A multidisciplinary scientific outreach journal designed for and made by middle and high school students to bring research closer to the classroom

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One mission of a researcher is to share their work and results with the general public but there is a real challenge in accurately and effectively sharing scientific results with a broad audience. Indeed, they are published in scientific journals that are mostly available at high costs; the vocabulary used makes it hard for people outside of the field to understand the concepts; and sometimes there is a language barrier for non-English speakers. However, to make informed decisions on a variety of scientific and societal topics, citizens need to have access to and keep up with these research results. To build critical thinking, this good practice should be developed from an early age. This paper describes the journal DECODER (French for "to decode", journal-decoder.fr), which enables a researcher and a class to work together on their own shortened research article. The middle and high school students can have the role of active reviewers on the researcher's shortened article or they can write an outreach article on a given topic in which the researcher is a specialist. Articles are then published under a creative commons license and are freely available on the journal website to benefit a majority. Our partner researchers work in space agencies, in academia, or in industry, in a variety of disciplines. The emphasis is set on multidisciplinarity to raise students' awareness about research wideness and show them that research is not limited to STEM fields but also exists in economics and humanities. This points out the significance and ubiquity of transdisciplinarity in solving real world's problems, especially for space exploration. In its

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first year and a half, the journal has already involved twelve classes in seven different schools and 30 articles have been submitted by 20 researchers.

I. Introduction: rationale for such a journal

THE role of a researcher is four-fold: generating scientific results, which are accessible in the form of academic articles, valuing these results through patents, training students and colleagues, and disseminating scientific information, through public outreach for instance[1]. This last role is often overlooked and in the facts research results are hardly accessible to a broad audience[2]. The prices charged by most scientific publishing companies are the first obstacle to a diffusion at large within a general audience[3]. Then, the vocabulary used in academic journals makes it challenging for outsiders of the field to understand the concepts detailed in a scientific article[4]. Finally, the fact that the default language for most journals is English can also be a major hindrance for non-English speakers.

The prime users of scientific results are the scientific community, authorities to meet societal challenges, entrepreneurs to develop new products, and all citizens to make informed decisions and have a critical look on their government's choices. If the latter cannot easily access scientific results, they will lack some necessary information or may rely on partially incorrect information[5],6 to build critical thinking on a variety of societal topics, understand the surrounding world, as well as understand the consequences of our past, present, and future actions, which are crucial to take action[7,8].

Besides, despite an ever-growing scientific production (3 million of academic articles per year[9], 9% of the French population[10] and 6% of the American population still believe that NASA Moon landings during Apollo missions are a hoax[11]; 10% of young Americans think climate change is not a problem and 17% have no opinion about it[12]; and 16% of the American population has doubts about the fact that the Earth is round[13].

It is our role, as researchers, to have a direct involvement in the dissemination of scientific information towards the general public, especially towards young students, through the implementation of research methods. It is crucial to accept the complexity of various concepts and to not give in to easiness, which often leads to unfortunate amalgams and inaccurate analyses[14,15]. Research popularization is not about changing the message, it is about changing the media and the code to adapt it to a given audience[6].

These observations led to the development of the scientific outreach journal DECODER, French for "to decode", which enables a researcher and a class to work together on their own shortened research article (http://journal-decoder.fr/). The acronym stands for Decouvrir, Etre Curieux, s'Ouvrir, Demontrer, Experimenter, Rechercher (to discover, to be curious, to be open-minded, to demonstrate, to experiment, to research). In a first part, we describe the object and the functioning processes of the journal, as well as its target audience. In a second part, we review a year and a half of existence, in terms of disciplines and classes grades, as well as lessons learned. Finally, we give some perspectives to this project.

II. DECODER: what, how and for whom?

A. Research within the classroom

1. Essence of the project

The main objective of this project is to enable middle and high school students to have firsthand experience with the research world. Therefore, they are in contact with a researcher and they play the role of reviewers and revisers on an actual but shortened academic paper, on current research topics. The shortened academic paper does not over simplify the main concepts, it may elude some details that are not of prime importance for the comprehension, while a simplified article already choses an angle to explain the main concepts. We want the students to choose their own angle for the understanding of the paper they work on, hence the researcher provides them with a shortened version of their original article.

