

Democratizing Access to Science and Technology in Rural Schools: Educational Innovation through Remote Laboratories. The R3 Project.

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Democratizando el acceso a la ciencia y la tecnología en escuelas rurales: innovación educativa mediante laboratorios remotos. El proyecto R3.

Democratitzant l'accés a la ciència i la tecnologia a les escoles rurals: innovació educativa mitjançant laboratoris remots. El Projecte R3.

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ABSTRACT

The R3 Project (<https://proyecto-r3.ingenieria.deusto.es/>) was created from the motivation of a group of professors and researchers at the Faculty of Engineering of the University of Deusto to foster scientific vocations in STEM (Science, Technology, Engineering, and Mathematics) among young people from rural areas—that is, to democratize access to experimental science and technology. Its objective is to reduce the educational gap between rural and urban schools by promoting interest in STEM disciplines and ensuring educational equity (SDG 4).

Through collaboration between technologists and experts from other disciplines, the project offers an innovative solution that allows students to interact with science without the need for expensive infrastructure. The University of Deusto, a leader in remote laboratories, works with LabsLand to develop this technology, facilitating its implementation in rural schools and enabling teachers and students to carry out real experiments via the Internet.

Moreover, the R3 Project promotes sustainability, as experiments are shared among educational centers, optimizing economic resources and reducing environ-

mental impact. The results show a positive impact on students' motivation and learning, strengthening their connection with science and technology.

Keywords: remote experimentation, rural school, STEM education

RESUMEN

El Proyecto R3 (<https://proyecto-r3.ingenieria.deusto.es/>) nació de la motivación de un grupo de profesores e investigadores de la Facultad de Ingeniería de la Universidad de Deusto para fomentar las vocaciones científicas en STEM (Ciencia, Tecnología, Ingeniería y Matemáticas) entre jóvenes de zonas rurales; es decir, para democratizar el acceso a la ciencia y la tecnología experimental. Su objetivo es reducir la brecha educativa entre escuelas rurales y urbanas promoviendo el interés por las disciplinas STEM y garantizando la equidad educativa (ODS 4).

A través de la colaboración entre tecnólogos y expertos de otras disciplinas, el proyecto ofrece una solución innovadora que permite a los estudiantes interactuar con la ciencia sin necesidad de infraestructuras costosas.



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La Universidad de Deusto, referente en laboratorios remotos, trabaja con LabsLand para desarrollar esta tecnología, facilitando su implementación en escuelas rurales y permitiendo que docentes y estudiantes realicen experimentos reales a través de Internet.

Además, el Proyecto R3 promueve la sostenibilidad, ya que los experimentos se comparten entre centros educativos, optimizando los recursos económicos y reduciendo el impacto ambiental. Los resultados muestran un impacto positivo en la motivación y el aprendizaje de los estudiantes, fortaleciendo su vínculo con la ciencia y la tecnología.

Palabra clave: Experimentación remota, escuela rural, educación STEM

RESUM

El Projecte R3 va néixer de la motivació d'un grup de professors i investigadors de la Facultat d'Enginyeria de la Universitat de Deusto per fomentar vocacions científiques en l'àmbit STEM (Ciència, Tecnologia, Enginyeria i Matemàtiques) entre els joves de zones rurals; és a dir, democratitzar l'accés a la ciència i la tecnologia experimental. El seu objectiu és reduir la bretxa educativa entre les escoles rurals i urbanes promovent l'interès per les disciplines STEM i garantint l'equitat educativa (ODS 4).

Mitjançant la col·laboració entre tecnòlegs i experts d'altres disciplines, el projecte ofereix una solució innovadora que permet als estudiants interactuar amb la ciència sense necessitat d'una infraestructura cara. La Universitat de Deusto, referent en laboratoris remots, treballa amb LabsLand per desenvolupar aquesta tecnologia, facilitant-ne la implementació a les escoles rurals i permetent que professors i estudiants realitzin experiments reals a través d'Internet.

