Working with the scientific community

LINKS

Learning from Innovation and Networking in STEM

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Introduction

STEM education should first of all give future citizens the fundamentals for decision-making in an increasingly complex world where environmental, technological and social issues are crucial. It should also encourage vocations for scientific careers to meet the needs of current and future trades.

Thus, one challenge for improved STEM education is to build a stronger connection between the way scientific disciplines are taught to students and the 'living science ' i.e. the way science and technology constantly develop new knowledge and new applications that have tremendous effects on our lives and future.

One option of major interest for the five Links project partners, in order to reduce the gap between the classroom and the 'living science', is to strengthen the cooperation between the educational system and the scientific community (technicians, researchers, academics…).

This cooperation is considered a key element also to address some specific needs of teachers, both at primary and secondary levels.

The majority of teachers experienced traditional science education during their schooling and may havehad little opportunity during their university curriculum to practice science in laboratories or companies – if ever science at all. This prevented them from understanding the importance of the scientific approach as an object of instruction and the indispensable link it constitutes with the professions related to science.

Moreover, while primary level teachers often lack confidence in teaching science for academic reasons (they mainly studied humanities), secondary teachers also need to acquire new scientific skills and knowledge to maintain and promote the interest of their students in relation with current scientific developments, especially those that have a strong connection with current issues (e.g. sustainable development).

The cooperation with the scientific community can help improve the competencies of all teachers and students, taking into account their needs.

LINKS partners, all convinced of the relevance of such an approach, have developed very diverse experience in this field on the basis of the profound tradition of school-supporting institutions and programmes in all countries that are not embedded directly in formal educational structures but are closely linked to them. Indeed, LINKS partners, even if diverse in status and organisation, are in this intermediary position in their respective school systems. They act as "missing link" providing a repository of scientific knowledge and specialist know-how in order to draw different participants and institutions into new relations of co-operation (Meyer and Kearnes 2013: 424f), namely here the scientific community and the teaching community[1].

There are numerous possible ways to improve the connection between both communities.

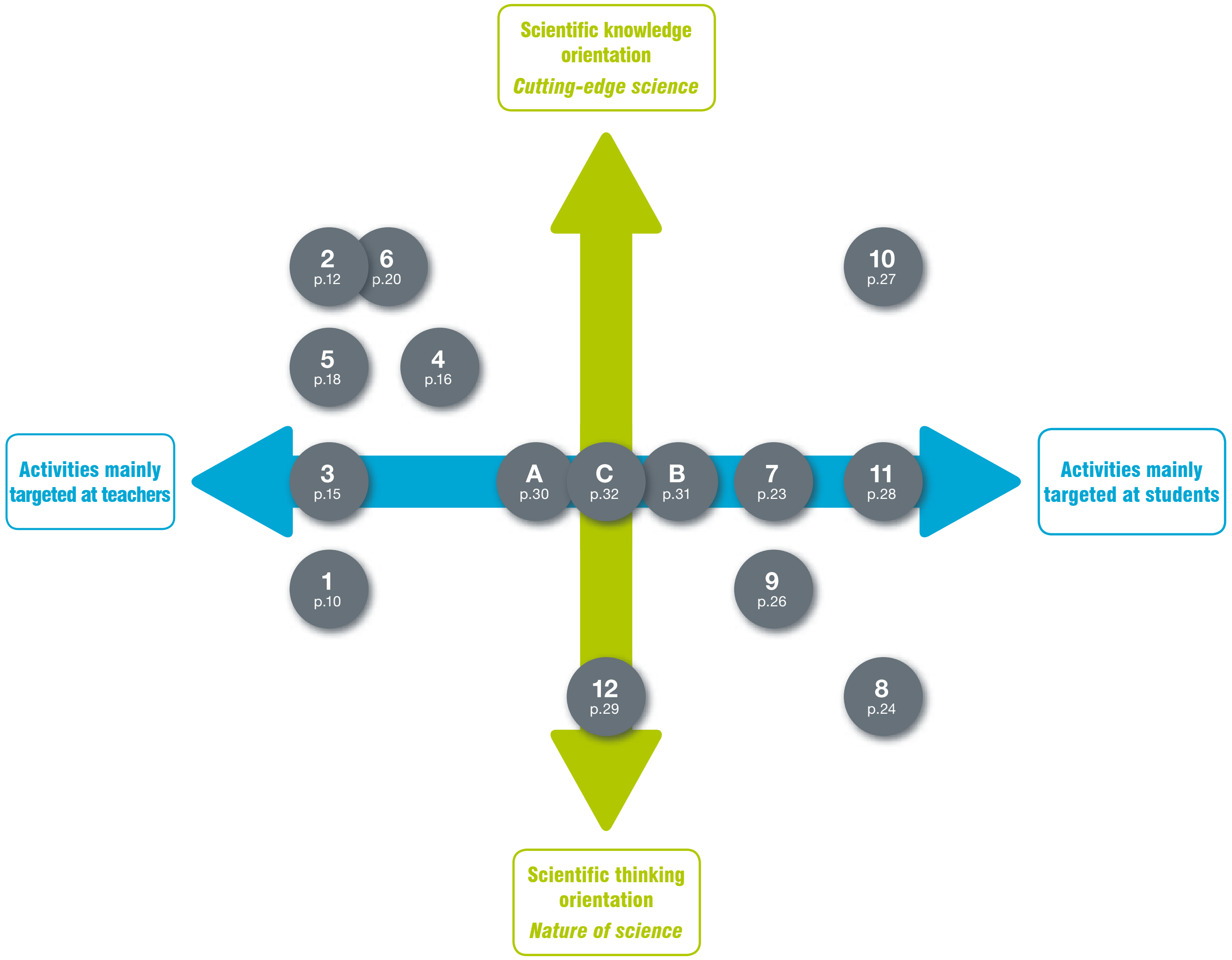
Through practical examples and details of the benefits that both parties can draw from getting closer from each other, this document aims to give a glimpse of different forms of collaboration allowing scientists to contribute directly in the training of teachers, including activities with students. Indeed, the intervention of a scientist in class, or the participation of students in a scientific partnership, requires that the teacher, during the preparation of such events, deepens the understanding of both the notions addressed with students and the scientific approach related to these notions. In addition, such actions provide a framework for implementing turnkey resources in class with the help of an educational trainer. They are therefore complementary to training sessions and have to be considered as part of the professional development approach.

The examples detailed in this document can be read independently. They present a broad spectrum of actions, from training sessions fully intended for teachers to activities designed for students, including more complex actions involving multiple partners.

The authors have represented this variety in the form of a diagram. The reader can thus choose the examples according to the target audience (horizontal axis) and/or the main orientation of the action (scientific update focused on the notions vs sharing of know-how in a «nature of science» approach).

Furthermore, the examples show what preconditions are necessary for successful cooperation between the scientific community and the educational system.

Involving scientists



[1] For more details about the notion of intermediary body/ institution, please refer to « Experiences in implementing effective continuous professionnal development for stem teachers in five european countries », the LINKS study published in 2018: <https://www.fondation-lamap.org/sites/default/files/upload/media/minisites/international/links _ Final _ Study.pdf>

2

Experiences in implementing professional development activities with the contribution of the scientific community