Their teachers will use this opportunity to illustrate their class with concrete research projects and show their students that research, especially in the space sector, rarely involves one single discipline[16], as it is compartmentalized at school. For this reason, the classes we work with often involve two or more teachers for one single article.

Because students are in the shoes of reviewers or experimenters, it also gives a chance for their teachers to talk about the scientific method and the peer-review process to publish scientific results. The students become familiar with the scientific method, with the need of giving scientifically-sound proofs, and of cross-checking results with the literature. All of these skills work towards developing the students' critical thinking.

Finally, interacting with a real-life researcher may contribute to reduce the distance, which might exist between the research world and these students, hence destroying potential myths behind scientific research, as well as showing them career opportunities. The researcher is not “the one who knows everything” but rather “the one who tries to answer a question”.

2. Practical set-up

From a practical point of view, there are two main ways for a class to participate in the journal DECODER: the first one is to revise a shortened academic paper from a researcher; the second is to write their own scientific outreach paper that will be revised by a researcher.

Regarding the first option, the process starts with a researcher submitting a title and a short abstract (about 5 lines) of one of their published academic articles. This can be in any discipline, from humanities to all STEAM (Science Technology Engineering Art Mathematics) fields. This abstract is then available online on our catalog (Figure 1, step 1 in blue).

The second step involves teachers who will scroll through the poll of abstracts and chose the one that fits their teaching goals the best (Figure 1, step 2 in blue).

After that, the editorial team puts the teacher and the researcher in contact and they start discussing practicalities of the project such as timeline and milestones, interaction with the students, depending on their respective calendar. At this stage, we put on emphasis on the fact that both parties are free to organize themselves as they wish, as this is a voluntary project for the researcher and often a new teaching experience for the class.

Once the organization is agreed upon, the researcher provides a 2000-word version (in French or in English) of their academic article (shortened but not over-simplified) that the class will work on. In the meantime, the researcher and the class typically organize a video-conference or a real-life meeting, when practical, to present the project, the particular article, and research in general, with an emphasis on the scientific method (Figure 1, step 3 in blue).

The students then start their revising job, with the aim of making this 2000-word version intelligible for students of their level, in other words a scientific outreach article. Therefore, they work on defining complex notions and words in their own terms, they propose figures and tables which can make the text easier to comprehend, and they can suggest reorganization of the text or ask questions on the scientific methods used if these appear unclear to them (Figure 1, step 4 in blue).

The revised version is sent to the researcher who will accept the changes, discuss them, or reject them (particularly if they think that scientific soundness is not respected). This can be done with any method, email, videoconferencing, or real-life meeting, if it is practical for both parties (Figure 1, step 5 in blue).

The students will review the comments of the researcher and the process will go on until both parties agree on a final version.

This final version is then formatted by the editorial team and uploaded on our website, under a creative commons license, for free and accessible to anybody (Figure 1, step 6 in blue).

