Ark of Inquiry: Inquiry Awards for Youth over Europe

Deliverable 7.6

Recommendations and Guidelines

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Editor: Lauren Bohatka (UNESCO)

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The Ark of Inquiry Consortium

1. TARTU ÜLIKOOL, Estonia (UT)
2. ELLINOGERMANIKI AGOGI SCHOLI PANAGEA SAVVA AE, Greece (EA)
3. TURUN YLIOPISTO, Finland (UTU)
4. UNIVERSITY OF CYPRUS, Cyprus (UCY)
5. UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION (UNESCO) REGIONAL BUREAU FOR SCIENCE AND CULTURE IN EUROPE, VENICE, Italy (UNESCO)
6. STICHTING HOGESCHOOL VAN ARNHEM ENNIJMEGEN HAN, The Netherlands (HAN)
7. BUNDESMINISTERIUM FÜR BILDUNG, Austria (BMB)
8. HUMBOLDT-UNIVERSITÄT ZU BERLIN, Germany (UBER)
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10. L'ECOLE DE L'ADN ASSOCIATION, France (EADN)
11. UNIVERSITY COLLEGES LEUVEN-LIMBURG (previously KATHOLIEKE HOGESCHOOL LIMBURG VZW), Belgium (UCLL)
12. KUTATO TANAROK ORSZAGOS SZOVETSEGE, Hungary (HRTA)
13. SIHTASUTUS TEADUSKESKUS AHHAA, Estonia (AHHAA)

Lead contributors

Lauren Bohatka, UNESCO

Emanuele Bardone, UT

Meelis Brikker, UT

Additional contributors

Margus Pedaste, UT

Tomi Jaakkola, Jiri Lallimo, UTU

Aliki Giannakopoulou, EA

Annelies Dickhout, Bregje de Vries, HAN

Monika Moises, BMB

Philippe Pypaert, UNESCO

Bulent Cavas, BEKAS

Szilvia Tóth, Mónika Réti, HRTA

Erica Andreotti, UCLL

Christian Siatka, EADN

Amany Annaggar, UBER

Marios Papaevripidou, Maria Irakleous, Zacharias Zacharia, UCY

Pille Randjärv, AHHAA

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Firstly, a great thanks goes out to all of the 13 partner institutions of the Ark of Inquiry project – all partners drafted inputs, offered comments and reviews, and otherwise contributed their time and efforts to ensuring that this document accurately and faithfully reflects the findings and results of the Ark of Inquiry project to the best of our combined abilities.

A special mention is made for contributor Meelis Brikker, who is responsible for the drawings present in this document.

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Lastly, we thank all of the teachers, educators, researchers, pupils and others who participated in the Ark of Inquiry project and through which provided the evidence upon which the findings contained herein are based. Keep up the good work!

Legal Notice

List of Acronyms

D7.6	Deliverable 7.6
DoW	Description of Work
EC	European Commission
ECSITE	European Network of Science Centres and Museums
ESEA	European Science Education Academy
ESERA	European Science Education Research Association
EU	European Union
FP7	Seventh Framework Programme for Research and Technological Development
HQ	Headquarters
IBL	Inquiry-Based Learning
IBSE	Inquiry-Based Science Education
IL	Inquiry Learning
ILS	Inquiry Learning Space
MINT	Mathematics, Informatics, Natural Science, Technology
PD	Professional Development
ReSciTEG	Research Group on Science Education and Technology, University of Cyprus
RRI	Responsible Research and Innovation
SCN	Science Centre Network
STEM	Science, Technology, Engineering, and Mathematics
WP	Work Package

Foreword

Dear Reader,

As the coordinator of the Ark of Inquiry project it is my pleasure to introduce you to the work my colleagues and I have done during the last four years.

As we began this journey, our main intent was to give our little contribution to one of the biggest challenges of our time in education, which is the promotion of scientific literacy. This is a task particularly relevant at the present time when the interest of young people in science has been declining, while the impact of science and technology has dramatically increased.

Ark of Inquiry focused on teachers. It goes without saying that teachers play a fundamental role in promoting scientific literacy and our little contribution precisely lied in supporting them with three main key elements.

The first can be considered as a toolkit helping teachers to use inquiry learning for engaging students and teaching science. The toolkit includes, for example, an inquiry model to structure classroom activities, formative evaluation instruments to fully exploit learning potential and, pedagogical scenarios to involve teachers as co-designers of learning activities.

The second element is not about tools, but people. Throughout the whole project, we have tried to make sure that we could provide the kind of human support that teachers needed. This translated into organizing training courses that would help teachers experience inquiry learning themselves and that would bring them together in order to promote the sense of conviviality and community that professionals are so much in need at any stage of development. In the pages of this document, you will find the main lessons that we have derived from our experience.

The third and last element is about ideas. Ark of Inquiry was built around the idea of inquiry learning, which has been deployed as the main theoretical framework for supporting teachers in promoting scientific literacy in school. During the project, we have also introduced teachers to the idea of Responsible Research and Innovation (RRI). This emerging theoretical framework is widely implemented in European Commission's research and development policy and could also improve interest in science education amongst girls and boys alike. Responsible Research and Innovation contributes to making sense of scientific progress and technological development not as an end in itself but in the broader context of societal needs and aspirations.

When a project is drawing to a close, the question is always the same: what to do next? The promotion of science in society is not the kind of problem that we can say is solved once and for all. Conversely, it requires constant attention and care from all parties concerned: researchers, teachers, educators, parents, and policy-makers. In a way the Ark of Inquiry represents our greatest auspice that the good things that we do and find during our journey can be preserved that will constitute new seeds to plant. We hope that you find the ideas and recommendations contained within this document useful on your own educational journey in life.

Margus Pedaste
Ark of Inquiry Project Coordinator

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Introduction

This Recommendation and Guidelines Document serves as Deliverable 7.6 (D7.6) for the project Ark of Inquiry: Inquiry Awards for Youth over Europe. This "final" deliverable of the 33 required deliverables of the project aims to "summarize the experience gained in the project and how to further exploit its outcomes."[1] It presents information of interest to different stakeholder groups on how to apply the findings from Ark of Inquiry beyond the project and provides a quantitative and qualitative showcase of the best practices and related success stories that were achieved throughout the project. Lastly, it serves to offer ideas and suggestions for designing and running analogous projects in the future.

The document itself is structured around a question that the Ark of Inquiry project attempted to answer as one of its main objectives: How to foster successful inquiry learning in the science classroom? The Ark of Inquiry project proposed, at its core, that the use of an inquiry model when undertaking scientific learning activities in the classroom would be the most effective path to success. However, that was not all that the project discovered would be useful for teachers in the science classroom. The Ark of Inquiry project has grouped its findings into three key messages, which are each in turn reinforced by a set of supportive statements or "rationales" that further elaborate upon the key message and offer a best practice, success story or other illustration of the point in question. Following the description of evidence for that rationale are recommendations for the relevant target audiences.