2.1 Twelve ideas to involve scientists in the professional development of teachers

1 Training teachers through hands-on sessions

Aims	To enable teachers to better understand scientific approaches (the nature of science) and to consider an inquiry-based science education (IBSE) by proposing them to experience investigative situations.
Lead	▸ Intermediate body which is the link between the scientific community and the educational community and takes care of general organization and communication. ▸ In the present framework, the training for teachers is prepared and implemented by a team consisting of a scientist and an educational trainer who take part equally.
Role of the scientists	Responsible for conveying the scientific process, highlighting important points of the scientific approach. A living illustration of the scientific careers by referring in particular to their daily experience.
Duration	▸ At least four one-day interventions (6h), each one dealing with different themes and allowing different types of research to be approached: experimentation, modelling, observation, engineering science... ▸ These days should be considered within the framework of a general training course giving teachers access to resources for the class and support during implementation with their students.
Preparation	▸ The intermediate body organises meetings in which scientists and educational trainers receive joint training on IBSE and the common objectives of co-interventions. ▸ The trainers and scientists then meet to establish the topics they will cover according to the needs of the teachers to be trained and how they will organise the training session (roles, methodologies, conditions, material needed, place…).
Scientists' activities	▸ Decide, jointly with the pedagogical trainer, the subject of the investigation- close enough to teaching practise- and test experiments. ▸ Provide teachers with the equipment they need to carry out their investigations. ▸ Observe the work of the different groups of teachers. ▸ Provide help to teachers when they are blocked but never deliver answers. ▸ Help teachers analyse their protocols, results, and approaches.
Teachers' activities	▸ Engage collectively in a process of scientific investigation: identify a question, hypothesise, write down and implement experimental protocols, analyse the results... ▸ Analyse the process followed and consider the outline of an IBSE with students in their class.
Evaluation	Formative evaluation of the teachers during the accompaniment in the classes by a trainer or during the feedback of the teachers to measure their capacities to implement IBSE.
Benefits for scientists	▸ Analyse and clarify the skills involved during the course of his / her job to make them explicit. ▸ Clarify certain concepts of science in order to communicate them to teachers. ▸ Communicate about his research. ▸ See their work valued by the recognition and interest shown by the teachers during training days. ▸ Reinvest the teaching skills acquired during teacher training in university education.
Benefits for teachers	▸ Get a picture of science that fits the reality of activities conducted by scientists. ▸ Understand that teaching methods involved in the discovery of science concepts is as important as teaching the concepts themselves. ▸ Understand that scientific concepts are more firmly acquired when discovered during an investigation process. ▸ Consider the benefits of active pedagogies. ▸ Better understand the situations of investigation they can make live to their students, by experiencing them themselves.
Benefits for students	▸ Experience a lively and practical teaching of sciences that matches with the approaches used by scientists in their various trades. ▸ Learn scientific concepts employing scientific method.

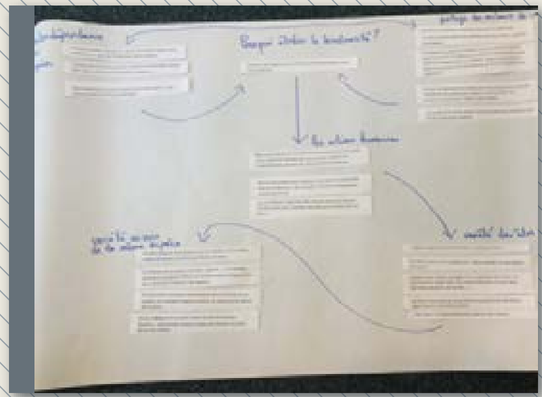
Teachers in training implementing their own experimental protocols to answer the following challenge: to create the best possible thermos.

Poster showing an experimental protocol to test the insulating capacities of the wool (including collected data and a conclusion).

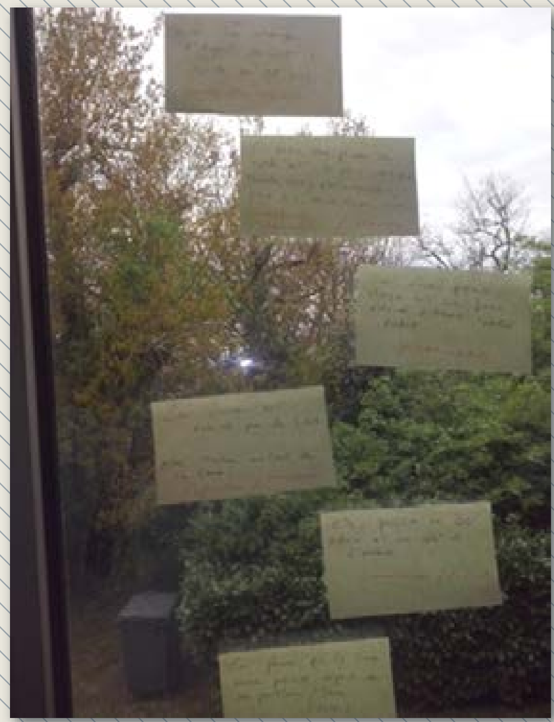
Teachers implementing an experiment to test the parameters which the diameter of a crater depends on, through modelling.

2 Preparing implementation in class: clarifying all the ideas related to a scientific concept

Aims	Allow teachers to: ► Update their scientific knowledge. ► Clarify all the aspects involved in the understanding of a scientific concept. ► Organise these aspects as a coherent whole. ► Consider wording of the different aspects according to students' age. ► Address the learning progression from kindergarten to the end of middle school. ► Get steady methodology and tools that can be used in the preparation of lessons for all scientific subjects (scenarios and concept maps).
Lead	► Intermediate body which is the link between the scientific community and the educational community and takes care of general organisation and communication. ► In the present framework, the training for teachers is prepared and implemented by a team consisting of a scientist and a teacher trainer who participate equally.
Role of the scientists	Responsible for scientific content knowledge.
Duration	► At least one 3-hour workshop related to each new scientific topic addressed during a previous hands-on session. ► These days should be considered within the more general framework of a training course giving teachers access to resources for the class and to support measures during implementation with their students.
Preparation	► The intermediate body organises meetings where scientists and teacher trainers receive joint training on IBSE and the common objectives of co-interventions. ► Then the trainers and scientists meet to decide the topics they will address according to teachers' needs and how they will organise the training session (roles, methodologies, conditions, material needed, place…).
Scientists' activities	► Help the teachers analyse their formulations to make them scientifically correct. ► Explain the links between basic ideas conveyed at the student level and the complex scientific concepts related to them. ► Propose new situations to overcome the conceptual difficulties still experienced by the teachers.
Teachers' activities	► Work individually and then in groups to formulate the set of ideas corresponding to a concept. ► Organise these ideas as a coherent whole (conceptual scenario/ concept map). ► Define activities associated with a set of notions for classroom implementation. ► Consider the interest of such work for the preparation of lessons and for the structuring of students' knowledge. ► Implement classroom activities using this scenario/ map. ► Give feedback on sessions implemented with students and exchange with trainers and colleagues to improve teaching skills.
Evaluation	Formative evaluation of the teachers during the attendance and observation in the classes by a trainer or during the feedback of the teachers to measure their capacities to imple-ment IBSE.
Benefits for scientists	► Clarify some ideas of science in order to communicate them to teachers. ► See their work valued by the recognition and interest shown by teachers during training days. ► Reinvest the teaching skills acquired during teacher training in their teaching activities at university.
Benefits for teachers	See "Aims of the intervention" plus: Own a tool to: ► Foresee students' learning difficulties. ► Carry out a formative evaluation of the scientific knowledge acquired by the students throughout a given teaching sequence. ► Offer solutions to students. ► Communicate with colleagues about learning progression.
Benefits for students	► Are better guided by the teachers during their learning. ► Experience formal sessions with teachers of structuring scientific knowledge by pro-ducing scenarios or concept maps highlighting the concepts acquired during the in-vestigations.



Teachers organising in a coherent way a set of ideas about biodiversity.



The Moon changes shape throughout a 28-day cycle.

The order of the main phases of the cycle is always the same: new moon, first quarter, full moon, last quarter…

The moon presents each night a different illuminated form called phase.

The moon is illuminated by the sun. It revolves around the Earth.

It has a lit side and a dark side.

The phase that the Moon presents to us depends on its position in relation to the Earth and the Sun.

Example of a conceptual storyline (a set of ideas) realised by a group of teachers on the teaching of a more general concept «the phases of the Moon".