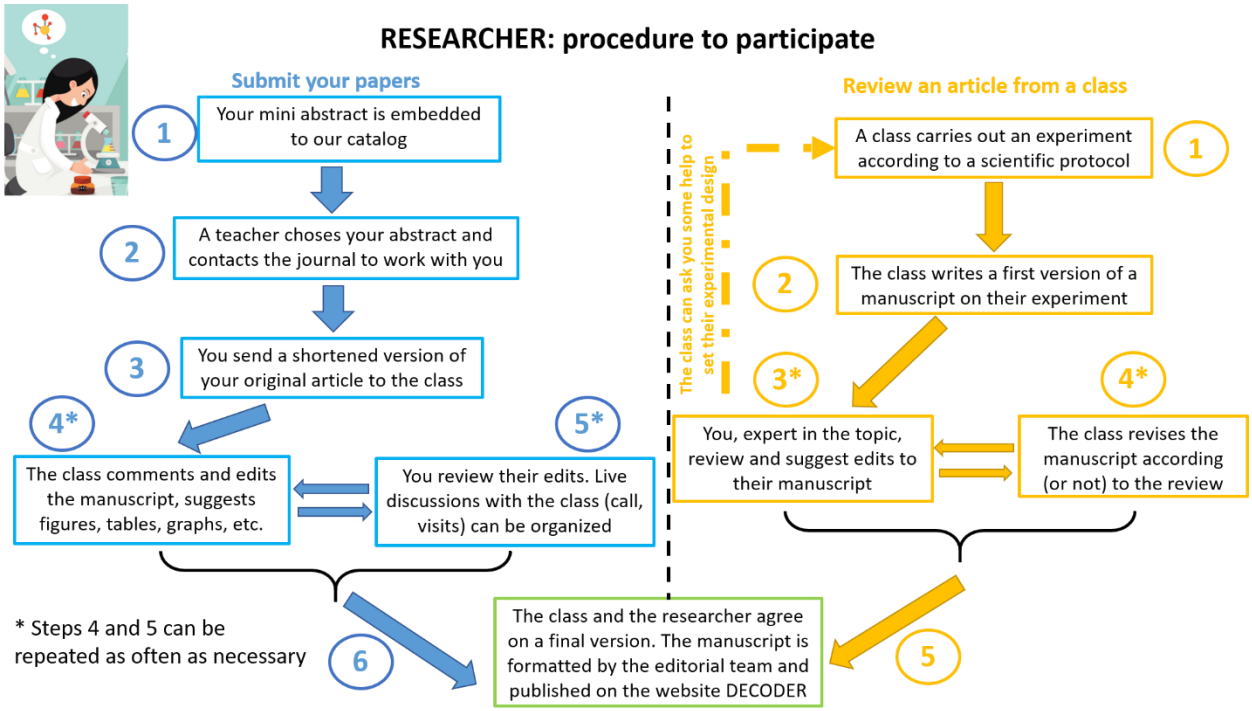

Figure 1. Schematic view of the participation process for a researcher getting involved in DECODER.

Regarding the second option, the process starts with a class desiring to learn more about a topic, via the set-up of an experiment and the writing of the scientific results obtained in the form of an outreach academic paper (Figure 1, step 1 in yellow).

The editorial team finds a researcher, who is willing to assist the class with their tasks throughout the year and puts them in contact with the teacher.

In terms of organization and virtual or real meeting, the process is the same as for the first option.

The class then sets up their experiment and can ask the researcher for assistance. Once their results are obtained and their paper is written, they send it to the researcher, who reviews it, proposing changes in the manuscript and even new experimentations if practical (Figure 1, step 2 to 4 in yellow). Once both parties agree on a final version, like for the first option, this article will be uploaded and accessible for free on our website (Figure 1, step 5 in yellow).

B. Targeted audience

The audience we target with the journal DECODER is the new generation, people who are currently developing their mind and going to school.

Indeed, if they are not trained to use their critical thinking, they will be the first victims of fake news and conspiracy theories. Indeed, as Petersen et al. (2019)[5] showed, the media visibility of contrarians is wider than the one of expert scientists in climate change, thus being able to distinguish real scientific information from opinions is fundamental.

Moreover, the youth feels concerned about big societal changes, such as the current climate crisis, as recent demonstrations have shown[17] and it is our duty to give it the tools needed to better apprehend the world it lives in. Additionally, children can be the prime movers of changes in their parents' behavior, on the climate crisis matter for example[18].

It is of prime importance to show the young generation that knowledge is something that is slowly built, with trials and errors[19], changes of paradigm, collaborative work[20], that it requires confrontations of theories and experimental data, rather than an information that is shared millions of times on social media[21].

For this purpose, an approach following popular education, i.e. experimenting, testing, and repeating[22] is key to develop scientific methodology and critical thinking[23]. These are the underlying principles of citizen science, which enables to actively involve the general public into real research projects (for example: the projects Growing Beyond Earth, in partnership with NASA, and Astroplant in partnership with ESA, are targeted towards citizen science in the classroom).

Therefore, the results of the shorten academic article that the students study within DECODER could almost be seen as a pretext: the way to build or recognize a scientific argument, which needs to meet all of the six properties listed in Figure 2, as opposed to an ideology or a belief, is the key point in our approach[24, 25]. During their collaboration with the researcher, students must question themselves and the researcher, to check if the article content still meet these requirements despite the outreach efforts.

