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BOOK CHAPTER

'What do I like about science-related activities?' Participatory indicators addressing students' motivations and needs when learning science.

María Heras, ICTA, Universitat Autònoma de Barcelona

Isabel Ruiz-Mallén, IN3, Universitat Oberta de Catalunya

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Stability and Change in Science Education – Meeting Basic Learning Needs

Homeostasis and Novelty in Teaching and Learning

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Abstract

While emerging approaches, like the RRI paradigm, put students' participation and appropriation of the learning process at the center of science education, attempts at open assessment and evaluation have been more slowly applied in practice – a homeostatic tendency to continue these practices in the older, continual methods. Assessment, however, is a fundamental topic in science education and pedagogy, permeating science education curriculum, teaching and learning practices and research. This chapter explores the novel role of participatory approaches in science education assessment to support learning and inform and adapt teaching practices that fulfill learners' basic needs, while approaching global challenges in novel and engaging ways. This is done through the analysis of an empirical experience of participatory indicators development in Spain, France and United Kingdom, as part of the H2020 EU PERFORM research project. The PERFORM project aims to engage secondary school students in science learning by using performing arts. Eight exploratory workshops were implemented in four selected secondary schools in each country to explore students' motivations to participate in science education activities and identify participatory assessment indicators. A total of 122 secondary-school students participated in the process. Workshop results provided not only specific contextual insights from each country, key to understand students' motivations, but also fresh and culturally relevant assessment indicators.

Introduction

The research presented in this chapter is born from the need to better understand secondary school students' motivations to learn science and integrate them in the design and monitoring of a participatory learning process, developed in the context of a European project, called PERFORM (www.perform-research.eu). PERFORM is a European Horizon 2020 research project aimed at exploring and generating suitable science education methods based on performing arts to foster secondary school students' motivation and engagement in Science, Technology, Engineering and Mathematics (STEM). The design and implementation of such innovative methods should embed and transmit the values of the Responsible Research and Innovation (RRI) conceptual framework (European Commission, 2015), promoting students' interest towards science and their learning and reflection about STEM concepts, scientists' practice and the impacts and applications of science in their daily lives. These methods are explored through the development of a participatory educational process with, for and by students in secondary schools (students aged 15-16 years old) in France and Spain.

As researchers involved in the assessment of such innovative educational process, we asked ourselves how to include students' motivations in the assessment methodology designed so as to involve them from the very beginning in a research process driven by inclusiveness and engagement. Thus, the aim of the presented research is twofold: (a) to better understand students' motivations towards and beliefs about science learning activities as a basis for the identification of assessment criteria and indicators relevant for them; and, through such identification, (b) to include students' perspectives in the design of the assessment methodology, fostering their engagement in the PERFORM project.

In this chapter, we analyse the results of a series of exploratory workshops in the involved schools exploring students' motivations to participate in science education activities and identifying participatory assessment indicators. The exploratory process and the resulting indicators are analysed through the lenses of *novelty*, through the exploration of the opportunities such indicators bring to the design of fresh and inspiring learning environments; and *homeostasis*, understood here as self-regulated learning by critically reflecting about students' diverse needs and motivations and how they can be addressed in formative science education assessments.

Context

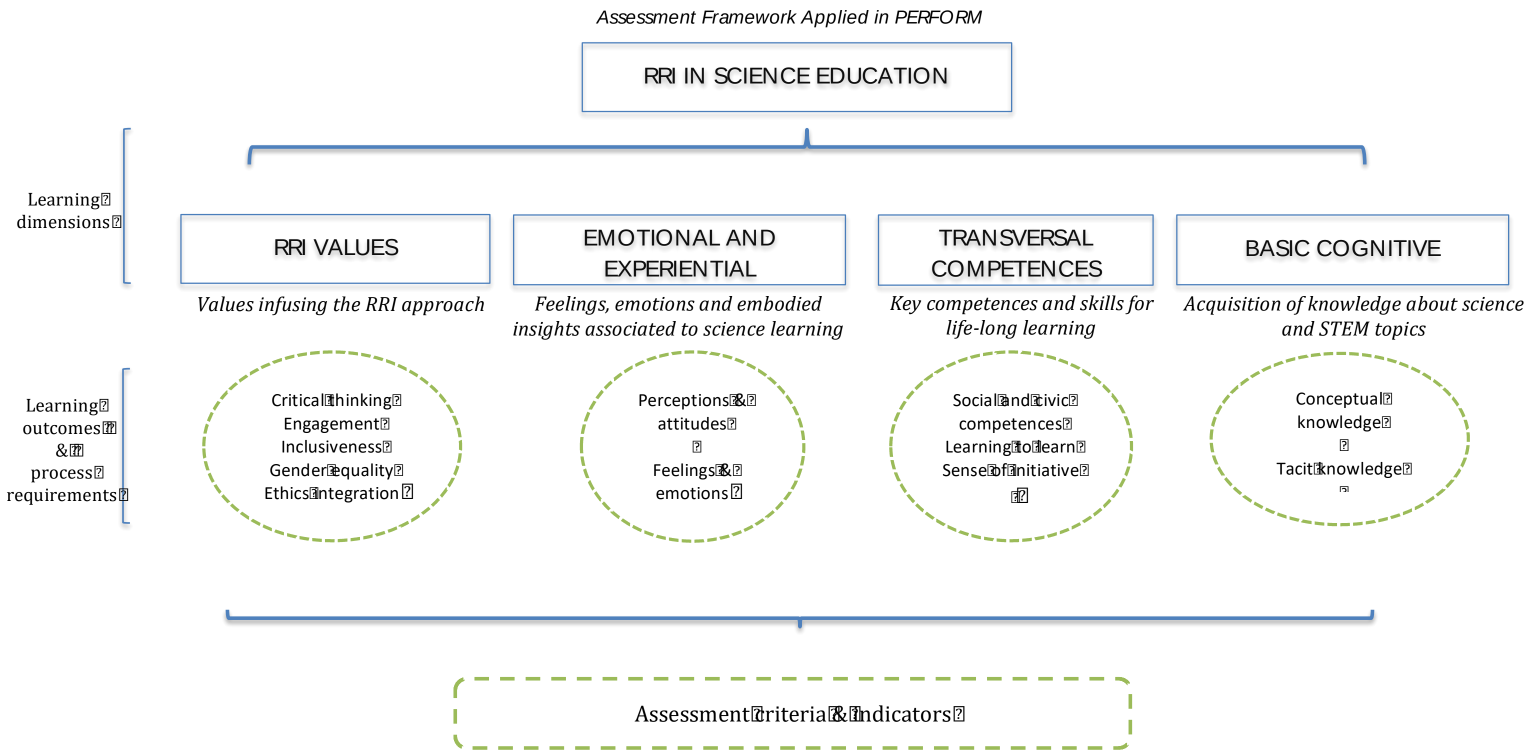
Science learning under the lenses of RRI: a conceptual framework from practice