3

Helping teachers with the appropriation of turnkey resources for the class

Aims	Allow teachers to: ► Take ownership of turnkey resources for the classroom. ► Prepare for the implementation of sessions with their students.
Lead	► Intermediate body which is the link between the scientific community and the educational community and takes care of general organisation and communication. ► In the present framework, the training for teachers is prepared and implemented by a team consisting of a scientist and an educational trainer who participate equally.
Role of the scientists	► Responsible for conveying the scientific process, highlighting important points of the scientific approach. ► Responsible for scientific content knowledge.
Duration	► At least four workshops of 3 hours, each dealing with the identification of the appropriate turn key resource related to a specific topic. ► These workshops should be included within a general training course giving access to hands-on workshops and support during implementation with the students.
Preparation	► The intermediate body organises meetings where scientists and educational trainers receive joint training on IBSE and the common objectives of co-interventions. ► Then, the trainers and scientists meet to choose the resources they will present according to teachers' needs and to decide how they will organise the training session (roles, methodologies, conditions, material needed, place…).
Scientists' activities	► Propose with the educational trainer experimental situations that are close enough from the teaching practices. ► With the educational trainer, use the experimental situation to provide context for teaching students. ► Assess with the educational trainer existing classroom resources to determine which ones are most consistent with the established knowledge and apply the scientific method. ► May participate in the adaptation of some of these resources to make them relevant to the specifications of IBSE. ► Offer, in some cases, classroom resources that he-she (co-)wrote as part of his-her outreach activities.
Teachers' activities	► Are acquainted with existing turnkey resources. ► Test additional material not experienced during hands-on session yet. ► Identify the difficulties that students will encounter. ► Exchange with the scientist and trainer on the issues raised by the resource. ► Develop complementary tools not provided by the resource (conceptual scenario, assessment grid for students...). ► Implement classroom activities. ► Report on sessions implemented with students and exchange with trainers and colleagues to improve teaching skills.
Evaluation	Formative evaluation of the teachers during the attendance in the classes by a trainer or during the feedback of the teachers to measure their capacities to implement IBSE.
Benefits for scientists	► Analyse and clarify their professional skills to make them explicit. ► Clarify and simplify some concepts of science in order to communicate them to teachers. ► Communicate about their research. ► See their work valued by the recognition and interest shown by teachers during training days. ► Reinvest the teaching skills acquired during teacher training in their teaching activities at university.
Benefits for teachers	► Meet teachers involved in the same dynamic. ► Interact with trainers who help them consider implementation in the classroom. ► Prepare IBSE sessions to be implemented with students, both scientific content knowledge and experiences. This allows to gain time for the preparation of future activities
Benefits for students	Experience a teaching of living sciences in accordance with the approaches used by scientists in their various trades.

4

Increasing scientific skills of teachers involving them in cutting-edge science protocols

Aims	▸ To bring teachers closer to cutting-edge science. ▸ Provide scientific work protocols to be used in classroom with students.
Lead	The intermediate body: ▸ Connects schools with research. ▸ Selects the teachers who will take part in the training. ▸ Organises trainings and provides teaching materials and resources.
Role of the scientists	▸ Prepare the molecular biology laboratory protocols. ▸ Assist in the application of protocols and in the appropriate use of work tools. ▸ Provide distant support to the teachers during the classroom activities.
Duration	Long-term collaboration with intensive residential moments (2 days of 8 hours/day, 2 times a year) at the laboratories of the University.
Preparation	The intermediate body: ▸ Organises intensive training sessions. ▸ Buys the instrumentation. ▸ Collects the needs of teachers in order to share them with the scientists. ▸ Prepares and delivers evaluation questionnaires. ▸ Collects reports and documentation produced by the teachers. ▸ Keeps the documentation and disseminates it. ▸ Takes care of the didactic aspects.
Scientists' activities	▸ Provide advanced theoretical and procedural knowledge. ▸ Observe, guide and support teachers in activities. ▸ Help the teachers in the analysis and interpretation of experimental results.
Teachers' activities	▸ Participate in the training. ▸ Study the documents given. ▸ Plan and implement classroom activities. ▸ Report on the activities carried out in different ways (reports, slides, videos, inter-views...).
Evaluation	▸ Questionnaires during the training of the teachers to get a feedback on the effec-tiveness of the workshops. ▸ Final evaluation based on the analysis of the reports provided by the teachers and on their documented outputs.
Benefits for scientists	▸ Promote some topical scientific issues of wide social interest. ▸ With the support of the teachers, bring the students closer to STEM, potentially increasing the enrolment in scientific studies. ▸ Understand more in depth the culture of the school, the needs and potential for support. ▸ Improve their communication skills for outreach.
Benefits for teachers	▸ Deepen their knowledge on cutting-edge issues. ▸ Have more direct contacts with researchers. ▸ Are guided and supported in their activities. ▸ Benefit from tools and materials that are usually difficult to find in a school.
Benefits for students	▸ Learn and explore some innovative topics with an active involvement. ▸ Use sophisticated instruments that are rarely available in a school laboratory. ▸ Get closer to research. ▸ Learn the protocols and materials used in a given scientific discipline.

Teachers at work during an intensive residential course on molecular biology at Department of Biology of the University of Naples (UNINA).

5

Placement for developing a better knowledge of the scientific professions

Aims	The placements give teachers an opportunity to experience first-hand working in a leading STEM industry or University science department. It provides teachers with a wealth of knowledge for their students to transform their understanding of STEM ca-reers and enrich the teaching of STEM subjects.
Lead	Intermediate body brokers the placement with the industry or the university and organ-ises the content of the placement.
Role of the scientists	Work alongside the teachers demonstrating the various aspects of their work.
Duration	Between 5 and 10 days.
Preparation	Teachers indicate which type of placement they would like and the locality of the placement.
Scientists’ activities	Scientist hosts the teacher in their workplace and helps them to understand the scientific work performed and the different types of professions encountered during the placement.
Teachers’ activities	Teacher shadows the scientist and others at the placement to gain first-hand experience of the scientist’s role. 6 months after the placement, the teachers attend a day of CPD looking at how they can capitalise on their learning from the placement.
Evaluation	External evaluation of the impact upon the hosts, the teacher participants and impact upon the school.
Benefits for scientists	► Building long term partnerships with local schools and colleges. ► Contributing to inspire a more diverse workforce.
Benefits for teachers	► Increased teacher’s understanding of current STEM jobs and career pathways. ► Greater ability to incorporate STEM insight experience into teaching to add context to the scientific concepts delivered in the classroom. ► Better informed to provide students with personal advice on potential career choices.
Benefits for students	► Increased number choosing STEM subjects post 16. ► Increased enjoyment, engagement and interest in STEM subjects.

Teacher on a STEM insight placement experiencing work within a STEM career.

6

Updating the knowledge of teachers on new scientific developments

Aims	Teachers at work during an intensive residential course on molecular biology at Department of Biology of the University of Naples (UNINA).
Lead	► Intermediate body which is the link between the scientific community and the educa-tional community takes care of general organisation and communications. ► Scientists from different departments take care of planning activities within the frame-work given by the intermediate body.
Role of the scientists	Introduce their current research topics, the methods they use, their results, etc. that have an added value for the teaching profession.
Duration	► In total, four half-day CPD (3h). ► These sessions are themed so that most teachers participate in two of these based on their specialist subjects (e.g. physics, chemistry, and mathematics for one teacher, bi-ology, forestry and environmental sciences for another one).Thus, typically, teachers get one-day CPD.
Preparation	► The intermediate body plans the timing of these CPDs with the cooperating city ac-cording to their CPD calendar and teachers' wishes. ► The intermediate body collects the requests of the teachers on some issues to be dealt with. ► The intermediate body contacts the science departments to find the most interesting researchers and topics and to inform them. ► Scientists prepare their lectures/workshops based on the instructions given by the in-termediate body. ► The intermediate body takes care of practical preparations (e.g. reserving halls) and communication.
Scientists' activities	► Scientists give lectures or workshops addressing their own research topics. ► As scientists have plenty of freedom in this form of CPD, their activities can include lectures, laboratory tours, workshops, etc.
Teachers' activities	As there is no one framework for this CPD session, teachers' activities are dependent on scientists' ideas but they are strongly encouraged to promote teachers' active en-gagement.
Evaluation	Teachers' learning is not evaluated in this CPD but feedback related to the following aspects is collected: usefulness of the CPD for the teaching profession, ideas for future scientific issues to be addressed…
Benefits for scientists	► Increased communication on and visibility for scientist's research project and universi-ty. ► Experience in discussing science for a non-scientific audience. ► Communicating about their research in general. ► See their work valued by the recognition and interest shown by teachers during train-ing days.
Benefits for teachers	► Get up-to-date information about local research, both content and methods used, which is relevant to subjects included in the curricula. ► Get fresh ideas for one's own teaching. ► Follow the requirements of curricula as they often include latest scientific discoveries.
Benefits for students	When teachers reinvest their newly acquired knowledge in the classroom, students get detailed information about ongoing research on current topics.