The intended audiences for this deliverable are a small variation on the target audiences identified for dissemination[2] and are denoted in the box to the right. While the recommendations and guidelines are written for European audiences, being a European project, the project team feels that they have a more global application and hopes that audiences from other parts of the world will find its contents equally relevant and adaptable to their local contexts as well. In annex to this Document is a tailored set of guidelines for each particular audience that summarizes what that particular target group can do with the information provided herein.

Target Audiences for D7.6:

- ✓ Teachers of Science and Science Teacher Societies
- ✓ National Educational Authorities and Policy-makers
- ✓ Teacher Educators
- ✓ Scientists and Researchers
- ✓ Science Centres and Museums
- ✓ Parents
- ✓ Pupils

The document then concludes with some general observations about next steps for the project partners, its various stakeholder groups, and a note about the sustainability of its products and findings.

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What is the Ark of Inquiry?

The project Ark of Inquiry: Inquiry Awards for Youth across Europe is a research and development project funded under the EU's Seventh Framework Programme for Research and Technological Development (FP7). Coordinated by the University of Tartu (Estonia), thirteen partners from twelve countries aspired to attract more young people, between the ages of 7 and 18, to the STEM subjects (science, technology, engineering and mathematics) through the application of Responsible Research and Innovation (RRI) and Inquiry-Based Science Education (IBSE).

Project Targets:

- ✓ 23,000 pupils
- ✓ 1,100 teachers
- ✓ 100 science and teacher education students
- ✓ 50 researchers/scientists and staff from science centres & museums

Throughout its activities, the Ark of Inquiry project has mainstreamed RRI into real-life educational activities and has demonstrated this approach in both formal and informal learning environments. By doing so, the project has built capacity of youth to tackle societal challenges in the long run through empowering teachers to create conducive learning environments that foster mutual learning and equal participation of both genders in the STEM subjects.

In order to achieve this ambitious goal, the Ark of Inquiry project has endeavoured to provide comprehensive and detailed training to over 1,100 teachers of STEM subjects on using the principles of RRI through inquiry learning methods. Here, authentic, challenging and higher-order learning experiences using tools and techniques, advocated by the project, facilitated the creation of a "new science classroom"; wherein pupils are encouraged to reflect, think critically, discuss and participate in scientific discourse and the inquiry process, i.e. scientific thinking. In addition to the teacher trainings, learner and teacher communities had access to an online portal comprised of over 500 (to-date) carefully selected inquiry activities, in at least the twelve partner languages. These activities could easily be customised and deployed in order to address diverse learning needs in and out of classroom settings. In keeping with the principles of open science, the portal is an open environment wherein inquiry and RRI-related activities are accessible to all stakeholders of science education.

The Ark of Inquiry and UN SDGs

The Ark of Inquiry project has also committed itself to the United Nation's Sustainable Development Goals, formulated in 2015 as a call to action on the many challenges facing the planet. Through the project's products, actions and inquiry activities, the following SDGs were impacted directly:

The project's inquiry model and pedagogical scenarios empower teachers to tailor their science lessons to ensure more authentic, challenging and relevant learning experiences for all.

Using relatable examples (such as role models), collaboration, reflection and dialogue, particularly encapsulated in the orientation and discussion phases of the project's inquiry model, results in making science more relatable and accessible for all genders.

The incorporation of RRI in learning environments drives economic development, employment and social stability later on through the proliferation of scientific research and innovation.

Indirectly, the project's inquiry activities themselves enable teachers to empower a new generation of scientific thinkers capable of driving innovative technology to ensure clean water and sanitation (goal 6), affordable and clean energy (goal 7), sustainable cities and communities (goal 11), climate action (goal 13), life below water (goal 14) and life on land (goal 15).

Overview of the project activities

Project activities were grouped under 8 diverse yet interrelated work packages (WP) as follows:

WP1 - Pedagogical Framework: The project developed support mechanisms to engage pupils in inquiry activities, stimulate wider views on research, support pupils in starting and completing the envisaged activities on time, and motivate them to take up challenges set by the Inquiry Awards system.

WP2 - Collection of inquiry activities and environments: In order to build a scientifically literate and responsible society through inquiry-based science education, the Ark of Inquiry portal has to-date assimilated over 500 inquiry activities in 13 languages encompassing the STEM subjects in three different difficulty levels. To support teachers evaluate, implement, adapt and reuse inquiry activities in their classrooms, the project has also devised six Pedagogical Scenarios. Available online in all partner languages, they provide teachers with the tools and ideas to address their pupils' diverse learning needs.

1. Introduction to the concept of inquiry learning and the Ark of Inquiry learning model
2. Promoting awareness of Responsible Research and Innovation (RRI)
3. Empowering girls in science
4. Adjusting the inquiry proficiency level
5. Adding or improving inquiry phases
6. Overcoming language and sociocultural barriers

WP3 - Supporting community: A supportive community of teachers was built and sustained chiefly through face-to-face teacher training. By providing skills, tools, collaboration and access to expertise, teachers were empowered to create classroom environments conducive to scientific thinking. Further, the project tried at a national levels to bring together researchers and staff of science centres and museums and to promote activities that would encourage the connection of pupils either with researchers or with informal learning organisations.

WP4 - Training: Teacher training sessions were provided for pre-service and in-service teachers and teacher educators to better support pupil engagement in and out of the classroom. This guidance allowed teachers to be positioned first as learners, then as thinkers and finally, as reflective practitioners, allowing teachers to experience inquiry learning first hand before incorporating it in their lesson plans.