RRI is the guiding paradigm of current European Commission science policy and research, oriented towards more inclusive and deliberative research and innovation processes in order to align research and innovation agendas with societal needs and concerns (Owen et al. 2012, RRI-Tools 2015). Born from academic concerns about unexpected risks and outcomes of new technologies and controversial scientific achievements (Owen et al. 2012), the RRI framework seeks to readdress the relationship between science and society in more democratic and responsible ways. RRI has six different policy agendas, including science education since today's students will be the scientists and citizens of tomorrow.

As a science education research project, PERFORM explores how science learning processes under the lenses of RRI could look like. Under such lenses, we understand that science education should foster critical thinking and reflexivity about science and scientific research, including social and ethical reflections to enhance critical scientific literacy (EC, 2015). This implies a shift in the focus of science education from learning discrete scientific facts to understanding how to apply science learning to different and new situations, stimulating curiosity, scientific thinking and the understanding of the nature of science (ibid). Such shift in learning outcomes is also expected to contribute to foster students' engagement with science, not only in cognitive terms, but also from an emotional perspective, enhancing students' motivation and interest to learn and facilitating a different relationship with science.

Within the context of PERFORM, we aimed to explore ways in which these RRI-related learning outcomes could be developed in practice through performance-based science education activities and –more relevant in terms of the focus of this chapter, how they could be assessed through participatory approaches. For that purpose, we first built a science education assessment framework, which could help us operationalise science learning under the lenses of RRI. Based on our understanding of RRI in science education, we identified four main learning dimensions: RRI values (Klaassen et al. 2014; Heras and Ruiz-Mallén forthcoming), transversal competences (as defined by the EC 2012), experiential aspects and basic cognitive aspects (see Figure 1). These dimensions contain twelve learning outcomes and process requirements, which are characterised by 32 assessment criteria and 86 indicators (Heras et al., 2016; see analysis categories in the me methodological section).

Figure 1 Outline of the assessment framework applied in PERFORM, based on RRI.



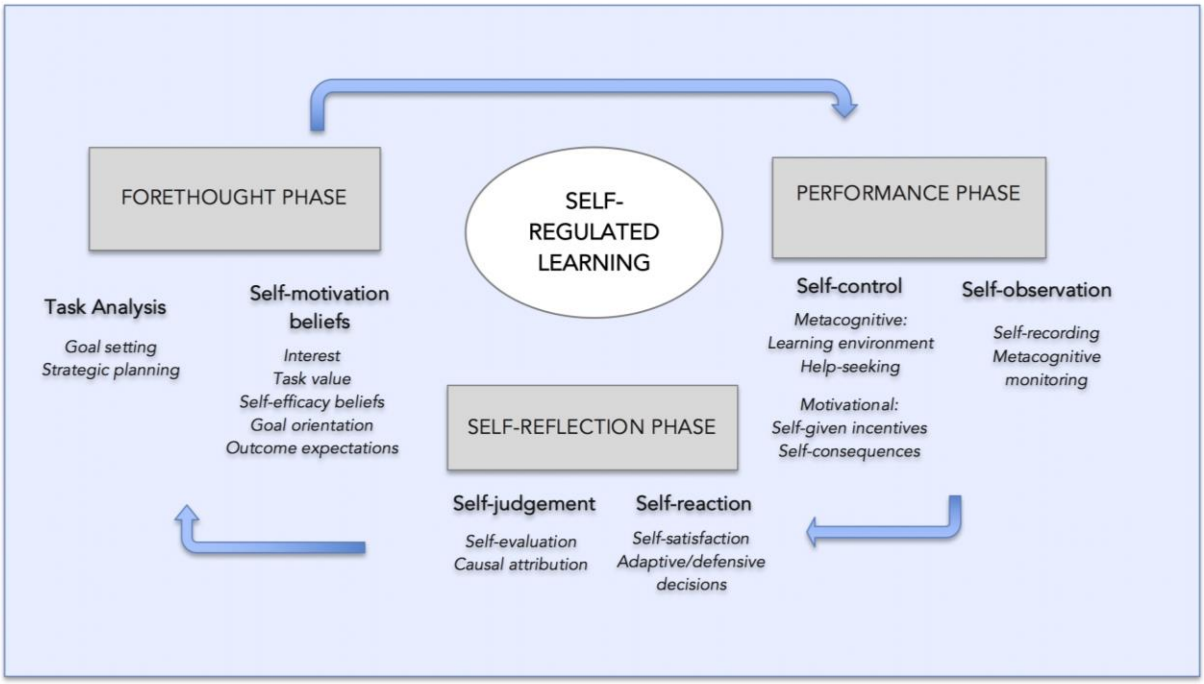
Crucial to our framework is the notion of students' reflexivity about and responsibility towards their own learning. In this regard, the experience and values developed through the engagement with science that is proposed by the RRI framework, aim at raising students' awareness of their learning process, stimulating reflective thinking about what they learn and how it relates to life experiences in which it can be applied, as well as their learning autonomy and creativity. Such an understanding deeply resonates with the concepts of novelty and homeostasis. On the one hand, the achievement of such learning outcomes requires the creation of open and transformative learning environments giving voice to students' ideas and engaging them in collaborative discussions that can bring their own perspectives to the science contents approached. On the other hand, by approaching and reflecting about students' diverse learning needs, interests and motivations, the RRI framework encourages students to take ownership of their learning process and also engage emotionally with science (e.g. by enhancing self-esteem and confidence). Seen in this light, these concepts connect with our RRI framework through the notion of self-regulated learning.