A més, el Projecte R3 promou la sostenibilitat, ja que els experiments es comparteixen entre centres educatius, optimitzant els recursos econòmics i reduint l'impacte ambiental. Els resultats mostren un impacte positiu en la motivació i l'aprenentatge dels estudiants, enfortint la seva connexió amb la ciència i la tecnologia.

Paraules clau: experimentació remota, escola rural, educació STEM

INTRODUCTION

Promoting Science, Technology, Engineering, and Mathematics (STEM) disciplines among students is a key objective addressed from multiple perspectives—communication, education, technology, and others. It is considered essential that children feel attracted to these areas of knowledge, since future generations must be capable of driving the development of new technologies, applying them in companies, and solving the problems of tomorrow's society¹. Several studies² conclude that scientific vocations are formed at an early age, have a

significant impact in rural areas, and largely depend on educational programs and teachers.

Although it was previously believed that interest in STEM developed among students during secondary education, this vocation actually emerges earlier³—that is, when students are still in primary school, before the age of 12. Therefore, it is crucial to foster scientific vocations during the early school years through specific classroom interventions and resources.

How can children's interest in science and technology be promoted and developed? Researchers point to direct contact and dialogue with the scientific method and research practice as key factors⁴. This "conversation" was eloquently described by Max Planck in his well-known statement: "An experiment is a question which science poses to Nature and a measurement is the recording of Nature's answer." Hence, it seems essential for educational institutions to have laboratories where scientific and technological experiments can be conducted.

If securing funding for a laboratory is already difficult for a school, its maintenance and organization so that students can access it efficiently—both for their own learning and for the teachers' workload—is even more challenging. This holds true for any educational center, but it is particularly problematic for rural schools, where isolation and small size hinder the implementation of science and technology laboratories. As a result, students in rural areas have fewer opportunities than those in urban settings, since they have less exposure to hands-on experimental practice. This raises two key questions: How can this situation be mitigated in rural contexts? How can equity be introduced into the educational system?

In Spain, as in other European countries such as Finland or Estonia, the problem of depopulation and isolation in rural areas is becoming increasingly evident (see Figure 1). Focusing on Spain—where 6% of students live outside urban areas—rural regions have very low population density. This means there are few rural schools, and their limited budgets often prevent them from acquiring the necessary equipment for experimentation in information and communication technologies. This situation is gradually improving through rural development projects aligned with the Sustainable Development Goals (SDGs) and through the creation of better-equipped rural schools with qualified teachers and adequate Information Technology (IT) resources. These initiatives aim to maintain the current population and, where possible, recover depopulated areas. However, this is a long-term process, and short-term actions are required to support today's students.

Paradoxically, despite the aforementioned limitations, students from rural environments often demonstrate higher digital and scientific competences than their peers in other settings. In other words, they are in a better position to make effective use of the digital tools available to them. The PISA 2019 report⁵, which analyzed academic performance in rural areas, stated that "rural schools in Spain, Estonia, Finland, and Lithuania can offer their students more added value than urban schools." Figure 2 shows that the European countries