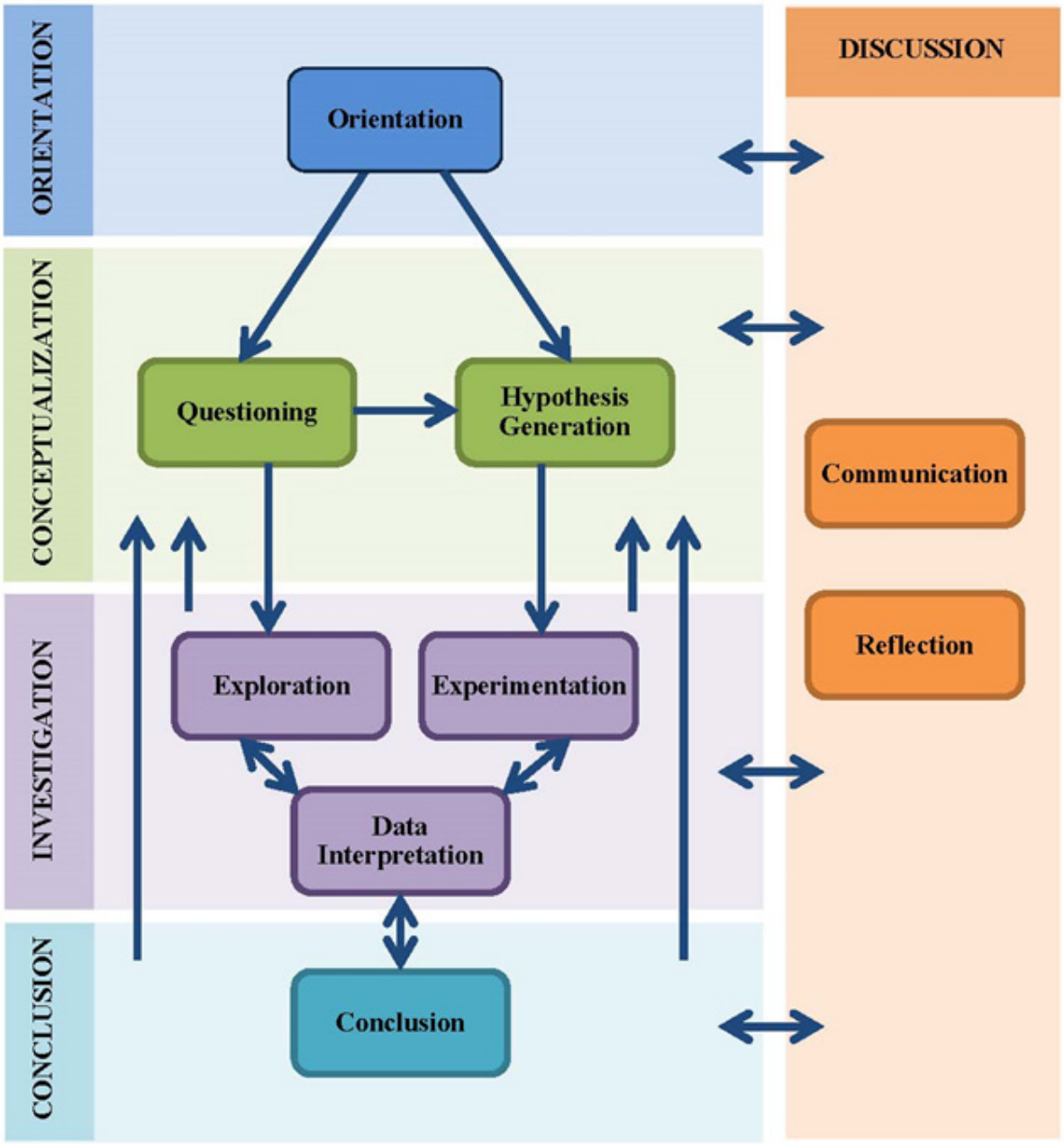
WP5 - Evaluation: In order to assess the impact of the project's activities, six studies were undertaken – with two studies at the European level and four studies in a single partner country. These studies used data from evaluations pertaining to the relevance and functionality of the project's tools, like the evaluation and award system, the repository of inquiry activities and the pedagogical scenarios. Additionally, another evaluation pertaining to the potential effectivity of the Ark of Inquiry to promote and sustain inquiry learning and awareness of Responsible Research and Innovation in the classroom as experienced by teachers were obtained.

WP6 - Implementation: Implementation of the project was carried out in two phases. The pilot phase, which lasted for six months from approximately September 2015 – February 2016, targeted pre-service and in-service primary and secondary science teachers from 7 countries. The large-scale implementation phase, with a duration of 2 years, is still ongoing at the time of this report and will end in February 2018. During the implementation phase, teachers are encouraged to use the activities and tools in the portal, applying lessons learned in trainings, and report back to the project on the success of these activities, both in and out of the classroom.

WP7 - Dissemination: The project is committed to disseminating its outcomes through internal and external channels. Internal dissemination, through the development/use of communication tools and templates, the facilitation of regular and ad-hoc meetings and undertaking regular reports, aims to effectively coordinate the flow of information between partners. External dissemination, through its website and social media, collaboration with other EU projects, academic and non-academic publications and events, aimed to share key messages, objectives and results of the project to all external stakeholders.

WP8 - Project management: Undertaken by the lead partner at University of Tartu, this work package set standards for the quality of project deliverables across all work packages, along with effective internal and external communication of the same.

Pedaste et al (2015) Inquiry Model[3]



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Rethinking science teaching via inquiry learning

From its inception, the research and innovation policy of the European Union has recognised the roles science and industrial fields play in tackling Grand Societal Challenges[4] such as climate change, health, energy, food security, green transportation, and inclusion. In order to be able to confront these societal challenges in the long term, a talented pool of young individuals with the technical expertise and knowledge must be created. Research, however, indicates an alarming decline of interest in the sciences by today's European youth, due, in part, to traditional science teaching being characterised by conventional lectures and memorizing facts. Current science teaching is not consistently triggering the excitement of discovery that is typical of scientific advancement. The challenge, therefore, is to reconfigure science pedagogy to make it relevant and accessible for all in the 21st century. This requires a pan-European collaboration that promotes research and innovation practices and processes at the school level to the extent of making science relatable.

Inquiry-based learning (IBL), or synonymously, inquiry learning (IL), is a pedagogical approach that starts by posing questions, problems or scenarios - rather than simply presenting established facts or portraying a smooth path to knowledge - from which the learner is then facilitated towards discovering the answer independently through scientific inquiry. The Ark of Inquiry project defines inquiry-based learning as "one of learning to do science"[5]. By learning through experiencing science and discovery, knowledge is more readily absorbed and retained by the learner. This new form of teaching moves away from rote learning and thus, enables a dialogue to form between teacher and pupil that in turn leads to enhancing learning potential.

Teachers trained in inquiry-based learning are thus key to enhancing this learning potential within pupils. For starters, there is a necessity to create opportunities within the classroom to practice inquiry learning. A conducive classroom environment also requires teachers to guide or facilitate the practice, discussion and dialogue of their pupils' scientific inquiry learning so that pupils may employ these inquiry tactics independently and in non-formal learning environments.

Pedaste's et al (2015) Inquiry Model

Inquiry-based learning facilitates authentic scientific inquiry by breaking this complex scientific process into smaller, logically connected units which cultivate scientific thinking. These units are referred to inquiry phases and their connections form an inquiry cycle. Although a "cycle" implies a suggested order of events, it is not a prescribed linear process.

The inquiry model used as the theoretical framework in the project[6] was synthesised from an academic review of 32 articles that employed 34 inquiry phases which were then reorganised into 11 phases. These 11 inquiry phases were further merged into five main inquiry phases within the project's inquiry model – orientation, conceptualisation, investigation, conclusion and discussion (see facing page for illustration). The target audiences for the use of this model are educators and others in the field of science education.

