of students who generally did not feel self-competent in science class. The entertainment value of the approach further contributed to such closeness by appealing to those students who had expressed in the surveys little interest or difficulties in science learning and by finding new connections with science. As with other drama-based approaches, such a combination of elements (i.e. inquiry, internal and collective reflection, external representation through improvisation and more scripted sketches) afforded to include cognitive, affective and aesthetical dimensions into students' learning experience, enriching it (Freeman, Sullivan & Fulton, 2003; Varelas et al., 2010).

Moreover, the collective research needed for artistic creation positioned students as active co-constructors of knowledge together with researchers and science communicators, putting them at the centre of their learning process and encouraging their self-confidence. Such positioning was further affirmed by the final act of performing in front of an audience, through which students were recognized by other students as knowledgeable and competent science communicators (Olitsky, 2007).

Broadening Students' View of Science: Humanizing Science

Our findings suggest that bringing science through a drama-based approach that involved early career researchers was also key for showing a more inclusive and diverse image of science and scientists. Throughout the inquiry and artistic process, science was

portrayed as a collaborative practice based on team-work and dialogic learning. This challenged the stereotypical storyline of science as individualist and isolated, encountered in many school science classrooms (Authors, 2018a; Kim, 2018). Curiosity, creativity, critical thinking, collaborative work or perseverance were highlighted throughout the process by science communicators and researchers. Emphasizing these skills gave students the opportunity to re-evaluate notions of self-competence in their learning of science.

Also, and similarly to previous research, humour, as a vertebral axis of the pedagogical approach, contributed to breaking stereotypical perceptions of science and scientists as serious and boring (Pinto et al., 2015). Again, this might help students moving beyond discourses of the scientist 'as a specialist', or as 'clever', notions that contribute to the othering of those who pursue science (DeWitt et al., 2013a). Similarly, the greater number of women among researchers was a source of inspiration for some girls, by challenging science stereotypes as male-dominated or 'mostly for men' (Todd & Zvoch, 2019) and explicitly bringing the topic of 'gender in science' into the discussion with students (Brickhouse, 2001). Moreover, bringing the collaborative dimension of science while putting students in contact with current research and researchers, contributed to broaden their views of science, by incorporating research practice into their storyline. Such opening-up of perceptions of science and scientists to include a wider diversity of topics, disciplines, skills and applications might 'make more evident the ways in which the pursuit of science could align with students' developing identity' (DeWitt et al., 2013a, p.1473).

Crucial to this richer portrayal of science was the immersion of researchers into an artistic context. Indeed, connecting students with researchers through an artistic practice implied a change in the codes of interaction and the roles enacted by participants. Our findings suggest that such an approach fostered a kind of relationship with the researchers that contributed to motivating some students to further engage in science learning. Although adults were clearly positioned as learning facilitators, researchers were also involved with students in many of the warm-up and theatrical exercises proposed, where they were invited to play and explore imaginatively without judgement. This provided an opportunity for students to interact with scientists within a very different context to the one they are used to seeing them (e.g., when visiting research labs), breaking some formal barriers and fostering closer interactions (Authors,

2018a). During the workshops, researchers could share other facets from their personality (e.g. more spontaneous and human) and the relationships created with the students were also positively affected (e.g. more personal). In this regard, the drama-based intervention in science education was able to bring role-models in science in a context that humanised the figure of the scientist, facilitating students' identification with it. This is relevant since students recognised holding stereotyped views of scientists before the intervention, seeing scientists as distant to them. Hence, experiences like the one presented here are valuable as they also portray a more diverse image of scientists, which might have the potential to encourage a vision of science 'for all' and tackle the often little overlap between students' perceptions of scientists and their images of themselves (DeWitt et al. 2013a, Cleaves, 2005).