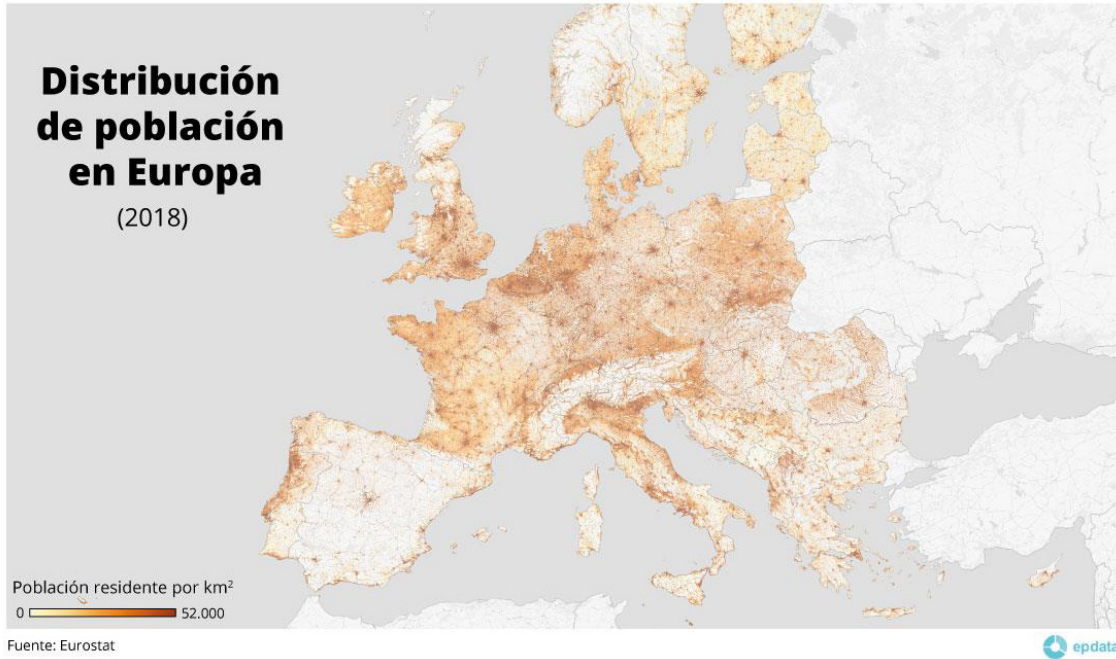


Figure 1. Population distribution in Europe in 2018 [source: Epdata]

where rural students perform best in science are those with larger rural populations—Estonia, Finland, Lithuania, Spain, and others. This finding reinforces the earlier observation that rural students tend to possess stronger digital competences than urban ones.

As highlighted in a headline from *La Voz de Asturias* (December 2018)⁷—“Rural students outperform urban students”—a study conducted by the Principality of Asturias concluded that “rural students tend to compensate for differences in resources with their performance.” Similarly, education experts Carrascal and Magro (2020)⁸ stated that “rural schools in Spain achieve good academic results, even better than those in urban areas.” Likewise, in the PISA report, Echezarra

and Radinger (2019)⁹ argue that “some characteristics of rural education—such as low student-teacher ratios, abundant social capital, and the emergence of new technologies—create real opportunities for rural schools.”

Finally, the association *DigitalES*¹⁰, in a 2019 study entitled *Why do young Spaniards reject science and technology studies?*, found that students themselves cited “the limited availability of technology-related subjects and the insufficient training of their teachers in these areas.” In its conclusions, the report proposed two main actions: (1) bringing technology closer to students through education, and (2) training teachers in STEM fields.