Briefly, in the orientation phase, curiosity about a topic is stimulated by posing questions or challenges in the form of a "problem statement". Generating research questions or formulating hypotheses pertaining to the problem statement is the crux of the conceptualisation phase. The investigation phase involves the processes of planning and conducting an experiment or research to test the hypotheses stated in the earlier conceptualisation phase. Here, pupils explore, experiment and collect, analyse and interpret data to test a hypothesis. Drawing inferences and conclusions from the data gathered is the focus of the conclusion phase. The inquiry cycle is not complete until the findings are presented and communicated.

Scientific discourse is fostered when the processes of reflection and communication are used throughout the inquiry cycle; this is encapsulated in the discussion phase, which can take place both at the end of the cycle but also permeates the other four phases of the model, too.

Key Messages from Ark of Inquiry

Throughout its four years of activity, the Ark of Inquiry project has found that via inquiry-based learning science teaching can be improved when teachers are provided with the "right" tools, supportive community and ideas. Thus, the three key messages that resulted from the project are:

Key message 1: The right tools can better enable teachers to utilize inquiry-based learning with their pupils.

The right tools, identified by the project, refer to the inquiry model which acts as a roadmap; the project's evaluation instruments and award systems which motivates, challenges and invests both teachers and pupils in the inquiry learning process; the repository of inquiry activities in a variety of languages; and, the pedagogical scenarios that allow educators to contextualise their lessons.

Key message 2: A supportive community can provide teachers with the training and resources needed to successfully use inquiry learning in the classroom.

Supportive communities allow teachers to experience autonomy and empowerment in their classroom endeavours by way of collaboration between various actors (parents, peers, teachers, researchers, etc.) and training provides the knowhow to design and implement their own inquiry activities in the classroom.

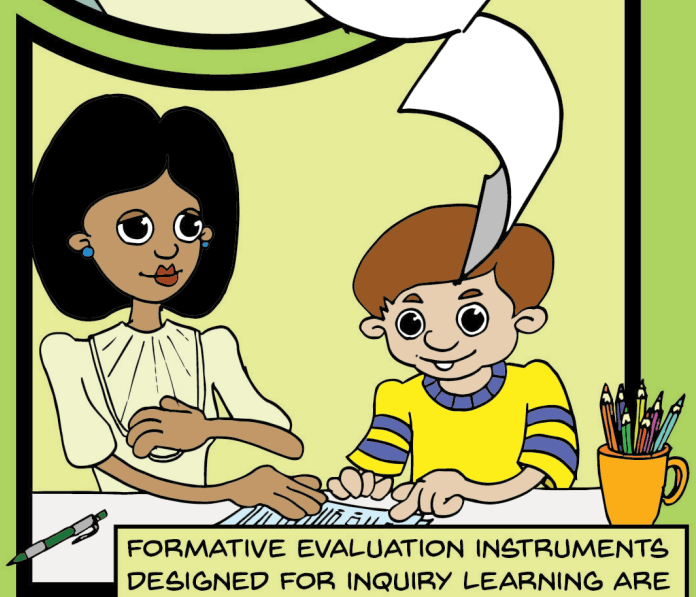
Key message 3: Concepts like Responsible Research and Innovation (RRI) are effective in enriching the inquiry learning process.

The six key RRI-related issues highlighted by the European Commission can be tackled by collaborative action between various segments of society. In this regard, the Ark of Inquiry project has strived to address this need by way of encouraging pupils to take ownership of one's own inquiry learning process; promoting scientific thinking in and out of the classroom; authentic learning experiences connected to big-picture global challenges and ethical dilemmas; and equal participation of the genders in inquiry activities.

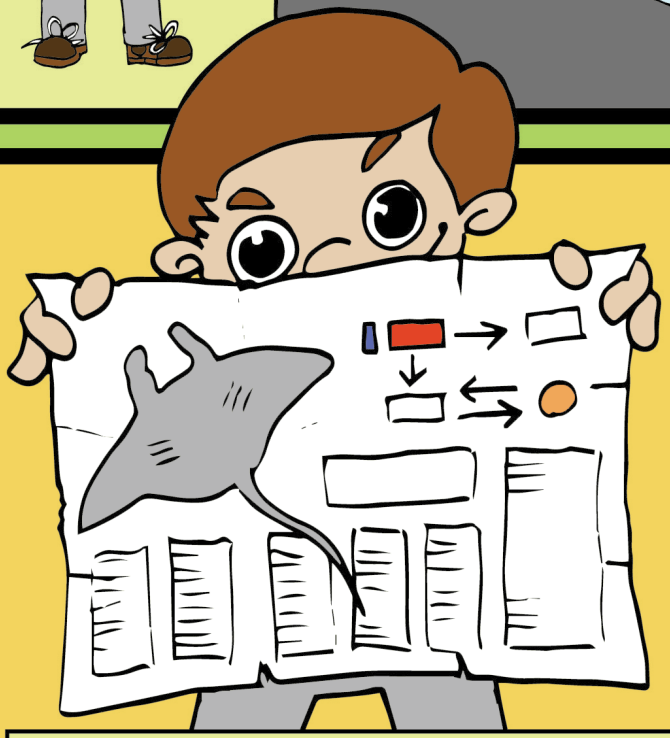
FOLLOWING AN INQUIRY MODEL HELPS TEACHERS STRUCTURE CLASSROOM ACTIVITIES, WHILE LEAVING ROOM FOR FLEXIBILITY WHEN NEEDED.

PEDAGOGICAL SCENARIOS HELP TEACHERS MAINTAIN AN ACTIVE ROLE AS DESIGNERS OF INQUIRY LEARNING ACTIVITIES.

USING BOTH FORMAL AND INFORMAL LEARNING ENVIRONMENTS HELPS PROMOTE INQUIRY LEARNING AND RRI.



FORMATIVE EVALUATION INSTRUMENTS DESIGNED FOR INQUIRY LEARNING ARE NECESSARY TOOLS FOR TEACHERS TO FULLY EXPLOIT LEARNING POTENTIAL IN THE CLASSROOM.



THE USE OF AN AWARDS SYSTEM IS MOTIVATING FOR TEACHERS AND PUPILS ALIKE AND WORKS BEST WHEN INTEGRATED INTO EXISTING CONTESTS AND COMMUNITIES.

3

Key message number 1: The right tools can better enable teachers to utilize inquiry learning with their pupils

Teachers have a huge responsibility in equipping the next generation with the necessary skills and knowledge to combat life's challenges, such as the ones identified by the EU's Grand Societal Challenges and the UN Sustainable Development Goals. This is no easy task especially because these necessary skills would not only need to be relevant in the modern age but would also continue to be relevant in the future. Traditional pedagogical methods, particularly in the STEM subjects, do little to inspire pioneering solutions from the next generation. Thus, to be able to tackle this head-on, teachers need to strive relentlessly to be abreast of new and innovative pedagogical strategies and subject knowledge. Recognising this impetus, instead of developing a "one-size fits all" solution, the Ark of Inquiry project has looked towards empowering teachers as experts of their classroom requirements by providing tools and techniques that allow teachers to identify learning needs in classes, design and tailor content to address these diverse learning needs and encourage participation in the classroom. The 'right' tools go a long way in promoting this sense of empowerment for teachers and in turn with their pupils.