Closing Remarks and Challenges Ahead

Through a specific drama-based approach based on stand-up comedy, this study illustrates the potential of what we conceptualised as the triad '*researchers' interaction - scientific inquiry - artistic creation-'* to facilitate an inclusive and creative science learning experience enriching students' storylines about science learning and about science as a practice. However, the configuration of students' aspirations is complex and influenced by other structural factors that go beyond the enjoyment of science learning and particular perceptions (Cleaves, 2005). In our case, for instance, some students' from Consell expressed a lack of family support to study science. We are aware that addressing these factors requires more holistic and long-term interventions than the one presented here. For instance, better integration into the science curriculum (i.e. arts-integrated programs) could enhance the effects of these experiences into students' aspirations and academic achievement (Rabkin & Redmond, 2004). Such integration would also be benefited if produced at earlier stages of schooling (e.g., primary education) since students' constructions of scientists and those who pursue science seem to be formed earlier in their life, defining their attitude and interest in the study of science (DeWitt et al., 2013b). Moreover, the integration in the curriculum could also allow to overcome one of the main limitations identified by participant students in the drama-based workshops: the need for more time to train students' performing skills. A greater flexibility in the curriculum could encourage interdisciplinary project-based approaches in science learning, potentially enhancing the long-term impacts of

experiences like the one introduced here in students' learning, beyond an occasional session or workshop. This could also enhance the scalability of the approach, which is, per se, resource-intensive; i.e. not only in terms of time but also of finding the schools and professionals needed in the intervention (teacher, science communicator, scientists) and training them in how to engage with young students in creative and funny ways through drama as we did before these workshops. Also, one potential way to diminish logistics and external dependencies would be that interested teachers could take ownership of these approaches and slowly integrate some of these tools in their classroom, in collaboration with researchers. Although not covered in this paper, the project offered trainings and toolkits to both scientists and teachers interested in such integration (available here). Similarly, we found a good strategy in working with early-career researchers, as there was a thirst for training and engaging in science outreach experiences that facilitated their recruitment and enthusiasm along the project. The direct collaboration between researchers and teachers requires, however, networking between schools and research institutions, which might be easier or harder to build depending on the functioning of the school and the orientation of the academic centres.

All in all, integrating the triad '*researchers' interaction - scientific inquiry - artistic creation '* within a science education approach can be challenging and requires efforts at different levels, but students' motivated responses to this experience encourage us to think that it can be worth it.

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Table 1. Description of participants.

Secondary School	IES Consell	INS Broggi
Participant group By socio-economic level By gender By ethnic origin	19 Low (19) 9 girls,10 boys Spanish (5), Foreign (14)	20 Medium (20) 16 girls, 4 boys Spanish (15), Foreign (5)
Control group By socio-economic level By gender	17 Low (17) 5 girls, 12 boys	9 Medium (9) 3 girls, 6 boys
Involved teachers By gender	2 1 woman, 1 man	2 2 women
Involved early career researchers By gender	5 4 women, 1 man	5 4 women, 1 man

Table 2 Data collection methods

<table>
<tr><th rowspan="2">Target</th><th rowspan="2">Assessment focus</th><th colspan="3">Assessment methods applied</th></tr>
<tr><th>Before the workshops</th><th>During the workshops</th><th>After the workshops</th></tr>
<tr><td rowspan="3">Secondary-school students</td><td rowspan="3">Perceptions and attitudes towards science and science learning

Perceptions and experiences of the workshops</td><td rowspan="3">Written Survey

PERFORM group n= 39;

(Consell= 19 Broggi=20)

CONTROL group n=26 (Consell=17, Broggi=9)</td><td rowspan="3">Systematic observation (All workshops)</td><td>Written Survey
PERFORM group n= 36
(Consell= 18 Broggi=18)

CONTROL group n=26
(Consell=17, Broggi=9)</td></tr>
<tr><td>Formative evaluation: reflective session
(39 students)</td></tr>
<tr><td>Focus Group
(Consell = 6 Broggi=8)</td></tr>
</table>

Table 3 - Changes in students' perceptions of and attitudes towards science and science learning before and after participating in the workshops (n=39 before, n=36 after the intervention); *significant difference to the Wilcoxon ranking test $p<0.1$ between the pre- and the post-survey; and significant difference to the Wilcoxon ranking test $p<0.1$ according to: [a] socio-economic level,[b]ethnic origin, and [c]gender.