Creating resilient learners: connection with self-regulated learning approaches

Self-regulated learning (SRL) is an active 'process whereby learners set goals for their learning and monitor, regulate, and control their cognition, motivation, and behaviour, guided and constrained by their goals and the contextual features of the environment' (Pintrich and Zusho 2002, p. 64). It has gained momentum in the last decades together with the raise of student-centred learning approaches, which place active engagement in learning and learners' responsibility at the core of the educational process (Lea et al., 2003).

Self-regulation defines different components of learning which relate to its cognitive, behavioural, emotional and motivational dimensions. This way, learning is recognised as a multi-dimensional process affected by and regulated through the control of cognitive processes (such as planning, setting goals or self-monitoring), but also to the learning environment that students create through their behaviour to optimize learning, the emotions experienced while performing the academic tasks and the maintenance of their self-motivation and interest towards that task (Panadero and Alonso-Tapia 2014).

Figure 2 Self-regulated learning: cyclic phases and main processes and strategies. Based on Zimmerman 2002 and Panadero and Alonso-Tapia 2014.



The emphasis placed on students' reflective learning and engagement within the RRI framework in science education points to fruitful connections with SRL. Under the lenses of RRI students need to be aware of their learning skills and motivations in order to fully engage with transformative learning processes applicable in their lives. From the perspective of science education assessment, SRL contributes to the RRI framework by identifying students' self-strategies, processes and attributes regulating their learning and their motivation to learn. The identification of students' motivations to be engaged in science-related activities is precisely the core of the work we did with targeted students during exploratory workshops to prepare the PERFORM assessment strategy. We present it in what follows. By gathering information on students' motivations, and relying on SRL, we discuss emerging participatory indicators as new opportunities to improve science learning environments more centred on students' motivational beliefs. Further, we identify self-regulation with the concept of *homeostasis* to discuss and reflect on students' awareness and use of self-control strategies to regulate their own learning in terms of their motivations towards and achievement of learning outcomes related to the RRI. Aligning our assessment with students' self-regulation and responsibilisation of their own learning is especially promising in student-centred pedagogies like the RRI, since assessment approaches also shape students' beliefs about learning goals and consequently their motivations towards such learning (Nicol & McFarlane-Dick, 2006).

Exploring students' motivations towards learning science: methods and analysis

Based on the participatory approach of the PERFORM project, we paid special attention to the inclusion of students' views and opinions about their motivations and interest on science learning and engagement in the evaluation process by conducting exploratory workshops with students in four selected schools in Paris, France, and Barcelona, Spain. We did so prior to the implementation of the performance-based science education activities whose impact on students' learning outcomes we wanted to test. Within this context, an exploratory workshop was designed with a twofold objective. First, to actively involve the students in the assessment since the beginning of the process. And, second, to contextualize the PERFORM impact assessment methodology in each educational setting. As a result of the analysis of students' responses in these exploratory workshops under the lenses of RRI and SRL, we identified both criteria and indicators that students considered important when participating in science-related activities both inside and outside school. These criteria and indicators were then used to complement the battery of assessment criteria identified through an expert-based literature review on the assessment of RRI aspects in science education activities (see Heras and Ruiz-Mallén, 2017).

A total of 122 secondary school students participated in the eight exploratory workshops we implemented, one in each of the four selected schools in each country, between March and May 2016: 65 students in Spain and 57 in France, including 67 girls and 55 boys. Informed consents to participate in PERFORM research were obtained from students' parents.

During the exploratory workshops, we first explained participant students that we were interested in knowing their opinions about the science-related activities they had the opportunity to engage both inside and outside school to be able to design engaging science education activities within the PERFORM project. We also explained them that we would use their feedback to elaborate indicators for the assessment of this kind of activities, so other researchers and practitioners interested in science teaching and learning could use them to evaluate their activities. We then asked students to split in small groups of 4-5 and think collectively about what they liked when participating in science-related activities, including also suggestions to design activities that foster their engagement in STEM, through these two guiding questions:

1) *When you are participating in a science-related activity (that is, a science class or science lab at school, or a science activity in a museum, in a festival, etc.) what are the things you like about it, if any?*
2) *If you were to design a scientific activity for your classmates, how would you do it to make sure to engage them?*

We provided students with post-its in which they wrote their thoughts and suggestions. When they finished, we asked each group to present their post-its and share the conversation they had on each question and the items they had identified. Other students were also asked to comment on the items and discuss if they agreed or not, and why. We then explored their relevance through drawing a line in the floor with colour tape representing a degree with three marks meaning i) very important, ii) important, and iii) not important, and asking students to place themselves along the line, according to the importance they gave to the items mentioned in post-its in the context of science learning.

Data were gathered through students' post-its and their comments and discussion about these topics, which were both audio-recorded and recorded in written notes by the facilitators. Notes on the number of students placed in each mark for each item (scores) were also collected. Facilitators also wrote their perceptions about the mood of the students, their reaction to the activity, and any other relevant contextual factors that could affect the implementation of the workshop. Facilitators' comments were thus useful to identify contextual particularities in the development of the activity.