Scientists' lectures during CPD

Topics are: Vaccines, Universe, Foods, Antibiotic resistance.

7

Building a network of STEM ambassadors

Aims	Stem ambassadors are volunteers who work in STEM industries or STEM university departments. Their work with teachers and schools has the following aims: ► To give teachers context to add to the teaching of STEM subjects. ► To demonstrate to teachers and students the value of Stem subjects in our lives. ► To demonstrate the opportunities there are in STEM careers.
Lead	► Intermediate body, which is the link between the scientific community and the educa-tional community takes care of general organisation and communications.
Role of the scientists	► Stem ambassadors volunteer their time and enthusiasm bringing their expertise to work with teachers and students in workshops, careers fairs, and presentations. ► To raise the profile of Stem careers and the application of the scientific method in their everyday work.
Duration	The intervention can vary from a short term one hour workshop session to a longer term one or two hours per week for 6 weeks.
Preparation	► STEM ambassadors receive either on-line or face to face training to prepare them to work in classrooms with groups of students and to give them ideas about the sorts of activities they could do. ► Before the intervention, the teacher and the stem ambassador meet to discuss and agree the aim and the mode of delivery for the intervention.
Scientists' activities	Scientists can use their expertise to work alongside teachers in a variety of modes of de-livery to include: student workshops, ► Presentations. ► Hands-on experiments demonstrating particular techniques. ► Mentoring for students. ► Careers talks and events.
Teachers' activities	Teacher works alongside the STEM ambassador in the classroom to gain knowledge and develop techniques.
Students' activities	Use equipment and techniques that might not be available in the class.
Evaluation	Each intervention is evaluated by feedback from the teachers and the students.
Benefits for scientists	► Raise awareness about their work is passed onto the students and through them to their parents.
Benefits for teachers	► Gain first-hand knowledge of a stem career and ideas for contextualising areas of the curriculum to make it more relevant to students. ► Get up-to-date information about local research, in terms of both content and meth-ods used.
Benefits for students	Students build links between what they are learning in the classroom and what is happening in the 'real world'.

8

Challenging students in their classroom by video

Aims	► Allow teachers and students to start an investigation. ► Involve a large number of students in the same project, using videos, even when it is not possible for all of them to meet the scientist in the classroom. ► Establish distant exchanges with a scientist.
Lead	Intermediate body, which is the link between the professors and the scientist. It pro-vides a pedagogical referent who translates educational objectives into scientific items and vice versa. The intermediate body takes care of general organisation and communication.
Role of the scientists	► Challenge the students. ► Analyse students' answers and complete them. ► Provide scientific inputs to teachers and students at the end of the challenge.
Duration	Series of two or three interventions : ► Recording and broadcasting of the video. ► Intervention in the class to provide advice to the students during their investigations (optional – see "Taking advantage of the presence of a scientist during an inquiry conducted in class by students"). ► Distant exchanges to analyse and provide scientific complements to the answers of the students to the challenge.
Preparation	► Meeting between the scientist, the teachers and the pedagogical referent of the middle school: they choose together the scientific topic of the challenge and the kind of production that will be expected from the students. ► Recording of the video: the scientist records the video with the help of the pedagogical referent.
Scientists' activities	► Propose scientific topics for the challenge. ► Contribute to the writing of the challenge. ► Record the video. ► Analyse the answers of the students. ► Provide scientific inputs to the teachers and the students.
Teachers' activities	► Identify an item of the curriculum that can benefit from this type of intervention. ► Contribute to the writing of the challenge. ► Present the challenge to the students: broadcast the video, explain what kind of production is expected, and reformulate the challenge if necessary. ► Collect the answers of the students (video, writings…), and send them to the scientist with a short summary of the different kinds of answers if there are too many contributions. ► Discuss the scientific complements provided by the scientist with their students.
Students' activities	► Access the challenge. ► Investigate to identify the best solution to answer the challenge. ► Produce an answer to the scientist (video, writing, poster…). ► Discuss with their teacher the scientific complements provided by the scientist.
Evaluation	Analysis of the videos made by the students and sent to the scientist.
Benefits for scientists	► Low work load. ► Lasting communication support that can be used again.
Benefits for teachers	► Involves many students. ► Ideal for geographically isolated school. ► Motivating for students. ► Favours teamwork.
Benefits for students	► The «challenge» type is exciting. ► Have the opportunity to correspond with a scientist.

The students, organised in groups, lead experimental investigations to answer the scientific challenge.

9

Taking advantage of the presence of a scientist during an inquiry conducted in class by students

Aims	The goal is to involve the scientist in a classroom to raise students' awareness of the nature of science and scientific careers. This special meeting is also a way for students to build their «models» of scientists. It is therefore desirable to favour the choice of young scientists, women, and ensure the diversity of the speakers.
Lead	Intermediate bodies, sometimes on the basis of personal contacts (parents for example). The intermediate body provides a pedagogical referent who will coach the teachers and the scientists during the design of the activity. The referent takes care of general organisation and communication.
Role of the scientists	The scientists coach the students during their investigations and provide scientific inputs to the students and the teachers. They also explain how a scientist works in a lab.
Duration	Depends on the project and on the availability of the scientist: single action (one day max) /series between two and six interventions /long-term engagement.
Preparation	The scientist first meets the teachers with the pedagogical referent (who is a member of an intermediate body) of the school. They choose together the scientific topic of the inquiry that will be proposed to the students. They also agree on the schedule of the lesson.
Scientists' activities	Before the lesson: ► Propose scientific topics for the lesson. ► Propose experiments or scientific material, if needed. During the lesson, in the class: ► Give advice to the students, without giving them directly the right answers. ► Provide a short scientific lecture to complete the investigations of the students. ► Explain their daily work, the reasons for choosing this kind of job, etc.
Teachers' activities	► Identify an item of the curriculum that can benefit from this type of intervention. ► Design a scientific investigation for the students. ► Before the lesson, inform the students about the coming of the scientist. ► At the beginning of the lesson, present the scientist to the students. ► After the intervention, provide a feedback to the scientists: students' testimonials, reports on experiments…
Students' activities	► Conduct their own investigations. ► Discuss the results or their difficulties with the scientist. ► Improve their knowledge of the nature of science and the different kind of scientific jobs.
Evaluation	The evaluation can focus on : ► Specific skills related to inquiry-based scientific education. ► Students' perceptions of the scientists.
Benefits for scientists	► Experience a real working collaboration with students and teachers, beyond a simple lecture. ► Inspire students and share their expertise with them. ► Communicate about their professional career.
Benefits for teachers	► Have a scientific referent in the class. ► Motivate and inspire the students. ► Benefit from an informal training by working together with a researcher during an investigation.
Benefits for students	► Meeting a " real scientist " is exciting. ► Take advantage of discussions with a researcher to discover or improve their knowledge of the nature of science. ► Discover a life course and a professional career.

10

Co-constructing a lecture with students

Aims	The aim is to strengthen students' knowledge by involving them in the design of a conference with the help of a scientist.
Lead	An intermediate body provides a pedagogical referent who will coach the teachers and the scientists during the design of the activity. The referent takes care of general organisation and communication.
Role of the scientists	The scientists provide first scientific inputs to the students and then coach them during the building of the lecture.
Duration	Series of one intervention for the teachers (preparation) and two interventions in the class.
Preparation	The scientist first meets the teachers with the pedagogical referent (who is a member of an intermediate body) of the school. They choose together the scientific topic of the lecture that will be designed with the students, and agree on the schedule of the interventions.
Scientists' activities	Before the intervention: ► Propose scientific topics for the lecture. ► Provide a short lecture that will be presented to the students in the class, and modify it depending on the remarks of the teachers (scientific level in particular). During the interventions in the class: ► Present a lecture to the students in order to give them the scientific inputs necessary for them to build their own lecture. ► Help the students to design their lectures, correct the errors.
Teachers' activities	► Identify an item of the curriculum that can benefit from this type of intervention. ► Help the students to design their lectures. ► Organise the presentations of students' lectures for the other classes.
Students' activities	► Appropriate the scientific inputs of the scientist (to be able to convey it further). ► Do further research to complete their own lectures. ► Present their lectures to other students.
Evaluation	The evaluation can focus on : ► The scientific and editorial quality of the lectures produced by the students. ► The skills related to the oral expression.
Benefits for scientists	► Experience a real working collaboration with students and teachers. ► Improve their skills related to scientific communication.
Benefits for teachers	► Have a scientific referent in the class. ► Motivate and give students confidence.
Benefits for students	► Meeting a " real scientist " is exciting. ► Improve their scientific knowledge by designing and giving a lecture to other students.