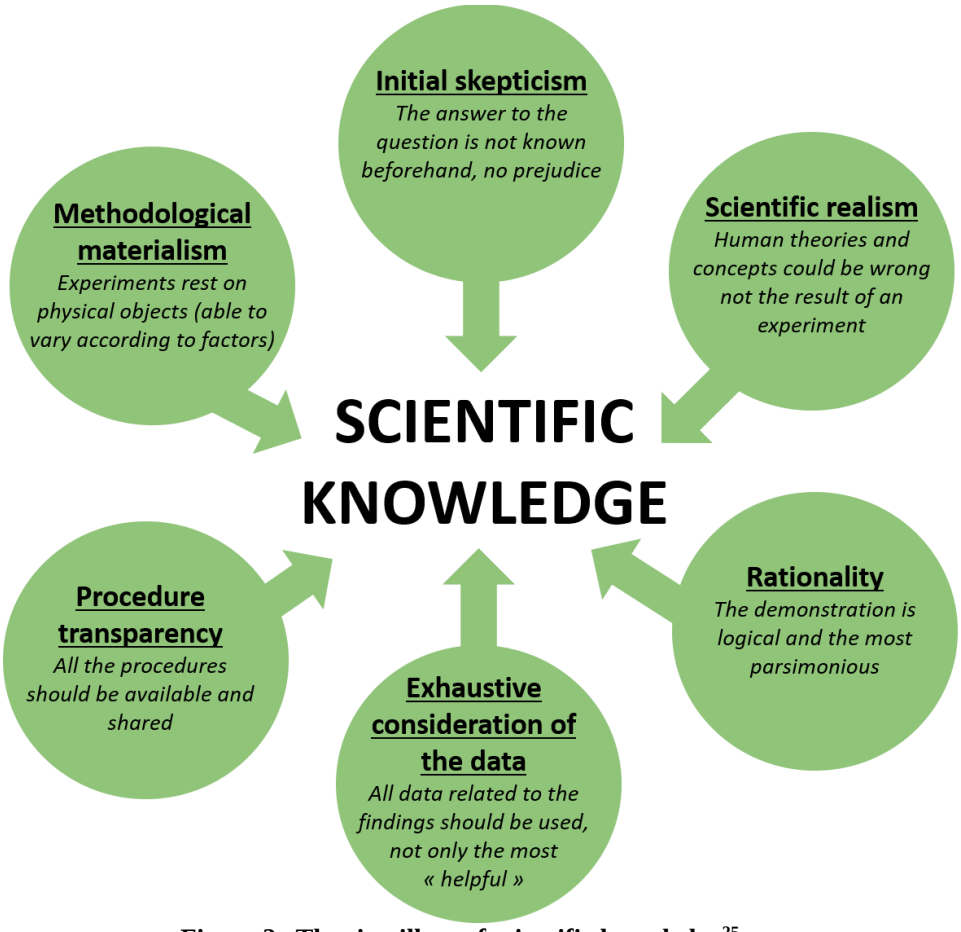

Figure 2. The six pillars of scientific knowledge[25].

III. DECODER: demographics and lessons learned

A. Demographics

DECODER was first launched in January 2019. Since then, four outreach articles were published on our website and seven are currently being worked, involving a total of twelve classes, in seven different primary, junior high and high schools (see Figure 3). We are present on two continents and five countries (Figure 4), with schools being currently exclusively located in France, but our researchers are based in many different countries. Their experience ranges from PhD student to university professor and the disciplines they work in are very diverse, from humanities to engineering, law, and fundamental and life sciences (Figure 5). Fifteen researchers have already trusted us, and 19 articles are in our online catalogue, waiting for a class to pick them.