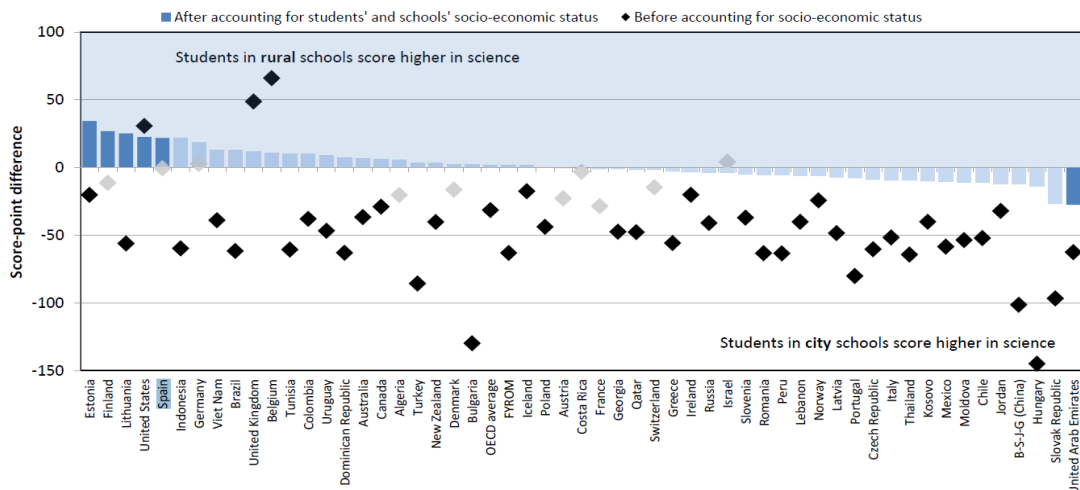


Figure 2. Science performance of rural and urban students⁶

Building upon these premises—primary education engagement, rural context, and teacher training in STEM culture—the R3 Project addresses this challenge through remote experimentation.

The remainder of this article is divided into three sections: Materials and Methods of the R3 Project, Results of the R3 Project, and Conclusions.

MATERIALS AND METHODS OF THE R3 PROJECT: RURAL, REMOTE, AND REAL

The overarching objective of the R3 Project is to foster scientific vocations in Science, Technology, Engineering, and Mathematics (STEM) among young people in rural areas through direct scientific practice using remote laboratories¹¹. The target audience is the rural school—both its teachers and its students.

With remote-laboratory technology, a student connects to a remote experiment through a web interface and carries out activities that are real—not simulated or virtual. In other words, a remote experiment is a real experiment conducted over the Internet, and the

experience is authentic even if the student is not physically handling laboratory equipment. Concretely, the experiments are performed on physical setups located at universities in Spain, Costa Rica, the United States, Brazil, or South Africa, and students access them via the Internet. For example, students can move and observe a real pendulum to learn the laws governing its motion, or observe the behavior of a planarian in different solutions through the remote labs.

The remote experiments used in the R3 Project are provided by the Spanish company LabsLand (labsland.com)¹². Its catalog offers more than 50 experiments. Among these, the most popular in the R3 Project are:

- **Planarians (Figure 3).** These are small flatworms that share some similarities with the human body. Students observe changes in behavior and activity when immersed in different substances and can understand the health consequences of consuming certain energy drinks.
- **Buoyancy and Archimedes (Figure 4).** Students learn why some objects float while others sink by dropping items with different volumes and weights into a container filled with liquid.



Figure 3. Planarian experiment. Healthy living habits—what do we drink?



Figure 4. Buoyancy experiment—will the sphere float when it falls?

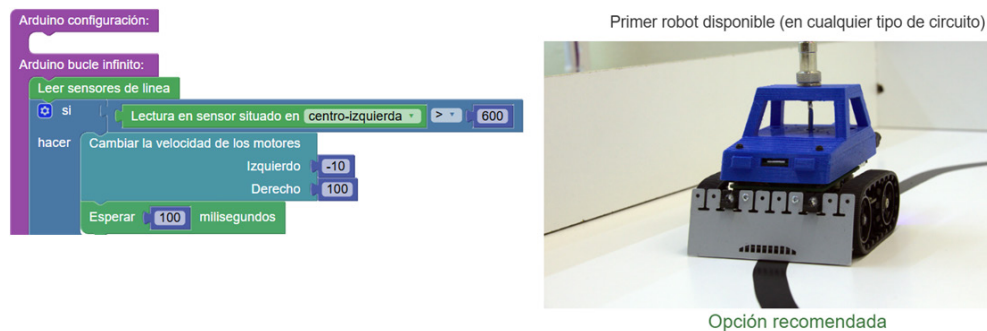


Figure 5. *Arduino experiment. Programming the robot—does it do what we intend?*



Figure 6. *Free-fall experiment—which ball reaches the ground first?*

- **Robots (Figure 5).** Students learn to program a robot using a visual language and observe how the robot moves and can be controlled. Notably, **computational thinking** is a competence included in the primary-education curriculum in many autonomous communities. The remote robotics experiment clearly illustrates the advantages for teachers: not only is there no need to purchase the equipment, but it also requires no maintenance and is always available. Any teacher who has managed a robotics classroom knows how complex it is to administer the robots and repair them when they break.
- **Free fall (Figure 6).** Students drop several balls with different masses and volumes from a certain height to determine which ones reach the ground first and why.