11 Strengthening students' knowledge concerning science careers

Aims	The aim is to strengthen students' knowledge concerning science careers and awaken their motivation and interest towards science and mathematics.
Lead	► Intermediate bodies take care of all practical arrangements, such as communicating with presenters, booking rooms, advertisement, etc. ► The content of presentations and tours is guided and instructed by the intermediate bodies but the presenters are free to choose details.
Role of the scientists	► Provide scientific input. ► Inspire students and teachers.
Duration	► Scientific working life days: 1 day ► Popular lectures with the community around the schools, the parents…: 1 hour
Preparation	► The intermediate body contacts the heads of science departments to find the most interesting researchers and other scientists working outside the academic world. ► Presenters prepare their speeches based on the instructions given by the intermediate body. ► The intermediate body takes care of practical preparation (e.g. reserving halls) and communication (e.g. to schools and advertisement).
Scientists' activities	► Introduce their current research topics, their study path, hints for students, etc. that are considered to be interesting for students according to the theme of the event. ► Show interest for the students and are a role model for them. ► Lead guided tours: prepare a tour with inspiring elements in University premises that foster students' interest towards science and mathematics.
Teachers' activities	► Take care of the communication between scientists and students. ► Make practical arrangements related to transportation of students.
Students' activities	Participate actively in lectures and guided tours according to the instructions given by their teacher or study advisors.
Evaluation	► Scientific working life days: feedback related to the value of the CPD session for their students is gathered from teachers. Both teacher and student perspectives are appreciated. ► Popular lectures: informal feedback from the participants is gathered afterwards.
Benefits for scientists	► Increased communication on and visibility for scientist's research project and University. ► Experience in discussing science for a non-scientific audience. ► Communicating about their research in general. ► See their work valued by the recognition and interest shown by teachers during training days.
Benefits for teachers	► Get up-to-date information about local research and scientific trades.
Benefits for students	► See real-life examples about possible career paths in science and mathematics and examples concerning the skills and know-how required in those. ► See highly recognised professional figures discussing themes with high relevance and interest.

12 Involving students in a research work of the scientists

Aims	► Enable personal contact between students and researchers and offer authentic insights into research. ► Raise students' interest and curiosity and foster procedural, epistemic, social and communicative competencies. ► Offer scientists an approved framework to communicate with children of different ages. ► Break down structural barriers between the education and science systems.
Lead	Either by an intermediary educational institution or by a research institution.
Role of the scientists	► Input on scientific and technical concepts and methods to teachers and science educators. ► Advice for children's research activities. ► Responsibility for valid execution of the research work.
Duration	From at least 2x4 hours up to annual projects.
Preparation	► Joint concept development by scientists and teachers. ► Preparatory workshops for scientists and for teachers led by intermediate educational institutions.
Scientists' activities	► Coordinate the research work. ► Give scientific input for teachers. ► Act as «science buddies" or mentors for students.
Teachers' activities	► Get involved in the application and project planning. ► Are responsible for the educational support of the project and complementary work in the classroom.
Students' activities	Actively take on sub-areas of research and work on them independently (adapted to their age level).
Evaluation	The evaluation concerns both scientific findings as well as the impact on the students (focusing on development of interest and plans for job decisions). Previous assessments have shown significant improvements in the understanding of «Nature of Science» and in the motivation of students.
Benefits for scientists	► Acquire competencies in science communication with heterogeneous target groups. ► Opportunity to attend specific educational trainings organised by the intermediate educational institution. ► New perspectives for their research work. ► Positive impact on the public perception of research. ► Address potential students or recruit trainees. ► Researchers either get paid for the workshops or receive funding for high-quality research projects.
Benefits for teachers	► Get support in preparing current research topics for teaching. ► Access resources to teach a demanding science class. ► Have insight into relevant research projects and institutions. ► Experience an opportunity to bring themselves up to the latest scientific standards.
Benefits for students	► The students get in personal contact with people involved in research and experience them in an authentic environment. ► Similar to apprentices learning from their professional role models. ► They acquire procedural skills through learning by doing and imitation. ► They break down emotional barriers and experience authentic approaches to scientific work. ► The individual approaches to the topic enable a variety of points of contact with one's own interests. ► The comprehensive project activities enable students to familiarise themselves with a scientific topic in the long term and to get to know the most diverse facets of the research work. ► Intensive contacts are developing between children and researchers, which can be helpful in making decisions on the choice of studies and careers. ► The children experience the importance of technology and research for their immediate social and natural environment. ► They carry out their own research activities and receive positive feedback from their residential community.

2.2 Integrating different types of contribution

Increasingly, funding agencies and local authorities are pushing for more comprehensive project lines to bring science and education systems closer, combining different types of interventions and thus supporting science education at several coordinated levels. In such projects, activities for coaching and further training of teachers, workshops and research projects for children, vocational orientation and the development of materials and methods for teaching are set in equal measure.

Still, such projects can be very diverse and allow for progressive involvement of the various stakeholders.

The following example shows a way to involve a scientist in an interaction with a whole middle school.

A. Mentoring a middle school

Inspired by the principles successfully tested in the framework of the Integrated Science and Technology Education programme (ISTT) and within the Houses for Science, the Foundation *La main à la pâte* (intermediate body, France) launched the gradual establishment, from September 2016 to August 2021, of a national network of 140 pilot middle schools.

One of the objectives of the « *La main à la pâte* middle schools » project is to associate a mentor to each pilot middle school, as a scientific referent. This mentor is a recognised scientist or engineer and comes from an institutional or entrepreneurial research structure. She or he is proposed by the House for Science or the *La main à la pâte* Foundation. By associating his/her name with the school, the "mentor" symbolizes the link between the pilot middle school and the world of science and technology and facilitates contacts with other partners.

The coming of the mentor, especially for the inauguration ceremony of the middle school as a pilot middle school, is an event for students and parents and the entire staff of the middle school. Her benevolent presence is extremely rewarding and represents recognition of the work done by teachers and students throughout the year, especially for middle schools located in priority educational districts.

The mentor:

- Participates in the annual event the middle school organises for parents. Depending on his/her availability:
- Is a facilitator for the identification of scientific or industrial partners.
- Is kept informed of the activity of the middle school by the pedagogical referent (member of an intermediate body, in charge of monitoring the pilot middle school).
- Should visit the school once or twice a year to meet students and teachers.
- Can also take part in distant exchanges and advise teachers on the objectives and coherence of their teaching project.

Examples of the mentors impact

The pilot middle school Blanqui (Aquitaine network) is in a priority educational area. For the students, the meeting with their mentor Pierre Léna, astrophysicist and member of the French Academy of Sciences, was a milestone of the year. Since then, they regularly ask for news.

The mentor can also boost the school's project: Academician Jean Weissenbach, mentor of Rosa Bonheur Middle school (Ile-de-France network) is one of the world's pioneers in the exploration and analysis of genomes. On his initiative, the pilot middle school has set up a partnership with an innovative company specialised in the detection of endocrine disruptors. The contact with the company was made through the mentor who participated in the meeting and the design of the class activity that resulted. The mentor has therefore not only benefited professors with his scientific expertise, but also with his contacts.

The following examples show models for the practical implementation of complex integrative project concepts

B. The Regional Talents Model

The «Regional Talents» programme of the Austrian research funding agency supports projects that enable children and young people to engage with research, technology and innovation (RTI) in the fields of science and technology over a longer period of time. Children and young people deal with exciting topics, research, experiment and get to know activities and job profiles in RTI. "Regional Talents" projects are characterised by the diversity of the participating actors as well as a variety of different interventions aimed at students, teachers and schools. Through these, as many people as possible are able to participate in the activities and the results of the project. The parents are specifically involved in the projects, because of their importance in education and careers choice. The projects have a long-term didactical benefit and project contents and results are usable in class after the end of the project. All activities are designed according to age and embedded as practical elements in teaching (i.e. reference is made to the project) or in school development. Innovative pedagogical concepts with an experimental character (such as interdisciplinary or cross-class work, peer mentoring or peer tutoring and hands-on activities) are particularly welcome.