To help teachers achieve this ambitious goal, the Ark of Inquiry project identified several strategies that have yielded promising results:

✓ Following an inquiry model helps teachers structure classroom activities, while leaving room for flexibility as needed;

✓ Using both formal and informal learning environments helps promote Inquiry learning and RRI;

✓ Involving pupils in evaluation of inquiry activities better engages them in the inquiry learning process;

✓ Pedagogical scenarios help teachers maintain an active role as designers of inquiry learning activities;

✓ The use of an awards system is motivating for teachers and pupils alike and works best when integrated into existing contests and communities;

✓ Inquiry activities engage pupils while promoting learning of 21st century skills.

Rationale 1.1: Following an inquiry model helps teachers structure classroom activities, while leaving room for flexibility when needed

Research has repeatedly shown that balancing structure and freedom in an inquiry-based learning environment is necessary to effectively reach learning goals. Often, teachers implement inquiry-based learning with too little structure and as a result, teachers find it challenging to guide their pupils. Following an inquiry model that divides the process of inquiry into phases helps both teachers and pupils to structure classroom activities and focus on learning goals.

For the Ark of Inquiry project, it was essential from the beginning to understand what inquiry-based learning is, why it is pedagogically effective and how inquiry skills and experiences are advanced through specific inquiry activities. As such the project rigorously reviewed over 100 different terms found in contemporary educational literature describing inquiry processes to act as a basis for developing an inquiry model that is easy to use by teachers for structuring classroom activities and also makes evaluating pupils' inquiry proficiency more approachable.

Teachers' feedback gathered during the teacher trainings, conducted in all 12 partner countries, suggests that the inquiry model developed supports inquiry-based learning by offering a systematic approach to the preparation and implementation of inquiry activities – the five inquiry phases contain nothing new or surprising for the teachers, but rather offer a way to break down an inquiry activity to its basic components, ensuring the equal development of different inquiry skills of the pupils.

Specifically, observations and interviews collected from teachers from primary schools in the Netherlands shows that explicit use of the five-phase model helps teachers to feel more confident about designing and implementing inquiry-based learning in the first place. Furthermore, the data show that teachers successfully used the five-phase model of inquiry learning to analyse and adapt existing inquiry activities according to their own needs. For instance, using the model helped teachers to redesign lessons so that they focused on specific inquiry phases or skills. Finally, using the model helped both teachers and pupils to evaluate inquiry proficiency and create metacognitive awareness of what it means to do inquiry. This paved the way to focus on different inquiry phases and skills with different (groups of) pupils, according to their individual needs.

✓ **Teachers** are encouraged to take advantage of the inquiry-based learning framework developed in the Ark of Inquiry project and (re)design their inquiry activities accordingly. Furthermore, they are encouraged to share the model of inquiry with their pupils to raise metacognitive awareness and use the framework for inquiry proficiency for evaluating pupils' progress.

✓ **Teacher educators** can use the project's inquiry model to help future and current teachers design inquiry-based learning activities that have both explicit structure as well as the freedom to be adapted.

✓ **National Educational Authorities and Policy-makers** are invited to recognize the potential of inquiry-based education when structure is balanced with freedom, and can lobby for school curricula and educational resources that enable such structured freedom.

✓ **Science centres and museums** can support teachers and educational authorities by following a similar design – the use of inquiry phases – in their science activities, and by putting even more emphasis on the topics of Responsible Research and Innovation.

Ark of Inquiry Teacher Perspective (Estonia)

"The most useful feature of the [Ark of Inquiry] training was the notion of thinking further than just conducting an experiment, dividing the inquiry process into five phases has helped me to plan my work better and it gave me the confidence to adapt the lesson on the go."

Rationale 1.2: Using both formal and informal learning environments helps promote Inquiry learning and RRI

During the teacher trainings, the project observed that teachers in many countries view the lack of attractive instructional materials and equipment within the school setting as one of the main reasons for not utilizing inquiry learning techniques as much as they would like to. When these trainings were conducted in informal learning environments, such as science centres, the exhibitions and equipment available helped to spark teachers´ creativity and allowed them to expand their initial ideas for inquiry activities to include different RRI-related topics. In Estonia, the results of previous collaboration with informal learning environments became evident during the final training sessions of all three groups of teachers, where they introduced their progress in constructing and implementing a new inquiry activity. The teachers who had previously collaborated with staff from various science centres and museums had more ways of explaining the connection between the inquiry activity and real-life situations in the orientation phase and were more comfortable with introducing RRI-related ideas during the discussion phases. Thus, when coupled together, formal and informal learning environments complement each other to further promote inquiry learning and RRI.

✓ **Teachers** are encouraged to design their lesson plans in a way that allows them to take their students out of the formal classroom setting to an informal learning environment, such as a science centre or a museum in order to enable the students to use different sets of skills for completing tasks and collaborating with peers and professionals.

✓ **National educational authorities** can collaborate with teachers as well as with educational policy-makers to develop educational resources and curricula implementation opportunities that make use of the best practices of both the informal as well as of the formal learning environments and support the collaboration between formal and informal learning environments for a more comprehensive take on education.

✓ **Science centres and museums** can continue to communicate to teachers and parties involved in shaping educational policies the opportunities for enhancing pupils' learning outcomes on their premises and have staff dedicated to making this link between formal and informal learning environments.

✓ **Scientists/researchers** can help by working closely with both formal and informal education institutions and sharing their expertise via this and other science communication channels.

✓ **Parents** can considering bringing their children to science centres and museums and recognize the advantages of supplementing formal learning environments with informal ones and support initiatives that bring the two together.

Ark of Inquiry Best Practice (Greece)

Ellinogermaniki Agogi, in collaboration with the National Observatory of Athens, organised a contest competition for secondary schools around Greece under the theme 'Make your own seismograph' (http://seismografos.ea.gr/). School teams were challenged to follow the Ark of Inquiry model and study, design and build their own seismograph. 25 school teams of about 150 students and 39 teachers eventually participated in the national contest of 2017. The activity enabled the students to take the role of researchers and scientists, and to bring up issues related to ethics, public engagement, use of data and other principles of responsible research and innovation. The project gave the opportunity to the participating students to meet and exchange with real scientists inside and outside the school walls providing a more realistic image of the world of research. The winners from across Greece gathered for a day in the National Observatory of Athens in order to present and discuss their projects. The collaboration with the National Observatory allowed the students to present their work in an informal environment and bring together besides the school communities, parents, researchers and policy-makers. Among the schools that won were a special school for the Speech and Hearing Impaired, vocational technical schools, as well as music and intercultural schools.