Illustrative videos are available at <https://proyecto-r3.ingenieria.deusto.es/recursos.html>.

Remote experimentation is an open gateway to democratizing access to science and technology for all. Rural schools can clearly benefit from this technology, as they typically have good computer equipment and Internet connectivity—at least in Spain. Remote experiments offer several clear advantages:

- They are available 24/7;
- They require no maintenance;

- They are sustainable, since a single experiment can be used by many rural schools;
- They are cost-effective because they are shared;
- They are safe for students;
- They are didactically shareable, because the same educational materials are valid for all rural schools.

Therefore, given the scarcity of scientific infrastructure in Spanish rural schools—which may negatively affect students' STEM vocations—the R3 Project seeks to provide scientific-technological training and enhance rural students' STEM competences through remote experimentation. In addition, the R3 Project aims to offer direct support to interested teachers through specific scientific activities and experiments, training and teaching materials, and assistance throughout the process.

Materials and Methodology of the R3 Project: Rural, Remote, and Real

The project is structured into several key phases during each academic year:

- **Outreach.** Contact with rural schools and online presentation of the R3 Project.
- **Training and didactics.** Teachers will not use remote experimentation in the classroom unless they know it and feel confident using it. The first activity therefore explains to rural teachers what a remote experiment is and how to use it—particu-

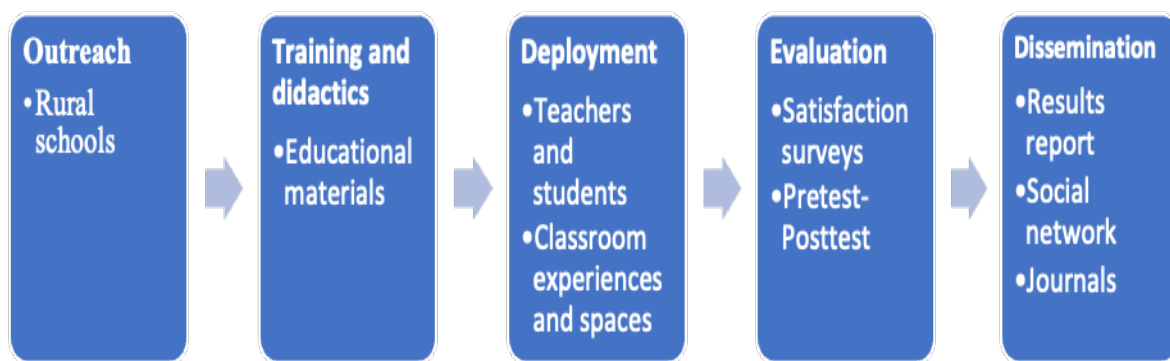


Figure 7. Project phases.

larly important because primary-school teachers, and some in secondary education, are often less accustomed to scientific practice. This training is delivered online.

- **Deployment.** Once trained, the teacher selects one (or more) remote experiments to use in the rural school, applying the pedagogical materials and the format they consider most suitable, with support from the R3 team. Students conduct experiments under the teacher’s guidance using inquiry and the scientific method. Each teacher plans the classroom activity according to their preferences and the students’ level.
- **Evaluation.** After the scientific activity, students and teachers can report their satisfaction with both the training and the classroom deployment. There is also an educational evaluation to assess the effect of scientific practice on learning outcomes.
- **Dissemination.** The project disseminates its results in conferences, journals, social media, etc.