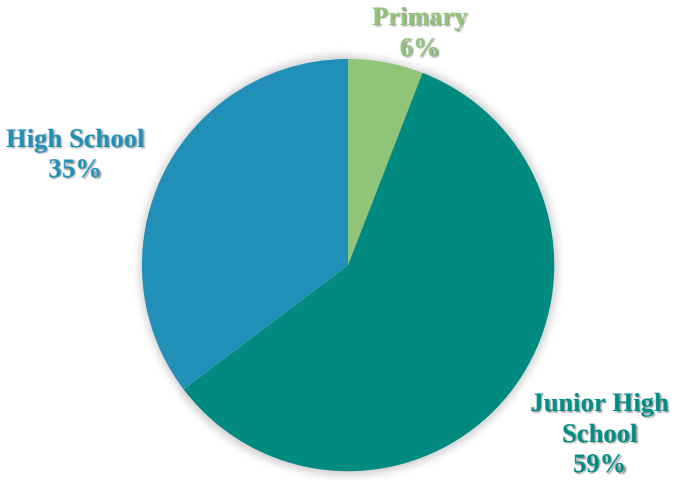

Figure 3. Study levels within DECODER.

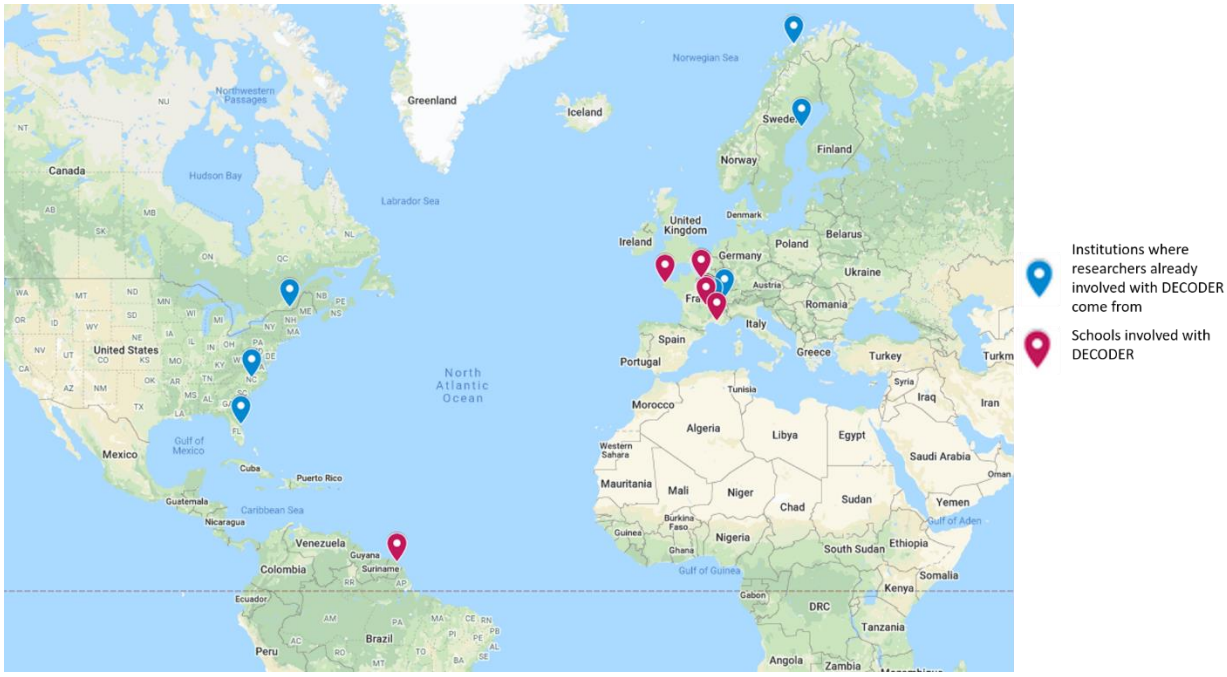

Figure 4. Schools and Institutions involved with DECODER.