Students' contributions were analysed through a conventional content analysis (Hiesh & Shannon, 2005). First, to identify indicators, we categorized students' responses according to seven RRI-related learning outcomes and process requirements. Then, we related these outcomes and requirements with the 11 identified RRI assessment criteria previously defined in the literature review, and created subcategories for them (Heras et al., 2016). Regarding RRI values, we found indicators related to two criteria referred to inclusiveness: *balanced participation* or providing opportunities for each participant to contribute in the activity, and *fostering dialogue* or promoting mutual exchange of ideas to integrate different perspectives. Both *cognitive engagement* or students' attention and mental effort during a task, and *emotional engagement* or their active implication in the activity were identified as criteria for the RRI value of engagement. We also identified indicators corresponding to two criteria referred to the RRI value of ethics integration:

social relevance of topics addressed or connecting scientific issues approached with broader social contexts and challenges, and *connecting scientific topics with values* or identifying values and normative aspects behind scientific practice. Regarding transversal competences, students' responses referred to two learning outcomes and criteria: learning to learn skills, approached by *reflective thinking* or students' ability to process new scientific learning through reasoned thinking, and social and civic competences, related to the acquisition of *collaborative skills* or behaviours helping them to work together and *communication skills*, or students' ability to communicate ideas about science effectively by using verbal, visual and written means. The experiential aspects of learning were represented by two criteria referring to students' feelings and emotions: *enjoyment* or feelings of pleasure caused by experiencing the activity, and *body and spatial awareness* or students' body expressiveness and relation with the physical space related to learning science. Finally, we identified indicators related to one assessment criteria of basic cognitive learning aspects: *acquisition of conceptual knowledge* or the recall and retention of science concepts, learning of facts, and conceptual change. We added an extra category emerging from students' responses that was not previously identified in the literature review: *scientific relevance* or students' own contribution to science when doing a science-related activity.

Second, we applied the lenses of SRL to identify students' motivational beliefs and self-control strategies affecting students' engagement in science learning and related them to identified indicators. Motivational beliefs refer to personal variables that generate and maintain the motivation to perform a task (Panadero and Alonso-Tapia 2014) and were expected to emerge since the exploratory questions revolved around students' motivations to engage in a science education activity. To identify motivational beliefs, we used the broad categories of Zimmerman's model (2002): *interest,* which can be personal (meaning of the task for the student) and situational (characteristics of the task); *task value* (utility), which relates to the importance of the task for students' goals; *self-efficacy* or students' beliefs about their individual capacity to perform a task; *outcome expectations*, that is, beliefs about the probability to success in the task and *goal orientation*, related to students' purposes for learning (Panadero and Alonso-Tapia 2014). Categories of analysis were then opened to self-control strategies - strategies to maintain concentration and interest in the tasks, identified within the performance-phase due to the applied nature of the exploratory question (i.e., performing science activities). Among these, we identified indicators related to the following subcategories (ibid): (a) *self-*

control strategies of metacognitive nature, such as learning environment and help-seeking (asking the teacher with the intention of learning); and, (b) *self-control strategies of motivational nature*, such as self-given incentives to maintain students' interest and self-consequences (enhancing the feeling of progress through self-praise and self-rewards).

Participatory indicators

A total of 17 indicators for the assessment of science education activities corresponding to the 11 RRI-related assessment criteria emerged from the exploratory workshops with students conducted in the two case studies. As shown in Table 2, identified participatory indicators mostly corresponded to RRI values (i.e., inclusiveness, engagement and ethics integration; 7 out of 17 indicators) and to experiential aspects of learning (i.e., emotions and feelings; 5 indicators). Cognitive aspects and transversal skills were also represented, but to a lesser extent (2 indicators each).

Interestingly, among the indicators identified, students' answers provided 7 new indicators that were not present in our RRI framework built through the literature review (in Italics in Table 1). Such new participatory indicators refer to *enjoyment* and *body and space awareness* as criteria for assessing experiential aspects of learning through emphasizing the importance of discovery and surprise as a key element of scientific practice (*Student's experience surprise doing the activity; Student discovery of something not previously known*) and highlighting the role of the body and the space where the activity takes place (*Inclusion of physical activity and movement in the activity; Inclusion of activities outdoors and/or outside the school*). Some of these new indicators also relate to process requirements focused on *ethics integration* and *scientific relevance* since they refer to a higher connection of the scientific topics approached in the activity within the social contexts and practical situations in which they emerge and are applied (*Connection of scientific topics to daily life experiences; Student's perception of contributing to science through the activity*). New indicators point as well to *emotional engagement* aspects through the exploration of new science education formats bringing other ways of learning and interacting with their teachers (*Use of arts-related methods in the activity; Supportive role of the teacher*).

Table 1. Participatory indicators identified from students' responses in the two countries: quotations from students' post-its, indicators and connection to RRI assessment criteria and learning outcomes or process requirements and to SRL processes and strategies.