Figure 8. Students from CRA Cuna del Jiloca Santa Eulalia performing the Planarian experiment.

RESULTS OF THE R3 PROJECT

The results of the R3 Project are diverse: educational, satisfaction-related, learning-related, and outreach-related.

a) Educational results

The primary result of the R3 Project is the students’ hands-on scientific experience. To this end, teachers rely on R3 training, their own experience, and that of earlier R3 teachers documented in published books.

Since the remote laboratory is the same, materials developed by one teacher can be reused by all.

The teacher’s role is fundamental. It is important to emphasize that the project does not seek to prescribe how teachers should do things. The R3 Project supports teachers in innovating in the classroom by promoting students’ use of digital tools for remote experimentation and stimulating interest in science and technology.

The R3 Project started in the 2020–21 academic year and remains active. The network of participating rural schools has expanded to include centers in Asturias, Cantabria, the Basque Country, Huesca, Aragón, Catalonia, Valencia, the Balearic Islands, Madrid, Murcia, Teruel, and others. To date, we have engaged more than 50 schools and over 100 participating teachers, reaching over 2,000 students who have made more than 10,000 accesses to different remote experiments.

b) Satisfaction with the R3 Project

Satisfaction levels were high for both teachers and students.

Student satisfaction with the R3 Project

After completing the classroom activity with remote experiments, teachers ask students to complete the project’s satisfaction survey, based on the model by Nickerson et al.¹³ All responses are anonymous. The questionnaire comprises three parts: satisfaction (first four questions), immersion (next two), and usability (next two), plus a final question on motivation.

In the 2023–24 academic year, 163 of the 269 participating students completed the questionnaire; results for 2024–25 are still being processed. Figure 9 presents the responses graphically: blue indicates positive satisfaction, yellow indicates dissatisfaction, and green indicates neutral satisfaction. As can be seen, positive satisfaction exceeds **80%** for all items.

At the end of the questionnaire, each student can describe their experience in writing. Some examples include:

- *I liked working as if I were in a laboratory. It seemed very interesting.*
- *I liked the R3 PROJECT so much, and I learned that drink xxx is really bad for you.*

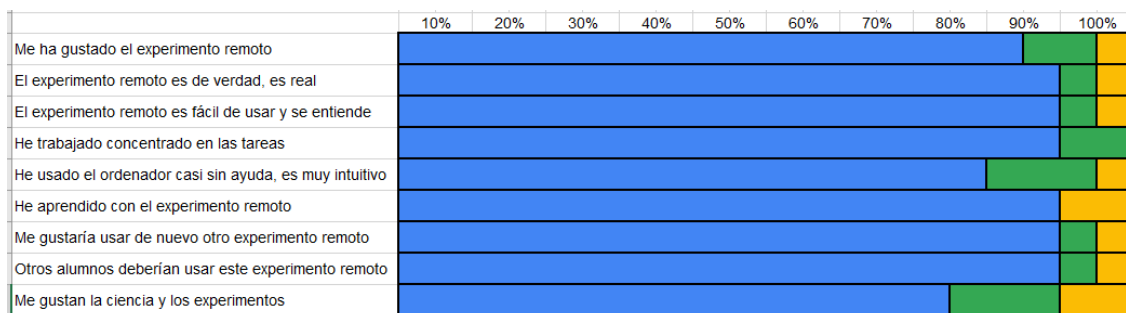


Figure 9. Student satisfaction results.

- *I really liked working this way because I learned a lot. Using the computer is another way of studying that I personally like quite a bit because things stick in my head.*
- *Honestly, I enjoyed this experience a lot and I would like to repeat it with other things we still don't fully know... Thanks to this experiment I learned things I didn't understand, and now I understand them better than ever. Thank you for this experience.*
- *I think it's a very fun way to learn, and you get to know your friends, teachers, and classmates much better.*
- *It seems like a very good experience to me, since some people don't have the chance to try these things.*

(minimum 1, maximum 5) for 2023–24, in which 37 of the 65 participating teachers responded (Table 1).