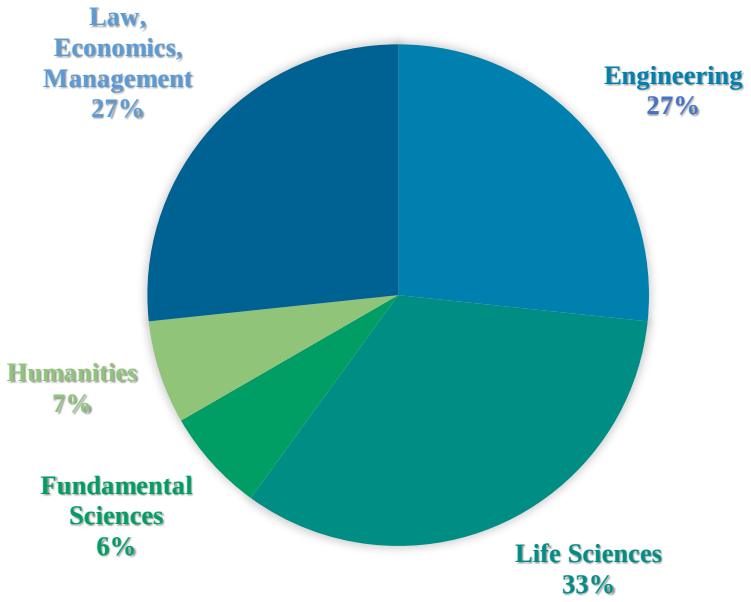

Figure 5. Discipline representation within DECODER.

B. Lessons learned

In this section, we would like to share takeaways from this project, regarding the teachers and the researchers we have worked with.

First off, we would like to emphasize the fact that the project success in the classroom is the result of highly motivated teachers, which is not always easy, given their work overload. Here are our lessons learned from our interactions with them:

- Most of the teachers we contacted are very eager to participate in this project and get strongly involved, going sometimes further than initially discussed.
- There is a huge demand from the teachers for this type of projects where research and (junior) high school students work together. This might be a sign perhaps that critical thinking teaching is lacking in the current education programs?
- Collaboration between multiple teachers is highly encouraged, as it has already been done in several classes. This way, students experience first-hand that writing a research paper is a transdisciplinary work and involves not only mastering your research topic, but also mastering the language you write in and being able to organize your thoughts and summarize them in an intelligible way. For French teachers, it is a great opportunity to work on a different kind of text, i.e. not literature. It also points out the importance (for French students) of mastering the English language, since most scientific literature is written in English.
- Not every teacher is familiar with the review process and research in general, it is thus important to give them a good overview of what they are, so that they do not expect the researcher to do most of the work: the revised paper really is a joint effort between the researcher, who provides a shortened research article and feedback to the class, and the class, who actively revises and edits it.

Finally, contacting other researchers and interaction with them led to the following takeaways:

- Many researchers we have contacted agreed to participate in the journal and liked the concept a lot, which suggests to us that this is a timely and relevant concept.
- Researchers have a tendency, when they shorten their article, to simplify it too much and to do the outreach work already. It is important that they refrain from doing so, so that students can be confronted to a somewhat complex version and so that they can build their own outreach version.

IV. Conclusion and perspectives

Our role as researchers is to share our scientific results with the widest audience, to make sure citizens have the tools to understand their surrounding world and make informed choices. With the growing impact of fake news and conspiracy theories in the mainstream media and social media, it is also crucial that students from an early age develop and sharpen their critical thinking and be acquainted with research practices and the scientific method.

We have presented here a journal that enables to do both: sharing scientific results, while involving students from an early age into research through frequent interactions with researchers. The organization needed within the classroom for the journal DECODER is very liberal so that it can fit in any program and researcher's calendar. After over a year of existence, the journal has already involved twelve classes and fifteen researchers (plus five researchers of the editorial board who submitted their paper as well) and has been very well received from the teachers' part, as well as from the researchers'' part.

In the future, we are planning to enroll researchers from an even more diverse range of disciplines, especially in fundamental sciences and humanities.

We would like to reach out to more classes and schools within France and have an involvement in most French regions. Then, we will reach out to other countries than France, perhaps starting with French speaking countries that are borderer from France, and then extend to the rest of Europe.

Our main targets now are students in junior high and high schools, but we also have one on-going paper in a primary school and we are currently discussing a project with an undergraduate program. So, we could be expanding to more levels soon.

Finally, DECODER could develop into more than just articles reviewing and writing about classroom experiments. We seeking to develop partnerships with classes to make science outreach videos in lieu of an outreach article. We are planning to organize live conferences with students, where they could present their project and listen to scientists explain theirs. Our ambition in the long-term would be to build collaborative citizen science projects targeted towards students.

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