Quotations from post-its and/or discussion	Indicator	RRI Criteria and Learning Outcome/ Process Requirement	Links to SRL
'Explain and understand the complexity of simple things" (Spain) *'Learn new things; Learn about research; Discover something new' (France)*	Student's acquisition of conceptual knowledge about scientific topic(s) addressed in the activity	COGNITIVE ASPECTS (Conceptual knowledge)	*SELF-MOTIVATION BELIEFS* *Goal Orientation*
'Discover something new that we didn't know before, something interesting for us' (Spain) *'We like discovering, to learn new things' (France)*	*Student discovery of something not previously known*	COGNITIVE ASPECTS (Conceptual knowledge) FEELINGS & EMOTIONS (Enjoyment)	*Goal Orientation* *Interest*
'Teachers must motivate us to learn science by doing something surprising, like experiments, something unexpected, to get our attention' (Spain) *'Do something magical' (France)*	*Student's experience surprise doing the activity*	FEELINGS & EMOTIONS (Enjoyment) ENGAGEMENT (Emotional engagement)	*Interest*
'Have fun when learning science' (Spain) *'Laughing; Humor in the activity' (France)*	Student's amusement during the activity	FEELINGS & EMOTIONS (Enjoyment)	*Interest*
'The result of an experiment; Contests and competitions with reward' (Spain)	Students' excitement caused by science	FEELINGS & EMOTIONS (Enjoyment)	*SELF-CONTROL STRATEGIES: Self-consequences*
'Less theory and less taking notes, more debates and exchange of ideas; Conduct experiments in the lab' (Spain) *'Conduct our own experiments; to build something new, like robots; Be allowed to touch the instruments' (France)*	Direct, active involvement during the activity	ENGAGEMENT (Cognitive & emotional engagement)	*SELF-MOTIVATION BELIEFS:* *Task value* *Interest*
'Go to places where science is present (real labs, universities; Visiting science museums and going to science festivals'' (Spain) *'Do workshops about food and nutrition, to learn how to fix a bike or how to check DNA evidence like in TV; See real science happening' (France)*	*Connection of scientific topics to daily life experiences*	ETHICS INTEGRATION (Social relevance of the topics assessed; Connecting topics with experience)	

Quotations from post-its and/or discussion	**Indicator**	**RRI Criteria and LO/PR**	**Links to SRL**
'Focus on scientific topics that are important for our generation, like climate change and energy' (Spain)	Contextualisation of scientific topics within societal challenges in the activity	ETHICS INTEGRATION Connecting topics with experience / Social relevance of the topics assessed	*SELF-MOTIVATION BELIEFS:* *Task value* *Interest*
'To do something really useful for science' (France)	*Student's perception of contributing to science through the activity*	*Scientific relevance*	*Task value*
'Do activities outside, like doing field-trips related to the topics'(Spain) *'To go out of school to visit exhibitions; Walk in the forest' (France)*	*Inclusion of activities outdoors and/or outside the school*	FEELINGS & EMOTIONS (Body and spatial awareness)	*Task value*
'We must have physically active science classes, we do not want to sit and observe all day; Movement' (Spain) *'See, touch… feel with every sense' (France)*	*Inclusion of physical activity and movement in the activity*	FEELINGS & EMOTIONS (Body and spatial awareness)	*SELFCONTROL STRATEGIES:* *Environmental structuring*
'Listen to music when learning about science because it motivates us, and it is relaxing too' (Spain) *'Dancing and painting' (France)*	*Use of arts-related methods in the activity*	FEELINGS & EMOTIONS (Enjoyment) ENGAGEMENT (Emotional engagement)	*Environmental structuring*
'Make sure that everyone participates in the scientific activity' (Spain) *'Make all students participate in science classes and not only those who always talk' (France)*	Use of participatory pedagogic approaches to reach all students in the activity	INCLUSIVENESS (Balanced participation)	*Environmental structuring*
'Use more videos and videogames in science classes, for instance from Youtube' (Spain) *'To use virtual reality to be able to feel with every sense' (France)*	Use of interactive ICT tools in the activity	INCLUSIVENESS (Fostering dialogue; Balanced participation)	*Environmental structuring*
'Teachers that know how to relate with us' (Spain) *'Trustful relationship with the teacher (inside & outside school)' (Spain)* *'More willingness of the teacher to help and to understand us' (Spain)*	Supportive teacher	INCLUSIVENESS (Fostering dialogue; Balanced participation) ENGAGEMENT (Cognitive and emotional engagement)	*Environmental structuring* *Help-Seeking*

Quotations from post-its and/or discussion	Indicator	RRI Criteria and Learning Outcome/ Process Requirement	Links to SRL
'Learn 'and improve my writing' (Spain)	Students ability to elaborate and share ideas verbally and written	SOCIAL COMPETENCES (Communication skills)	*SELF-MOTIVATION BELIEFS: Goal Orientation*
'Correct our exams in class' (Spain)	Students' assessment of and reflection about their performance in the activity	LEARNING TO LEARN SKILLS (Reflective thinking)	*SELF-JUDGEMENT: Self-evaluation*

In purple: RRI assessment criteria related to cognitive aspects; in blue, RRI assessment criteria related to RRI values; in orange, RRI assessment criteria related to experiential aspects; in green, RRI assessment criteria related to transversal competences. In italics: new indicators not present in the literature review.

Regarding discovery and surprise, in all schools in both countries students emphasized the importance of discovering and learning new things about topics of their interest for their engagement in science education activities. Such engagement was framed sometimes in cognitive terms, by identifying learning with being able to better understand and explain the topics approached (connected as well to the indicator of *Acquisition of conceptual knowledge*); but mostly in emotional ones, as discovering about topics of their interest is perceived key to enhance their intrinsic motivation about and affective involvement in the activity. Also related to interest in learning, and specifically in Spain, students in one school identified improving their writing as a learning motivation to engage in scientific activities, which we associated to the criterion 'Communication Skills' through the indicator *Students ability to elaborate and share ideas verbally and written.* Similarly, Spanish students also found important the possibility to review their own exams, so as to learn from mistakes and identify areas of improvement. We associated this statement to the indicator *Students' assessment of and reflection about their performance in the activity*, related to learning to learn skills, such as 'Reflective Thinking'. Furthermore, how students engage in this discovery or learning of new things was also identified as a key motivational element in both countries, connecting to the 'Enjoyment' assessment criterion. Overall, 'Enjoyment' was scored as one of the two most important criteria according to students in both countries, and is present also through other indicators identified in their answers which relate to *students' amusement and excitement* while doing science education activities. 'Enjoyment' is associated to dynamic, entertaining and surprising activities, such as experiments involving chemical reactions or outcomes they can see, educative games and interesting topics. In the case of Spain, students also identified classroom contests and competition games with small rewards as a motivation to participate and engage in the activity. Furthermore, 'Enjoyment' is also connected to learning through *direct and active involvement during the activity*, another indicator identified, which was scored in both countries as the second most important aspect for science learning and engagement. Having less theory and passive listening and more debates and hands-on activities, allowing students to experiment, manipulate instruments and build artefacts was perceived by French and Spanish students as essential to become motivated to participate and interested in science-related activities.