Rationale 1.3: Involving pupils in evaluation of inquiry activities better engages them in the inquiry learning process

In general, summative assessment of any learning content by testing pupils provides teachers and pupils information on if and what (most) pupils have learned. To a lesser extent, summative evaluation provides information about what steps to take next in order to take pupils further. If pupils are actively involved in evaluating themselves formatively by collecting feedback from themselves, other learners and/or the teacher, it is generally expected that learning improves.

In 20 case studies in the Netherlands, teachers and their pupils used three instruments of formative evaluation: self-evaluation, peer feedback and formative dialogue. The format of the instruments reflected the five-phase Ark of Inquiry model of inquiry proficiency. Anecdotal evidence collected by the teachers and researchers show that the use of the formative evaluation instruments improves several matters related to inquiry learning. First, it improves pupils' awareness of the process of scientific inquiry. The pupils evaluate their behaviour and results according to the five-phase model of scientific inquiry and by doing so become more aware of those five phases. Second, the teachers indicate that they gained better insight in the differences between their pupils. Some pupils experience difficulties in specific phases, and pupils differ in the way they need structure during the inquiry activity. The formative evaluation helped the teachers to recognize those differences and adjust activities accordingly. Third, involving pupils in formative evaluation created a classroom atmosphere in which knowledge and questions could be raised, feedback was welcomed, and experiences and products were discussed. The formative evaluation instruments gave rise to dialogue and collective progressive inquiry. The findings support the idea that by involving pupils in formative evaluation in several ways the overall inquiry process is stimulated and becomes a matter of ongoing collective activity.

✓ **Teachers** are invited to use formative evaluation instruments to encourage progressive inquiry in their classrooms and to gain insight in the skills and talents of all pupils involved.

✓ **National Educational Authorities and Educational policy-makers** are invited to encourage schools and teachers to use formative evaluation instruments and to formally recognize the less standardized but equally valuable evidence that stems from it in national educational policies.

✓ **Pupils** are invited to engage enthusiastically in formative evaluation of their and their peers' inquiry proficiency.

Ark of Inquiry Best Practice (The Netherlands)

In the Netherlands, one grade 3 teacher started an ill-structured inquiry activity in her classroom in which pupils designed and build animal cages in small groups. One of her aims was to promote and evaluate collaborative inquiry. At the start of the project, she declared the importance of collaboration and discussed with her pupils what 'good collaboration' might look like. At the end of the project, which took several lesson hours in one week, she used a self-evaluation form to stimulate all pupils to think about how the group work went. Then, she had a classroom discussion on the topic. In this formative dialogue, the pupils first noted that 'group work went well'. The teacher then asked what exactly went well, and the pupils started adding more detail to their observations. The teacher concluded from her experiences that the combination of self-evaluation and classroom dialogue helps pupils to become engaged in evaluation, and helps to improve group work in future inquiry activities. This example illustrates that pupils, even those in lower grades, need to learn to evaluate their own and each other's performances, and the teacher's role in this is crucial at the beginning.

Rationale 1.4: Pedagogical scenarios help teachers maintain an active role as designers of inquiry learning activities

A number of studies across Europe have shown that one of the greatest challenges for teachers in primary and secondary schools is how to manage to implement the heavy curriculum as set by the relevant educational authorities. This means that in most of the cases teachers have limited flexibility to introduce new activities and projects in their classrooms. Providing teachers with concrete guidance and mechanisms in order to amend and adapt their existing activities to their specific needs and goals is extremely useful. A pedagogical scenario is a tool that lets educators to design complete and rich scenarios for many pedagogical formats (face-to-face, at distance or mixed form) and to associate student activities with other tools[7]. The six pedagogical scenarios[8] the project has developed support teachers in taking ownership of the activities and in developing new professional competencies.

As noted in the forthcoming Deliverable 4.3 on the overall teacher trainings[9], the pedagogical scenarios were found to be helpful enough for the teachers (39% strongly agree and 26% agree), although a small but noteworthy proportion of teachers did not find this material useful (12% strongly disagree and 22% disagree). A probable reason for this finding might be that in some countries, no much emphasis was given on the pedagogical scenarios during the training sessions. Nonetheless, the overall data across all 12 countries suggests that the Ark of Inquiry pedagogical scenarios allow the flexible and widespread use of the existing activities in Ark of Inquiry portal that has a great wealth of resources and it makes it easier to adapt individual activities into various classrooms, age groups, cultural contexts and settings. The scenarios have empowered the teachers to innovate both on their existing previous activities and assigns them an important role in designing the inquiry learning activities and scenarios.

✓ **Teachers of Science and Science Teacher Societies** can design their lessons by incorporating the one or more of the six Ark of Inquiry pedagogical scenarios into their teaching, adapting the scenarios to the students and curriculum needs and the needed tools.

✓ **Teacher educators** can work with teachers to adapt existing classroom activities and use them as part of professional development courses and trainings. A particular attention should be paid to pre-service teachers in getting them accustomed to such pedagogical ideas earl in their career. Teacher educators can also work together to develop and design effective inquiry scenarios with a scientific background and to be updated with the new tools.

✓ **Pupils** can help in designing the inquiry scenarios and activities by expressing their problems and their strengths and weaknesses in the subject.

✓ **National Educational Authorities and Policy-makers** can work alongside their counterparts in other disciplines to ensure continuity between education, economic and social policies in their countries.

Ark of Inquiry Teacher Perspective (Turkey)

After participating in Ark of Inquiry teacher trainings in Turkey, one science teacher noted, “It is not easy to use each IBSE activity because of the timing and current science curriculum’s strict implementation rules. I strongly believe that the Ark of Inquiry project and its platform with inquiry learning materials and with its pedagogical scenarios will provide more opportunities to science teachers and their students to enhance and extend the quality of science education.”

Rationale 1.5: The use of an Awards system is motivating for teachers and pupils alike and works best when integrated into existing contests and communities

Award systems can potentially motivate pupils and their teachers when performing inquiry activities involving RRI elements. This was the motivation between the Ark of Inquiry project's approach in designing an online awards systems for use by teachers of scientific inquiry activities. As experienced during project implementation in Belgium, an award system can work in its best if integrated within an existing contest, in which pupils, guided by their teachers, will have to compete to some extent with each other. It can work even better when pupils have to present their work to e.g. a group of experts, which will evaluate it, but also to the other participating pupils. The experience of presenting the results of the own work, like real researchers do, has a great positive impact on young people.

Similarly, the inclusion of such an award system into existing local communities of schools could be of support, provided that the local context (such as curricula constrains, available lesson time, structure of local education system) are also taken into account.

✓ **Teachers of Science and Science Teacher Societies** are encouraged to recognize the potential of an award system for the motivation of pupils and make time within their lessons to support pupils' work related to it. They could also take the initiative to engage in existing contests with their pupils and look for the support of their school directors when doing this.

✓ **Teacher educators and teachers** could work together to create opportunities for inquiry award contests within local communities.

✓ Political and financial support for the organization of inquiry award contests could be beneficial from **National Educational Authorities and Policy-makers**.