On a 1–5 scale, all mean values are above 4.0, and the most common response to every item is 5. The highest rating corresponds to item 12, indicating that teachers perceive the activity as fostering STEM. It is also noteworthy that teachers are, in general, willing to participate again (4.4) and, even more so (interestingly), to recommend the project to others (4.6). The two lowest ratings—still above 4—relate to the suitability of tasks for students (4.1) and alignment with the teacher's own objectives. In any case, teacher satisfaction is high.

Teachers' comments help us better understand their views on the project—especially critical feedback, which is key for improvement in subsequent editions. Selected comments include:

Teacher satisfaction with the R3 Project

Teachers also complete a questionnaire to evaluate their satisfaction. The following table shows the results

- *As I mentioned in the satisfaction questionnaire, the opportunity to train with you and put it into practice with my class has been very positive*

Table 1. Teacher survey results (Likert 1–5)

#	Item	Mean	SD	Mode
1	The resources provided by the R3 Project	4.4	0.87	5
2	The suitability of the classroom activities deployed with students	4.1	0.98	5
3	The information received from the organizer (Univ. of Deusto) during project execution	4.5	1.01	5
4	The fluidity of communication with the R3 project organization team	4.5	0.97	5
5	The support received from the organization throughout the R3 project	4.5	0.91	5
6	I fulfilled my initial objectives and expectations	4.3	0.79	5
7	It has been an enriching experience for my school	4.3	0.81	5
8	It has been an enriching experience in the classroom for students	4.4	0.73	5
9	The R3 Project aligned with my didactic goals in the classroom	4.2	0.82	5
10	I would like to participate in the next edition	4.4	0.91	5
11	I would recommend that other schools participate in the R3 Project	4.6	0.72	5
12	The R3 Project fosters the development of STEM competences: science and technology	4.7	0.72	5
13	Students generally liked the R3 Project	4.4	0.65	5
14	Overall, I am satisfied with the R3 Project	4.5	0.77	5

in every respect. On the one hand, it allowed me to systematize the scientific method more and better and adapt it for first-grade children. In fact, they really realized that not everything happens NOW; it requires thinking, planning, anticipating, drawing conclusions... In other words, given the society we live in, following the scientific method step by step enables reflection and a calm yet meaningful learning process. On the other hand, access to real laboratories, with all their materials... in a rural environment as limited as ours—there are no words to express our gratitude. Finally, I admit that sometimes a lack of time and “memory” did not allow me to get as much out of it as I now think I could have (I’ll try to pick it up again in the coming weeks). I hope this project stays ALIVE next year, and I would love to continue being part of it at the new school where I have been assigned. Many thanks for everything.

- *More experiments suited to the primary stage.*
- *It would be nice to have a videoconference with the kids so they could meet the people behind the project.*
- *Instead of varying the mass of the launched object so much, it would be more useful to have several additional launch distances to plot more than three points and obtain a good straight line.*

c) Learning outcomes

Beyond student and teacher satisfaction, a key concern for the R3 Project is to ensure that remote experiments foster scientific-technological learning^{14, 15}. Although not straightforward to measure, evaluations using a pretest–posttest design indicate positive results that should be confirmed with additional in-class experiments. In this regard, IQS experts collaborated with faculty at the University of Deusto to design the questionnaires and analyze the results.

The planarian questionnaire comprises six questions and is available to students on the project website (proyecto-r3.ingenieria.deusto.es). First, the teacher explains what a planarian is and how it lives; students then complete the test (pretest) before the remote experiment. Next, students carry out the activity with the remote planarian experiment and subsequently complete the same test again (posttest).