Partners from research and industry form a consortium and implement the project together with the educational institutions. Fundable organisations (as consortium leader or consortium partner) are those outside the Federal Administration:

- Intermediaries / technology transfer institutions: e.g. regional management, science centres, academic start-up centres, impulse centres (incubators and technology centres, technology transfer and innovation centres), business clusters.
- Universities and technical colleges
- Non-university research institutions.
- Companies.

Each consortium consisting of a research partner, an economic partner and at least five educational institutions of different levels can apply for funding in the maximum amount of EUR 130,000.

The goals of the "Regional Talents" program are focused on:

- Increasing the interest of children and young people in research, technology and innovation (RTI) and the deepening of the reference to science and technology through active involvement in the projects.
- The involvement of children and young people independently of their social or geographical origin in order to prepare them for a career in applied research.
- The comprehensive consideration of gender aspects and the gender balance throughout the project.
- The networking of educational institutions and partners from business and industry, and research-based on innovative topics from natural sciences and technology.

Cooperation grants are an integral part of "Regional Talents". These are lump-sum grants for other educational institutions that are not yet involved in the "Regional Talents" project. Ten cooperation grants amounting to a lump sum of EUR 1,000 are awarded in each regional talent project supported. This means that the network and the activities can be scaled up to other institutions.

Example of the «Keep Moving» project - children and young people explore their own mobility situation

In the project «Keep Moving» the NaturErlebnisPark Graz together with the University of Applied Sciences developed age-appropriate methods for the research and discovery of the local mobility situation with the participation of regional innovation companies for schools and kindergartens in the Styrian region "Mürztal".

C. Integrating the participation of scientists into a coherent project

Example of the Blaise Pascal pilot middle school (Massy, France)

Context

The pilot middle school Blaise Pascal in Massy is in a priority educational area. Before the beginning of the project, two teachers (technology and physics and chemistry) had already designed a project around space exploration.

The collaboration with the *La main à la pâte* Foundation (intermediate body) has allowed to:

- Increase the size and coherence of the existing project.
- Reinforce the development of this project through the intervention of scientists, targeted both at students and teachers.
- Take advantage of the dynamics of this project to promote interactions between primary and secondary schools as well as the relationship with parents.

Roles and types of scientific stakeholders involved in the project

- The scientific mentor of the pilot middle school (see first example of this section 2/c):
  - Involve other scientists in the project.
  - Provide technical and scientific advice on possible achievements with students.
- Young researchers:
  - Contribute to the organisation of an evening of astronomical observation.
  - Welcome students to the observatory of Paris for a visit.
- Scientists from a private scientific company:
  - Advises on the technical elaboration of the challenge.
  - Contributes to the teacher training session.

Progress of the project

This project was implemented through several stages, each one involving one or more scientists.

Stage 1. Contribution of the scientific mentor: brainstorming and advice for the development of the project.

Two months before the school year, a meeting was organised between the teachers, the pedagogical referent (member of the *La main à la pâte* Foundation, responsible for monitoring the pilot middle school) and the scientific mentor of the middle school.

The scientific mentor is an astrophysicist specialised in the detection of exoplanets. He is a member of the French Academy of sciences.

The discussion with the mentor helped to target a topic that can involve students on several levels of a give issue, namely the analysis of light. In addition, the mentor suggested an experiment for the students: the construction of a spectrometer. This led the teaching team to contact a scientist specialised in remote sensing devices.

Stage 2. Conception of a scientific challenge to mobilise the students of the middle school and a network of primary schools.

The challenge was developed with the advice of a scientist who is a member of a small company specialising in remote sensing. The theme of the analysis of light was designed as a challenge on 3 levels in order to propose activities towards the students of the middle school and the surrounding schools:

- Grades 7, 8 and 9 (students between 13 and 15 years old): construction of a spectrometer, improvement of its accuracy and presentation of this work to a jury of scientists and professors responsible for awarding prizes to the most coherent projects.
- Grades 4, 5 and 6 (students between 9 and 12 years old): production of an experiment to produce a rainbow, by identifying main elements (dispersive medium, light source).
- Grades 1, 2 and 3 (students between 6 and 8 years) and kindergarten: make an observation and a drawing of a rainbow, indicating main elements (order of the colours, presence of rain and sun).

Stage 3. Training to help volunteer teachers to implement the challenge.

At the beginning of the school year, a training course was delivered jointly with the teachers of secondary and primary schools to carry out the challenge. It included an experimental workshop on the production of devices for dispersing light and using rudimentary equipment (glasses, jars, and desk lamps) as well as scientific presentation on rainbows, the production of light spectra and their use in science and technology.

This training was co-constructed and co-presented with the scientist involved in Stage 2.

Stage 4. Main achievement: the «Science Month».

The «Science Month» has been the flagship action that ended the «Rainbow» challenge. This event entitled «In the heart of light» offered various activities: conferences for students, cross-degree exchanges, visit of the observatory of Meudon, evening of observation of the sky accompanied by scientists and opened to the students, parents and teachers of the middle school and primary schools of its network.

3

Benefits for the scientific community to participate in such actions

When analysing the different cooperation models in the LINKS networks, the following motivational categories to get scientists involved are outstanding:

- Motivation to strengthen the link between science and society
- Personal intrinsic motivation
- Personal skills motivation
- New research modalities motivation (participating sciences)

3.1 Motivation to strengthen the link between science and society

When scientists engage in projects which involve them working with teachers and students in schools either through workshops, lectures or hosting short term work placements there is a wide variety of benefits which can be garnered. First and foremost, it will raise public awareness of the work they are doing and create a wider understanding within the general population.

Raising awareness of global issues (environment, new technologies...)

Dissemination of research to the general public via teachers and students is an opportunity as the message can be multiplied by teachers, especially in the case of research on so-called «hot issues» in science such as climate change or fake news.

Testimonial: Laurent Chevalier, researcher at CEA and CERN (involved in *La main à la pâte* trainings about physics of matter) - France

Outreach, that is to say «to make known» to the greatest number the scientific knowledge in a field, is one of the pillars of my work as a researcher. The society supports me to do research; part of my duties is to make intelligible the subjects on which I work.

I must be able to report on my work at all levels of society, from children to policy makers.

Moreover, at a time when the world is invaded by «fake news» the scientific approach is essential to promote at all levels of society. The analysis tools that I describe must allow the public to avoid any manipulation.

Informing about scientific careers to promote vocations in science and technology

A strong motive for the commitment of research institutions is the need to acquire new talents for their own research discipline. Many technical and scientific courses are struggling with low student numbers. It is expected that early contact with potential students will lead to more decisions for these fields of study. For women scientists, these actions also help to spread the idea as soon as possible that science is also for women.

Testimonial: Pasi Vahimaa, Professor in photonics in Department of Physics and Mathematics in University of Eastern Finland - Finland

To promote scientific careers, it is important to show that we really do something that gives some benefit to people. Too often the presentations on science are about technical devices and results forgetting the benefits. Fortunately in optics, one can very easily spot our everyday life devices and say that this part here is why we learn optics. It can be virtual reality glasses used in the training of medical sciences. Here I can show that this is not possible without deep understanding of optics.

3.2 Personal Intrinsic motivation

In many cases, the commitment of scientists in STEM education is based on very personal motives. For example, friendship relations or social cooperation in a village form the basis for cooperation. Often it is also the experience that scientists themselves gain as parents that motivates them to become involved in their children's schools. Personal enthusiasm for one's own subject can also be an important motivating factor. For retired university professors, the collaboration represents a way to avoid losing years of study and work and continue to play a social role. Cooperation based on voluntarism, personal commitment and personal relationships can be very fruitful and imaginative.

Testimonial: Frédéric Pitout, Astrophysicist at the French Institute for Research in Astrophysics and Planetology - France

I consider these contacts with young people in schools as a real and indispensable oxygen balloon: they take me out of my daily routine (…).Seeing pairs of eyes wide-open when I tell them about the universe has something very exhilarating and satisfying. In fact, all these activities that I can do with students remind me and fully justify why I do research and teaching: explore and explore, discover and discover.