✓ **Parents** could support the importance of award systems as an alternative opportunity for children to learn more both in and out of the classroom.

✓ **Pupils** should trust their capacities and see award systems as a potential positive experience from which they will learn a lot.

Ark of Inquiry Best Practice (Belgium)

The implementation of the Quantum SpinOff trajectory within Ark of Inquiry has been a successful story in Belgium. During the school year 2016-17 five secondary school classes participated in this contest. They encountered the world of quantum physics through learning material (uploaded on the Ark of Inquiry portal), but also by meeting real researchers and entrepreneurs. The participating pupils developed their final work and presented it and their trajectory to a jury of experts during the SpinOff day. The teachers of the participating classes were as enthusiastic as their pupils were about the awarding system. In particular, they consider the possibility for pupils to present their own work as a very positive experience, and as an opportunity to grow.

Rationale 1.6: Inquiry activities engage pupils and may help promote learning of 21st-century skills

International studies such as PISA show that pupils' interest in STEM topics is in steady decline. This decline could also have an impact on pupils' future career opportunities as they will not be equipped with the technical skills necessary for the needs of the future. But beyond that, pupils need to be prepared to deal with the challenges of work, life, and citizenship in the 21st century and beyond, as well as ensure ongoing innovation in the economy and the health of democracy[10].

Data collected across multiple EU member countries shows that pupils enjoy inquiry activities they have conducted in various STEM domains and topics. This implies that inquiry activities could help restoring pupils' interest in STEM and more generally make teaching and learning in and outside the classroom more fun! Furthermore, while working on inquiry activities, pupils can learn various 21st-century skills. These include various literacy skills (ICT literacy, information and media literacy, math and science literacy), life skills (collaboration, communication, cultural awareness, citizenship), and learning skills (problem-solving, critical and creative thinking, metacognition, lifelong learning).

Preliminary results from the implementation of inquiry activities in Finnish schools suggest that pupils' perceive different types of inquiry activities as highly engaging. The data is from approximately 120 elementary schools students that completed two of five available inquiry activities. In the first inquiry activity, which was the same for all pupils, the pupils used an electricity simulation to study the basic principles of simple electric circuits. Overall, pupils reported high on-task interest throughout the whole activity. Boys had a significantly higher interest in the beginning of the activity compared with girls, whereas upon completion of the activity the gender differences disappeared. Pupils indicated that they were eager to learn more about the topic in the future, suggesting that the inquiry activity was able to trigger and maintain pupils' interest on the topic.

✓ **Teachers of Science and Science Teacher Societies** are encouraged to recognise the potential of inquiry activities to engage pupils and teach important 21st-century skills, and thus to increase the use of inquiry learning in their classrooms.

✓ **Teacher educators** should emphasize inquiry learning and student-centred pedagogies in teacher training, in order to prepare competent teachers that have a good theoretical and pedagogical understanding of inquiry learning, know both the benefits and challenges related to inquiry learning, and can implement inquiry learning and activities in a pedagogically meaningful way in their classrooms.

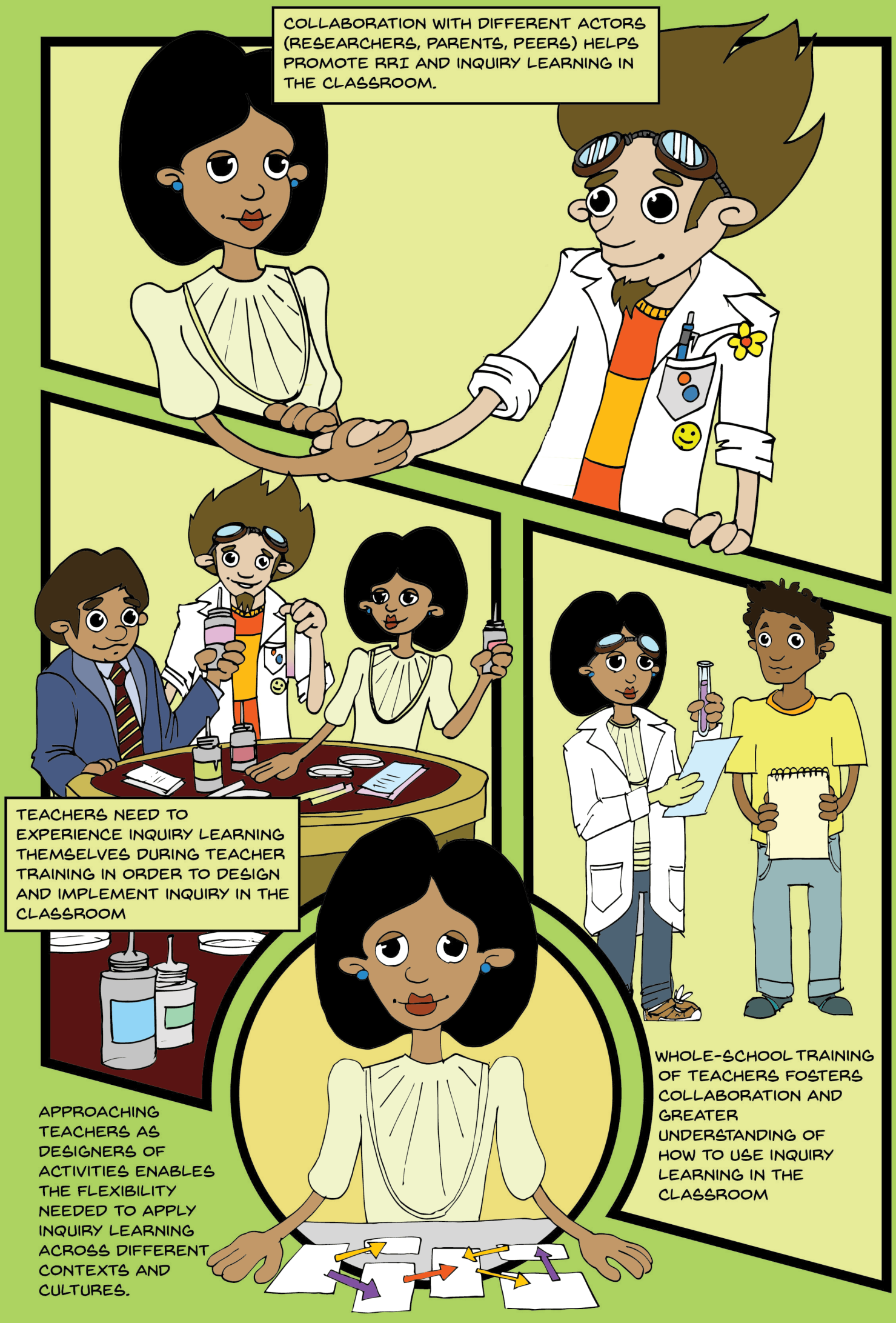
✓ **National Educational Authorities and Policy-makers** should recognise the potential of inquiry-based education to educate competent future citizens.