CATEGORIES	Item description		Totally Agree % (n)	Agree % (n)	Disagree % (n)	Totally disagree % (n)	No answer
Perceptions of science	Scientific jobs are important for a better society	Before	35.9 (14)	61.5 (24)	0	2.6 (1)	0
		After [b]	61.1 (22)	33.3 (12)	5.6 (2)	0	0
	Science has nothing to do with real-life problems	Before [a]	5.1 (2)	5.1 (2)	61.5 (24)	28.3 (11)	0
		After [a]	0	16.7 (6)	47.2 (17)	36.1 (13)	0
	Good scientists do not fail while doing science	Before [b]	2.6 (1)	12.8 (5)	41.0 (16)	41.0 (16)	2.6 (1)
		After [a]	0	11.1 (4)	47.2 (17)	41.7 (15)	0
	Science only has good impacts on people	Before	2.6 (1)	23.1 (9)	58.9 (23)	12.8 (5)	2.6 (1)
		After	2.8 (1)	22.2 (8)	44.4 (16)	27.8 (10)	2.8 (1)
	The production of scientific knowledge involves creativity	Before[c]	15.3 (6)	64.1 (25)	15.4 (6)	2.6 (1)	2.6 (1)
		After	27.8 (10)	52.8(19)	16.6 (6)	0	2.8 (1)
	Science will help me understand more about global issues	Before [a b]	30.7 (12)	59.0 (23)	7.7 (3)	2.6 (1)	0
		After	33.3 (12)	66.7 (24)	0	0	0
	What I learn in science class will help me get a job*	Before [a]	15.3(6)	56.4 (22)	23.1 (9)	2.6 (1)	2.6 (1)
		After[c]	30.6 (11)	50.0 (18)	19.4 (7)	0	0
	I do not expect to use science much when I get out of school	Before [b]	2.6 (1)	23.1(9)	56.4 (22)	15.3 (6)	2.6 (1)
		After	2.8 (1)	19.4 (7)	47.2 (17)	30.6 (11)	0
Attitudes towards science learning at school	In general, I enjoy acquiring new knowledge about science at school	Before [b]	33.3 (13)	53.8 (21)	10.3 (4)	2.6 (1)	0
		After	33.3 (12)	55.6 (20)	11.1 (4)	0	0
	In general, I feel comfortable	Before	35.9 (14)	43.6 (17)	17.9 (7)	0	2.6 (1)
		After	30.6	58.3	5.5 (2)	2.8 (1)	2.8 (1)

	while doing scientific activities or tasks		(11)	(21)			
	It often stresses me to take a science class	Before [a b]	2.6 (1)	28.2 (11)	51.2 (20)	18.0 (7)	0
		After	8.3 (3)	16.7 (6)	58.3 (21)	13.9 (5)	2.8 (1)
	I often feel useless in science class	Before	5.1 (2)	15.4 (6)	59.0 (23)	20.5 (8)	0
		After	5.6 (2)	19.4 (7)	50 (18)	22.2 (8)	2.8 (1)
	In general, science is easy for me	Before [b]	5.1 (2)	41 (16)	43.6 (17)	7.7 (3)	2.6 (1)
		After	2.8 (1)	41.7 (15)	44.4 (16)	11.1 (4)	0
	I feel able to talk about scientific topics	Before [b]	7.7 (3)	46.1 (18)	33.3 (13)	10.3 (4)	2.6 (1)
		After	8.3 (3)	52.8 (19)	33.3 (12)	2.8 (1)	2.8 (1)
	I am able to come up with research questions that allow me to investigate something*	Before [b]	10.2 (4)	43.6 (17)	30.8 (12)	15.4 (6)	0
		After	27.8 (10)	44.4 (16)	25 (9)	0	2.8 (1)
Attitudes towards pursuing scientific careers	I would like to study a career involving science *	Before [a]	35.9 (14)	23.1 (9)	23.1 (9)	17.9 (7)	0
		After	44.4 (16)	30.6 (11)	13.9 (5)	11.1 (4)	0