3.3 Personal skills motivation

Scientists can also benefit from such collaboration, in terms of knowledge of methodological issues, more deep understanding of educational needs for teachers and students.

Developing one's communication skills

Researchers are increasingly confronted with the challenge of communicating their work to the public in an understandable way. Participation in STEM learning projects can lead to valuable experience and support the acquisition of skills and methodological know-how in science communication. This is particularly effective when projects include coaching method for scientists that prepares them for the different target groups.

Testimonial: Professors of the technological institute of Epinal, partner of a pilot *La main à la pâte* middle school - France

As scientists, we work on very specific issues, not very accessible to the general public, in a rather closed circle ... Certainly, we must project ourselves internationally but we must also refocus on the local, develop the interactions with local industries, policies, education to value our research.

Testimonial: Aldo Donizetti, professor in molecular biology researcher in the department of biology of the University of Naples Federico II - Italy

The collaboration with high school teachers and their students in a didactic project strengthened my opinion that even behind a simple experiment, there is a great educational challenge. Each step of an experiment, although obvious to an expert scientist, offers the opportunity to stimulate the vision of the surrounding world through scientific reasoning. Sharing and helping to spread this vision increased my awareness of my role in society and the importance of being able to communicate my research at all levels.

Furthermore, the opportunity to share my passion for science and discovery with the community has refreshed my child's eyes that were the engine that drove me to my scientific path.»

Stepping back on one's professional practice and teaching

When scientists share their professional know-how with teachers and students, they have to identify the fundamental components of their scientific approach and make them explicit.

For university professors, such actions represent an opportunity to understand the reality of schools, and deepen the understanding of students' difficulties. These collaborations can enable them to acquire new active teaching methods to teach their students at university. In addition, better connectivity with schools reduces the drop-out rate at universities.

Testimonial: Professor of the technological institute of Epinal, partner of a pilot *La main à la pâte* middle school - France

It seems to me that one of the ways to counter the failure of school to create links from kindergarten to higher education is to fight the pessimistic discourse» the students are becoming worse": we must trust them for them to progress and these moments of exchange make it possible.

In the pilot middle school, I saw students' experiments of a formidable efficiency! We were far from equations, complex protocols that are proposed to students and yet, the results were relevant… This partnership also brings me a lot as a teacher.

I've been teaching students for over 20 years and I've been able to see the added value of experimentation and project pedagogy to engage young people. The La main à la pâte middle school project is part of this dynamic, I recognize it and it is for this reason that the exchanges between the teachers of the middle school and those of the tertiary level seem fundamental to me.

Testimonial: Jacques Bouffette, university professor at the Rennes University - France

"Since I have been collaborating with the Maison pour la science, I greatly modified some of my teaching methods by introducing the inquiry approach. This is very favourable - and highly appreciated - both at the L1 level (good transition from high school to university) and an excellent basis for designing a rigorous scientific approach (especially in the choice and control of the parameter tested) at the level of training of future teachers and teachers".

Deepening one's understanding of scientific notions

Scientists involved in outreach activities sometimes need to explain implicit notions and make them understandable without using their usual vocabulary. This encourages them to deepen the scientific notions involved, even if they are specialists of their discipline. This approach contributes to improve their understanding of their scientific field. This benefit is unexpected and yet essential to scientific communication.

Testimonial: Laurent Chevalier, researcher at CEA and CERN (involved in *La main à la pâte* trainings about physics of matter) - France

"The work of popularization requires caution in the choice of images, often extremely simplified, that I give to the public. We must not distort the reality often described by mathematics with little meaning for non-experts. The description of the nature or more generally of the universe in which we live often asks me to question what I think I understand. This process invariably leads me to prune the technical details of calculations or measures to bring out the fundamental points of my research.

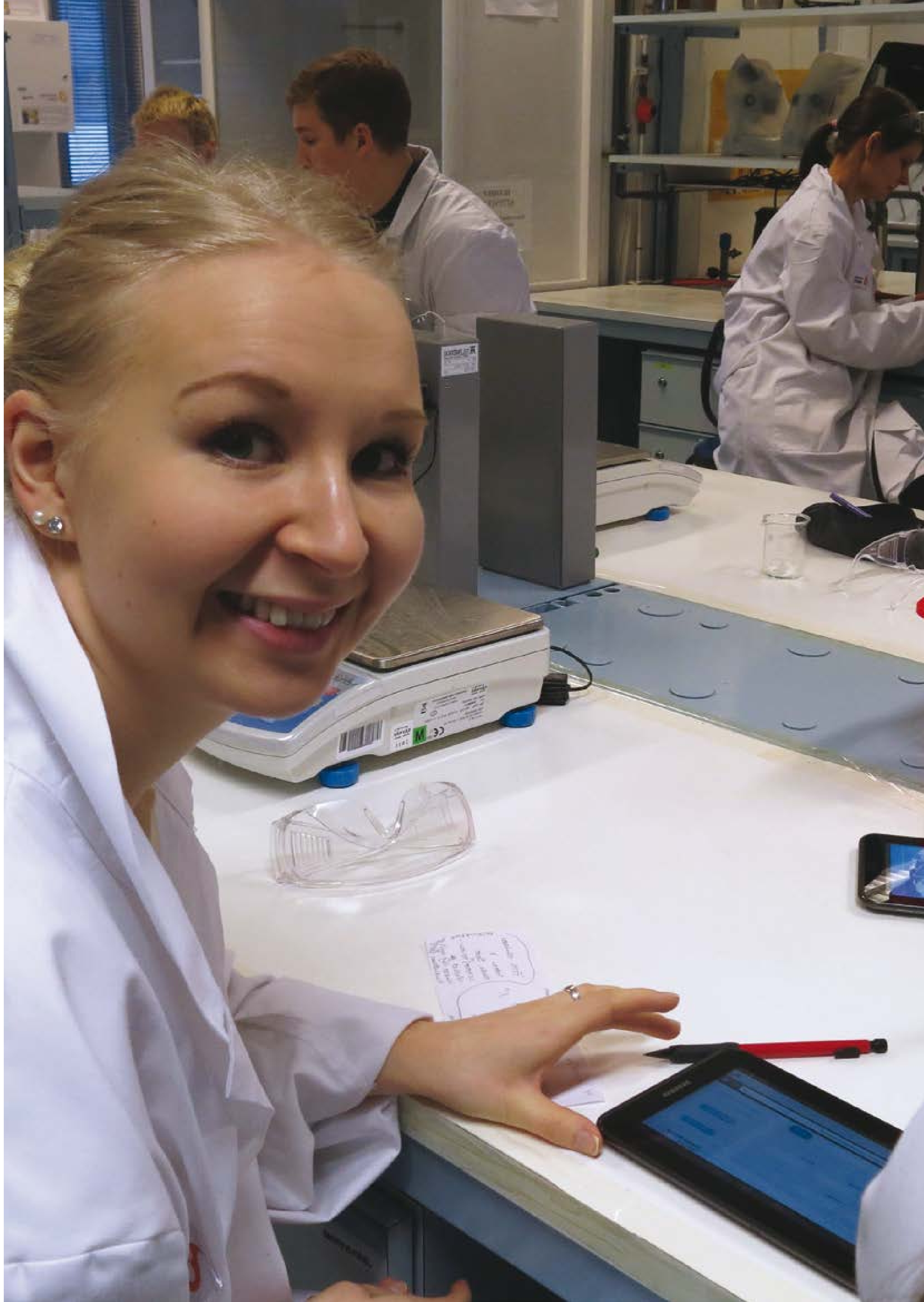
These reflections for the purpose of popularization then allow me a much better communication with my colleagues. I am convinced that by finding explanations of my research work for the general public I am improving my understanding of my field."

3.4 Interest for new research methods (participating sciences)

The increasing demand for responsible research and the consideration of science in society aspects means that research projects are aimed at incorporating additional perspectives in the sense of citizen science and participatory research. Cooperation projects with educational institutions can provide a way to involve structured laypersons in the research projects and thereby achieve findings with a broader effectiveness. This is particularly important in research projects that combine technical and scientific issues with socio-political issues (e.g. in mobility research). For researchers, the opportunity given in educational projects to improve the quality of their own research is thus a central driving factor for participation.