Such involvement was also connected to students' interest in the contextualization of science learning within their personal experience and the social context in which it can be applied, identifying two assessment indicators related to 'Ethics integration' within our RRI framework (*Connection of scientific topics to daily life experiences* and *Contextualization of scientific topics within societal challenges in the activity*). In this regard, students in both countries expressed their desire to approach scientific topics of concern for their generation (such as environmental issues) and to 'live scientific experiences in first person', for instance, by engaging in practical learning that is afterwards transferable and applicable to real-life situations. Students also expressed their desire to 'see real science happening', connected to going to places where science is alive, where it is practiced and scientists can be met, like labs, research centres or science festivals. Very interestingly, as a particularity in France, students highlighted 'doing something useful for science' as a motivation to engage in a science education activity. This led to the creation of a new indicator 'Student's perception of contributing to science through the activity', which was classified into the new criteria of 'Scientific Relevance'.

Described indicators related to engaging students' in discovery and contextualizing topics during science-related activities inform about the weight of self-motivation beliefs in students' self-regulated learning. These are mostly manifested through elements related to Goal-orientation, Interest and Task value beliefs. First, students' answers in the workshops suggest beliefs about their learning purposes revolving around cognitive aspects such as the discovery and learning of new things and the acquisition of conceptual knowledge, and to a lesser extent, around their training in skills needed to effectively participate in science education activities, like their writing skills. Second, the discovery element is deeply connected to students' enjoyment of and interest towards the scientific task (situational interest), as reported through the identification of actions related to their liking of and engagement in the task, such as trying new things, having space for surprise and unexpected events, approaching topics of their interest, involving humour and fun, or making sure that everyone participates. Third, indicators emerging from students' answers also reflected a set of activity characteristics or design elements that are perceived to be relevant for achieving their learning goals. Tasks fostering active participation were identified as crucial for their motivation and learning of science in all the schools. Such participation is expressed both through active experimentation (e.g., doing experiments, building artefacts, manipulating instruments) and through pedagogical approaches that involve social interaction and cognitive engagement beyond memorization (e.g., debates in class, exchange of ideas, elaboration of group reports instead of just having exams). Such participatory approaches involving learners cognitively, emotionally and physically in the task are valued by students as effective for their science learning. To a lesser extent, self-control strategies of motivational nature and self-evaluation were also mentioned. In this sense, students' motivation can be modulated using self-consequences to enhance their feeling of progress in their performance; in this case, through acknowledging the results of an experiment and through rewards provided by class contexts and competition games. Students' assessment of their own performance, raised in Spain, also informs of self-judgement strategies that help students review and judge their work in the last phase of SRL.

Finally, students' answers generated a third group of indicators, none of them previously found in the literature review, related to experiential aspects of learning, inclusiveness and engagement. These indicators related to the explicit inclusion of the body in the science education activities (*Inclusion of physical activity and movement in the activity*), the possibility to explore outdoor spaces beyond classroom settings (*Inclusion of activities outdoors and/or outside the school*) and the integration of artistic tools and resources in the learning experience (*Use of arts-related methods in the activity*). Embodiment was brought up by students not only through direct involvement in practical activities, but also through the explicit mentioning to sensing through the body (for instance, 'touch' and 'feel with all senses' in France) and keeping the body in motion (for instance, bringing physical movement to the activities in Spain). Moreover, Spanish and French students specifically valued the opportunity to do science-related activities outdoors and/or outside the classroom, acknowledging the influence of physical space in their learning experience and claiming for other learning spaces outside the school (e.g. in nature, in the city) and more field-trips connected to the scientific issues approached.

Connected to this learning awareness, students' responses also revolved around methods and pedagogical approaches implemented through science education activities. In both countries, students expressed their interest towards the integration of artistic resources and practices (e.g., music, painting and dancing) and information and communication technologies (ICT, e.g., tablets, power-point, YouTube videos and searches through the internet), to enhance their participation, foster their dialogue and induce inquiry through new forms of exploration. The *Use of arts-related methods, interactive ICT tools and participatory pedagogic approaches* was identified as indicators of pedagogical approaches aimed at fostering the inclusiveness of the activity, by offering different learning and exploration formats reaching different student profiles, beyond those 'who always participate' as mentioned by one of the students. In one of the French schools, mixing scientific content and artistic methods when doing a science-related activity was the most valued aspect for being motivated. Also, as a particularity in the Spanish case study, this inclusiveness and engaging capacity is also explicitly related to the role of the teacher, identifying one specific indicator: *Supportive role of the teacher*. In the four Spanish schools, students complained about the traditional teaching methods and one-way science communication tools that many of their teachers use to teach them science and claimed instead for more dynamic and tailored relationships. In this regard, students identified as key for their engagement and motivation having empathetic teachers that facilitate trustful relationships with their students and take time to listen and understand them, providing help when needed and caring about their motivation to learn.

This last set of indicators informed us about students' perceptions of the conditions (in this case, pedagogical approaches, teacher-student relationships and physical space) that create and structure different learning environments. These indicators have been associated with control strategies of a metacognitive nature developed through the performance phase of learning. These strategies were adapted to (i) enhance a learning environment to meet students' needs and motivations to learn (environmental structuring strategies); and (ii) facilitate students' access to help from their teachers (help-seeking strategies). In regard to environmental structuring strategies, students' responses point to more creative and diverse learning environments, in which learning strategies beyond repetition and rote memorization are put into place. This was yet another way that students responded to the homeostasis of traditional teaching methods. Key to these creative learning environments are the support of ICT (audio-visual content of the lessons and autonomous searches through the internet), the 'appropriateness of the classrooms' (having the material resources needed to both teach and learn); or the access to science in-action (as inspiring sites for students). In addition, the relationship developed with the teacher and the perception of teachers' support might foster students' use of help-seeking strategies, focused towards overcoming learning difficulties and reaching the learning outcomes.