During the 2024–2025 academic year, teachers who used the planarian experiment were invited to participate in the pretest/posttest evaluation. In total, 55 students from four primary schools of different ages completed both tests. Figure 10 shows the results with a boxplot. Using the Wilcoxon test ($W = 138$, $p = 0.000001$, $n = 55$ pairs), there is statistically significant evidence against the null hypothesis; that is, students learned with the remote experiment. Cohen’s $d = 0.84$, also indicating a positive effect for students.

d) Outreach results of the R3 Project

An important aspect of the R3 Project is the dissemination of results in various forums. On one hand, the project compiles all materials developed by teachers

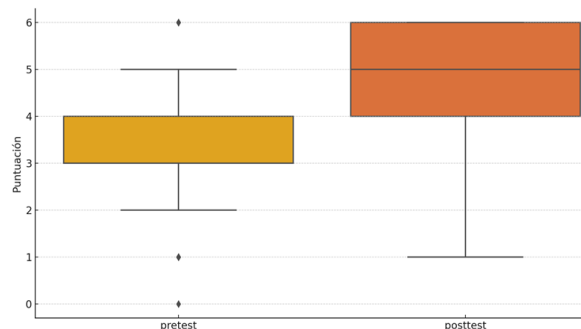


Figure 10. Boxplot for the evaluation of the planarian experiment.

for each experiment. The idea is for teachers to share their experience—especially because the materials and ideas are applicable to any teacher, given that the remote experiments are exactly the same. Teachers also value seeing their work published in a book. In a similar vein, participating classes receive T-shirts with the R3 Project logo and often take a photo to share on social media. It is not only about learning; it is also about celebrating.



Figure 11. Students and teachers from the rural school of Beire (Navarre) wearing the R3 Project T-shirt.

On the other hand, the R3 Project encourages teachers to share their experiences, for example, in the online magazine *Educación 3.0* (<https://www.educaciontrespuntocero.com/experiencias/proyecto-r3/>), at conferences (e.g., TAE 2022), on radio programs (RNE1’s *La España Rural*, hosted by Manolo HH) with interviews of coordinators, teachers, and children, or through web platforms such as *educando.es*, which has disseminated the R3 Project through interviews and articles, and the specialized site *escuelarural.net*, which has published several news items about the R3 Project and serves as a reference portal for rural-school projects and activities.

CONCLUSIONS

The R3 Project: Rural, Remote, and Real aims to democratize access to science through remote experi-

mentation, with particular attention to rural schools in Spain. Aligned with the University of Deusto's commitment to social development, this initiative seeks to transform STEM education in contexts with limited access to scientific infrastructure, fostering inclusive, equitable, and sustainable learning.

Over three years of implementation, the project has engaged more than 100 teachers and over 2,000 students from more than 50 rural schools, who have performed more than 10,000 remote experiments. Evaluations reported in various scientific publications and conferences show high satisfaction among both teachers and students, highlighting increased interest in science and technology as well as a positive effect on student learning.

The impact of the R3 Project goes beyond the immediate educational sphere, generating relevant institutional collaborations not only among Jesuit universities (University of Deusto–IQS) but also with organizations such as the Princess of Girona Foundation, the Provincial Council of Tarragona, *Eskola Txikiak*, and several regional education departments in the autonomous governments of the Basque Country, Galicia, La Rioja, and Andalusia, among others. These alliances position the project as a potential benchmark for the design of public policies aimed at educational equity and the digitalization of rural areas.

The R3 Project also contributes to the Sustainable Development Goals, particularly SDG 4, by promoting quality education and sustainability through the shared use of experimental resources, which results in significant economic and ecological savings.

In sum, the R3 Project constitutes an educational innovation initiative with direct social impact that has strengthened science teaching in rural areas of Spain. Its collaborative and sustainable approach demonstrates that integrating technology and science into rural education is feasible, effective, and essential to prepare new generations for the challenges of an increasingly digital and globalized future.

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