Testimonial: Pasi Vahimaa, professor in photonics in department of Physics and Mathematics in University of Eastern Finland - Finland

Creating virtual research environments enables us to engage people to do science. We can ask people to give us the problem that we will solve. If we at the same time make that experiment available openly in the internet, people can follow how the results will be obtained. And hopefully they will also find some issues where we can improve our own work.



4

Conclusion
Recommendations for a successful involvement of the scientific community

The cooperation between the scientific community and teachers and their students is considered a key element by the five Links project partners.

This document gives examples of concrete and varied actions to promote work between the two communities.

However, the examples show what preconditions are necessary for successful cooperation between the scientific community and the educational system.

4.1 The involvement of scientists in teachers' PD or directly intended for students is effective…

Involving scientists at all stages of a training session or an intervention intended for students, from its preparation to its implementation without forgetting its evaluation, has turned out to be quite relevant. It contributes changing teaching practices by giving teachers the opportunity to understand how science is built, to exchange with scientists on their research topic, on the issues addressed, on career paths and the work of the scientist on a daily basis. This is thus a very effective way to improve teachers' and students' scientific knowledge, but not only knowledge. The acquisition of new skills and a better understanding is also improved with the support and challenge from someone with expertise in the area.

Experts help participants to access new learning giving them new ideas, strategies and materials for delivering lessons in a more engaging and effective way. They also make teachers think about their existing practice in new ways.

The intervention in pairs, educator and scientist, favours a professional development using active methods, consistent with both IBSE and scientific approaches. Objectives related to a better understanding of science are even more easily achieved when part of the training or teaching takes place at science sites, in laboratories or in companies, at the very place where scientists involved as trainers work.

4.2 … When paying attention to some points

The presence of external experts, however, is not enough to guarantee success. To have a truly lasting effect, continuous professional development experiences must embed throughout cutting-edge subject, pedagogical knowledge, and understanding of teachers' needs. Experts need more than their knowledge; they also need to know how to make the content meaningful to teachers and manageable within the context of teaching practice. This is the role of CPD provider and trainers, as intermediate body, to guide the scientists in that way when they build their training contents. Forming pairs consisting of both a scientist and an educator specialist in IBSE is in this case highly advisable and mutual training times should be arranged.

This form of collaboration allows scientists to better situate their interventions within training sessions or during sessions with students.

In this preparation process, educators shall also pay attention to the fact that scientists may also be influenced by their own school experience.

4.3 Towards sustainable cooperation

A common trend within the LINKS partner networks is that scientific as well as business-partners most of the time work free of charge in educational projects. Their motivations are mainly aroused by personal relations and/or they see benefits in disseminating knowledge about their research topic. However, if the success of such projects depends on the relations and networks of educators, there is a risk that the reach of these programmes may be limited.

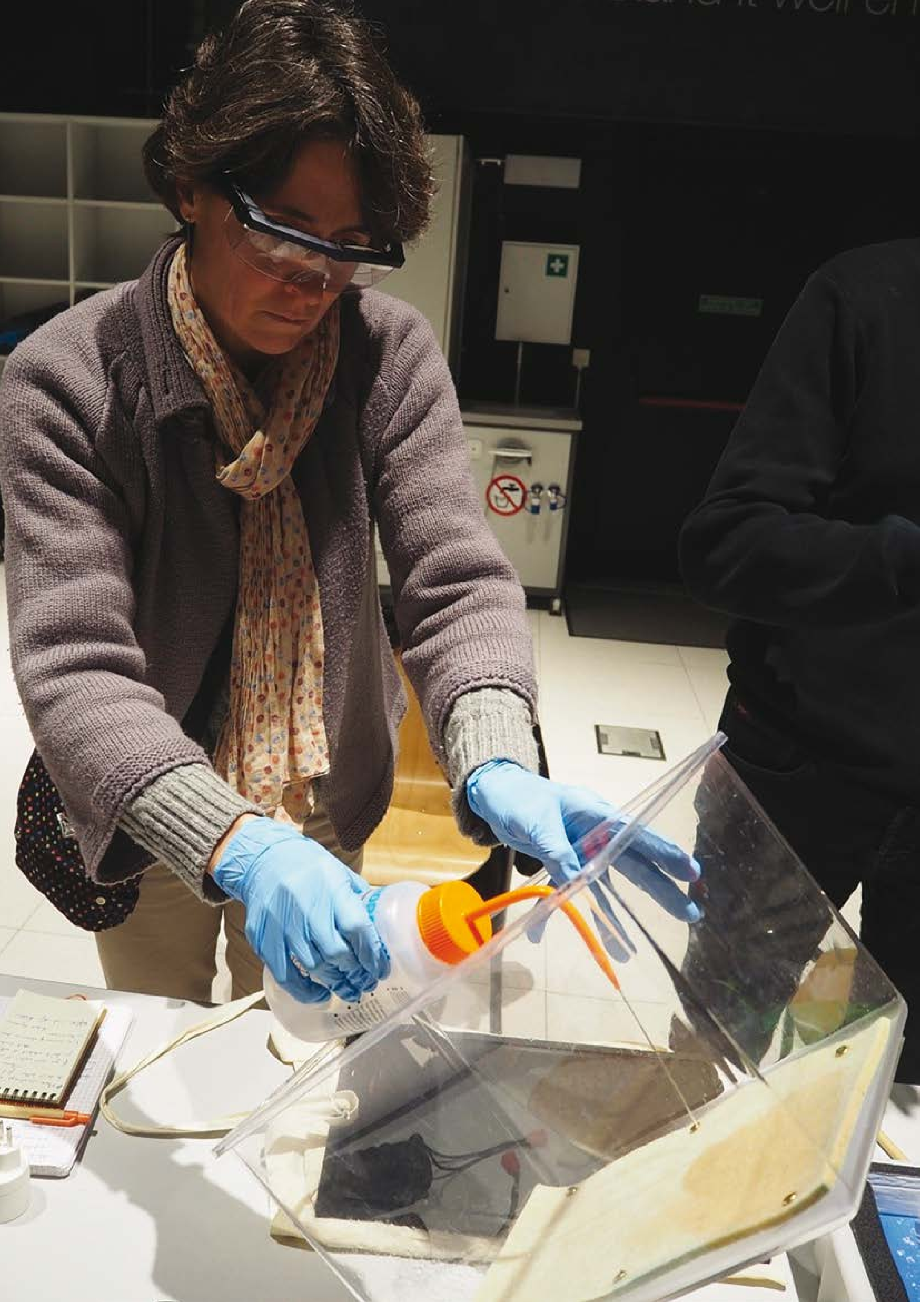
That is why the LINKS Network partners want to stress that the development of more sustainable cooperation structures requires more effort.

One proven successful approach is the continuous cooperation between CPD coordinator institutions and umbrella organizations in science and economy (e.g. Academy of sciences, chamber of commerce, loose platforms of teacher trainers, schools, universities, scientists and enterprises). In this cooperation, the majority of work is done on a voluntary basis as well, but in many cases, resources like human resources, rooms or public relations structures of the partners are incorporated. Such permanent collaboration between structures makes it much easier to find appropriate cooperation partners for specific projects. In order to maintain such close contacts, it is necessary to entrust persons with the coordination. This can for instance work via service allocations for a few working hours of teachers or teacher trainers in the public service or of employees of the partners and eventually results in the creation of an intermediate body. In spite of successful voluntary collaborations, we have to state clearly that a substantial, intensive cooperation between CPD-, science- and economic structures call for adequate and secure financial resources and/or reliable frameworks.

Among the LINKS partners, we found some approaches to institutionalise science-education cooperation:

- Systematic inclusion of cooperation activities into research proposals (relying on the dedication of a certain amount of the grants to outreach activities and participative research with schools);
- Specific grant programs of research promotion agencies under the condition of cooperation between schools, scientific and economic institutions;
- Funding for intermediary structures (science centres, networks) that bridge science, educational and business organisations.

To start this type of partnership, it is also crucial to rely on the experience developed by others and for example, to make available to scientists and educators intervention protocols as detailed in this document.



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