All in all, the new indicators identified by the students brought novelty to our assessment framework, mostly concerning to experiential aspects of learning and the use of new science learning languages. Such fresh eyes emphasized students' discovery and surprise as key aspects of the learning process to consider, as well as the role of embodiment, physical space and new languages that foster communication and dialogue (indicators on arts and ICT). Furthermore, students' indicators emphasise the permeation of scientific contents into their personal experience and broader societal contexts, and their willingness to contribute to science and to assess their own performance (indicators on contextualising scientific topics within daily life experiences and societal challenges and students' perception of contributing to science). The section below further revolves around such contributions.

Contributions and implications of participatory indicators for the assessment in PERFORM

Through the identification of participatory indicators emerging from students' thoughts and discussions during exploratory workshops, we have established connections between participation, RRI and self-regulated learning applied to science education assessment. While building an analytical picture allowing us to connect our RRI inspired assessment framework with students' motivations to learn and engage in science, a first question came up: *what contribution do participatory indicators make to the framework*? An immediate response relates to the innovative contribution of such participatory approach to the design of our assessment strategy in PERFORM, resulting from the novelty brought by indicators that were not identified in previous expert literature. Further, and diving deeper into this question, the analysis of RRI indicators under the lenses of SRL allowed us to identify formative assessment as a trigger for homeostasis and self-regulation in

PERFORM, by addressing simultaneously motivational, cognitive and metacognitive aspects of learning.

First, as introduced above, students brought up through their answers novel elements that were not present in the literature review conducted of 'expert-based' indicators, allowing us to look with fresh eyes at our assessment. While our literature review showed an assessment predominance of basic cognitive and attitudinal aspects (see Heras et al., 2016), students' responses highlighted several experiential aspects as key motivational elements for their engagement. Such elements mostly refer to the capacity of the activity conducted and the learning environment that it fosters to provoke emotional responses. We found as especially salient the role of surprise and discovery, which is approached by students as an experiential aspect (rather than a cognitive one) that allows them to 'live' and feel science as an exciting experience beyond learning facts and numbers. Inspiration emerges, thus, both as a quality of the activity and a desired outcome of it. Similarly, this excitement of discovery, which they mostly connect to enjoyment, can be associated to curiosity; in words of a student: 'learning things we did not know before and are interesting for us'. Crucial to stimulating such curiosity and inspiration is the connection of science education activities to real-life challenges, not only to appreciate their relevance and value in society, but also to connect scientific practice with their concerns and their own universe, generating a direct personal experience of science they can relate to.

In sum, inspiration, curiosity and the contextualization of science teaching within personal experience bring novelty to our assessment framework by introducing students' development of emotional connections and a personal rapport with science (which can, in turn, affect knowledge acquisition, attitudes, perceptions and other beliefs shaping science learning) as a pivotal element. In this sense, identified participatory indicators allowed us to reinforce the focus of our assessment on certain experiential aspects that are key for RRI learning outcomes and process requirements, such as engagement and ethics integration. By putting the emphasis on students' engagement (mainly emotional but also cognitive), novelty is brought through the indicators as an experiential dimension that adds complexity to the different cognitive and motivational processes involved in learning and emphasises students' appropriation of their learning process. By bringing ethical values and social contexts to scientific topics, learning science can be also oriented towards enhancing students' understanding the nature of science, an aspect increasingly recognised as relevant in science education (Kuhn et al., 2017). Moreover, inspiration and curiosity are also connected to creativity, a key element of the RRI approach, as part of students' critical thinking and sense of initiative (EC 2015).

According to our particular interpretation of homeostasis in this analysis, it is also understood as the projected effort to maintain the self-regulated strategies and instructional practices that helped students to be aware of, influence, and monitor their own learning process. These allowed us to explore the potential of formative assessments for approaching RRI learning outcomes and process requirements in the context of PERFORM. Motivational beliefs are key in engaging students in science learning tasks and consequently, are triggers of students' self-regulation (Zimmerman 2012, Nicol et al., 2006). Students' interventions through the workshops showed motivational beliefs oriented towards an increased interest or liking for the science related activity, together with enhanced perceptions of task value. Interest was expressed by students mostly as situational (fuelled by task characteristics, as mentioned above), rather than personal. Students' responses emphasized an eagerness to be involved in activities that are more connected to hands-on and active experimentation. While this was expressed as motivation to be engaged, tasks mentioned by students, such as experimenting, touching, manipulating, observing can also be understood as active cognitive strategies fostering secondary school students' learning, by facilitating their assimilation of concepts and development of understanding through active involvement. This later understanding is already being embedded into early childhood science education curricula design by supporting students' skills associated with selfregulation, such as construction of knowledge through participation in and reflection about hands-on experience, since they are seen to benefit children's development and learning (French, 2008).

Similarly, an important number of students' answers connected motivations with self-control strategies of metacognitive nature, through their references to learning environments. Interestingly and coherently with their motivational beliefs, students associated the structuration of learning environments with openness (allowing students to fully participate and guide outcomes), creativity (fostering their participation in creative ways and stimulating their curiosity) and diversity (combining different instructional formats). Such associations referred to participatory indicators approaching the use of participatory pedagogic approaches, arts-based methods, technology tools and the presence of embodied learning. In this way, the diversification of typologies of science education activities through flexible and personalized didactic approaches, which has been already pointed as contributing to SRL (Ferrer-Esteban 2016), supports important

RRI process requirements within our assessment framework, such as inclusiveness and engagement.

Students' focus on experience rather than on specific learning goals and self-efficacy beliefs is aligned with the observation that students' goals are not always oriented towards learning (Alonso-Tapia et al., 2010; Boekaerts & Niemivirta 2000). Moreover, the lack of explicit mentions to critical thinking, an RRI learning outcome whose relevance for science education is increasingly recognized (EC 2015; Schraw et al., 2006), suggests the need to complement participatory with expert-based indicators for the sake of balance. Indeed, students' motivations to learn are also influenced by their views about science (Schraw et al., 2006) which in turn –as they themselves acknowledged, lack of a proper understanding of the nature and practice of science. Therefore, promoting learning environments in which students can be reflective about their learning and activate learning goals becomes essential to raise students' understanding about science and meaningful learning (Panadero and Alonso-Tapia 2014).

Formative assessment emerges thus, as a key strategy in PERFORM to promote students' awareness about their learning process and make explicit some of the implicit connections between motivational and cognitive and metacognitive aspects of learning identified in our analysis. Through formative assessment developed throughout the performance-based educational processes science educators can create opportunities for making these connections visible by exploring students' purposes to learn and be engaged in the activity, reviewing their learning goals and monitoring their progress and the way they are learning, in a supportive environment. Students' motivations towards technology tools and arts-based methods suggest as well the potential of integrating them in the assessment, since these methods are generally seen as less-intrusive assessment approaches and formative in nature (McGregor 2014; Varelas 2010), and thus are of interest for PERFORM to assess the participatory educational process.

In this process, the role of the science educator is essential, as emphasized by Spanish students. Students answers point to the relevance of teachers' skills to motivate them and foster empathic learning environments, in which their effort is recognized and a relation of trust and support is established. This trait might be influenced by the increase in the pupil-teacher ratio together with a decrease in educational budget in the last decade in Spanish public schools because of the economic crisis (Forteza & Sureda, 2012). Besides structural conditions of the educative system, educational research suggests that teachers' self-regulation matters too: being sensitive to students' basic needs requires mindful listening from teachers and their awareness of their own skills and emotional reactions (Jennings et al., 2011). Indeed, self-regulated learning approaches demand as well a shift in learning environments from coercive teaching approaches to authoritative ones in which students cooperate out of a sense of responsibility towards their learning, rather than to avoid punishment or earn rewards (Jennings et al., 2011; Woolfolk Hoy & Weinstein, 2006). These proactive approaches to classroom management require social and emotional competences from teachers in order to foster students' engagement and cooperation (Jennings & Greenberg, 2009), especially in those challenging educational environments in which stressors are common (e.g., students with special needs within high ratio pupil-teacher classrooms). The way science educators provide feedback to students has, indeed, an impact on their motivation and self-esteem, influencing both the learning goals that students set and their commitment to them (Nichol & McFarlane-Dick, 2006).

As shown through the example of Spanish students' emphasis on the role of the teacher, our assessment framework also stress the importance of looking at the impact of local particularities on students' science learning through indicators that are adapted to the local context and students' needs. This was possible in PERFORM thanks to the exploratory workshops, which facilitated students' participation in the assessment design. As pointed by other authors, despite the shift in conceptions of teaching and learning towards student-centred approaches, a parallel shift to participatory assessments has been slower to emerge (Nicol & McFarlane-Dick 2006). PERFORM is currently addressing such participation through the development of participatory indicators and the inclusion of formative assessment tools throughout the performance-based educational process, such as self-monitoring methods within the activities and reflexive sessions with the students. As an educational research project committed to RRI values, by including students' perspectives (together with their teachers') of their learning progress and the design of the activities we expect to critically reflect on the methodological development and implementation of our assessment framework. Careful listening and active observation of the learning experience, together with gathering evidence and feedback from involved actors as we implement the educational process, will allow us, hopefully, to adapt and improve our assessment framework while learning from students and their educational context.

Closing thoughts

As pointed out by previous research (Nicol, 2006), the shift in conceptions of science teaching and learning towards student-centred approaches has not yet experienced a similar shift in relation to the inclusion of participatory approaches to assessment design and implementation in the field of science education. Through the empirical experience presented here we aimed at addressing this field of opportunity through exploratory workshops contributing to our understanding of students' motivations towards and beliefs about science learning activities. But more than that, the added value of conducting these workshops was the identification of new RRI assessment indicators in a participatory way, reflecting students' views about what is important for them to be motivated and actively engaged in the science education activities proposed by the PERFORM project. By bringing novelty, students' motivational beliefs and local particularities to our assessment, the indicators identified provide opportunities for designing inspiring and adaptive learning environments in which students can feel comfortable, but also challenged and inspired in constructive and empowering ways. In this sense, students' answers pointed to a focus not only on looking at or evaluating their progress in performance, but also on the assessment of learning environments and the instruction strategies that are created and developed by examining how they trigger (or not) their learning motivations.

The analysis of students' indicators from the perspective of homeostasis as self-regulated learning also suggests the relevance of formative evaluation approaches to promote students' awareness about their learning purposes and the specific strategies they apply to learn more effectively. Indeed, while the identified participatory indicators contribute to approach motivational beliefs that inform experiential learning aspects assessed in our framework, they also show a gap in students' explicit identification of elements of cognitive and metacognitive nature. Such elements are addressed in formative assessments and are deeply connected to critical thinking and learning to learn skills, both relevant dimensions of RRI and self-regulation.

This novel process has been intended to help students explore their learning expectations and motivations (set by the homeostasis of a long-lived older paradigm of teaching methods) through a set of participatory and selfreflective methods that might contribute to a newer, strongly researched homeostatic state. All in all, formative evaluation together with participatory indicators represent potential ways of including students' perspectives in our science education assessment design, while fostering their engagement in the PERFORM project. We hope that this research might inspire other similar initiatives to contribute to this line of science education reform.

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