✓ **Parents** - Inquiry activities are fun! Many inquiry activities can be conducted everywhere, also at home. The whole family can conduct inquiry activities together, or parents can provide support for pupils when they conduct inquiry activities in informal settings.

✓ **Pupils** - Inquiry activities are fun way to learn and they allow you and your friends to explore some cool stuff.

Ark of Inquiry Pupil Perspective (Finland)

While undertaking an inquiry activity to solve electricity problems in a virtual environment, a Finnish fifth grade remarked, "Hey teacher, this so cool. This is the best lesson I've had in school. I wish there were more lessons like this". Similar remarks were received from other pupils as well.


COLLABORATION WITH DIFFERENT ACTORS (RESEARCHERS, PARENTS, PEERS) HELPS PROMOTE RRI AND INQUIRY LEARNING IN THE CLASSROOM.
TEACHERS NEED TO EXPERIENCE INQUIRY LEARNING THEMSELVES DURING TEACHER TRAINING IN ORDER TO DESIGN AND IMPLEMENT INQUIRY IN THE CLASSROOM
WHOLE-SCHOOL TRAINING OF TEACHERS FOSTERS COLLABORATION AND GREATER UNDERSTANDING OF HOW TO USE INQUIRY LEARNING IN THE CLASSROOM
APPROACHING TEACHERS AS DESIGNERS OF ACTIVITIES ENABLES THE FLEXIBILITY NEEDED TO APPLY INQUIRY LEARNING ACROSS DIFFERENT CONTEXTS AND CULTURES.

4

Key message number 2: A supportive community can provide teachers with the training and resources needed to successfully use inquiry learning in the classroom

In a broad sense, teachers work within contexts – contexts influenced not only by pupils, but also by policies, curricula, practices, school staff and parent groups. These contexts are constantly shifting, changing and growing. While teachers are expected to interact with these contexts, it tends to be a solitary effort[11]. Teachers in science education are no different; given the developments in the STEM fields and the need for an improvement in the labour force in these fields, science teachers have to meet this ambitious goal through innovative teaching strategies that are rooted in 21st century advancements thereby making science more accessible, interesting and relatable to pupils. Being part of a supportive community allows teachers to develop their expertise in the pursuit of this goal. A supportive community enables the restructuring and reimagining of professional learning; it presents an opportunity for teachers to learn from one another in a cooperative and collaborative manner, taking turns being the learner and teacher. Within the Ark of Inquiry project, the trainings were designed to facilitate a strong sense of community by orienting teachers within a group context, first as "learners", then as "thinkers" and finally as "reflective practitioners".

Based on qualitative and quantitative information, the following results attest to the important role played by a supportive community in enhancing teachers' expertise:

✓ Collaboration with different actors (researchers, parents, peers) helps promote RRI and inquiry learning in the classroom

✓ Teachers need to experience inquiry learning themselves during teacher training in order to design and implement inquiry in the classroom

✓ Whole-school training of teachers fosters collaboration and greater understanding of how to use inquiry learning in the classroom

✓ Approaching teachers as designers of activities enables the flexibility needed to apply inquiry learning across different contexts and cultures

Rationale 2.1: Collaboration with different actors (researchers, parents, peers) helps promote RRI and inquiry learning in the classroom

Researchers have argued that giving pupils the chance to get in contact with and thus engage different actors outside of the school environs, such as researchers, educators and parents, is key to a number of educational goals: it improves pupils' attitude towards school, develops inquiry learning and promote interpersonal and intergroup relations. For example, Harada and Yoshina (2004)[12] acknowledges that the collaboration with different actors provides access to a wide range of resources – including technological equipment needed for carrying out specific learning activities. It also provides opportunities for creative synergies to emerge and collaborative problem solving.

Collaboration with different actors is also central to RRI and its promotion in science education. By getting in contact with researchers and other actors involved in research-related activities, pupils have the chance to experience science not as a solitary effort but as a collective enterprise, which involve different people as well as resources.

During a science fair held in the Institute of Chemistry at Humboldt-University of Berlin in Germany, preschool pupils had a chance to perform in collaboration with researchers and educators a series of experiments devoted to investigating how colours change. The educators and the parents were all too happy to give the pupils the opportunity to visit a real chemistry lab and carry out the experiments and the inquiry activities themselves. The event was a success. It helped the different actors involved understand the importance of collaboration and it encouraged educators to organize such events on a regular basis.

✓ **Teachers of Science** can seek out opportunities to engage more with other actors, both inside and outside the classroom. Because of the teacher's experience, they are well-suited to support the other actors by steering the pedagogical approach to best suit the pupils' needs.

✓ **Researchers and scientists** can seek out opportunities to engage themselves more with pupils and offer themselves as effective resources for the teachers, parents, and pupils.

✓ **Parents** can encourage and support the school to organize events in which their children can meet and interact with real scientists and researchers.

✓ **National Educational Authorities and Policy-makers** can work alongside their counterparts in other disciplines to ensure continuity between education, economic and social policies in their countries.

Ark of Inquiry Teacher Perspective (Germany)

During the aforementioned science fair held in collaboration between researchers and educators at the Institute of Chemistry at Humboldt-University of Berlin in Germany, one of the educators asked, "May we organize such an event regularly and cooperate together to implement such activities in our community?" The event also received very good feedback from parents, as they were very happy with such cooperation between the Institute and the pre-school educators.

Rationale 2.2: Teachers need to experience inquiry learning themselves during teacher training in order to design and implement inquiry in the classroom

Based on evidence from the teacher trainings conducted, positioning teachers in the role of active learners rather than as simple information-gatherers, as well as enabling them to experience the same learning journeys that their students would be expected to follow, was beneficial for their Professional Development (PD) and sense of efficacy.

Specifically, positioning teachers in the roles of learners and thinkers during the teacher trainings enabled them to ask themselves (i) what they knew and what they did not know about enacting inquiry and RRI in their teaching practice; (ii) what type of knowledge, skills or abilities were needed to be applied for enacting inquiry and RRI; and (iii) what epistemic considerations were required for assessing the validity of the acquired knowledge about inquiry, RRI and the process that has been followed for the development of these knowledge bases. Consequently, teachers as learners were allowed to directly experience and become aware of the various types of learning difficulties that their pupils would be confronted with during their exposure to Ark of Inquiry activities and thus were able to take them into consideration for the design of their own instructional settings.

The third and final role of reflective practitioner was also considered essential for teachers. Teachers implemented curriculum materials they developed or received within the context of their trainings into their own practice, collected evidence to evaluate and reflect on the effectiveness of their teaching, brought reports of their field experiences to the training course and analysed teaching strategies with their mentors and colleagues. This part of the training increased teachers' abilities to use existing materials and to adapt them to their own needs and practices.

Lastly, the teacher training course had a positive impact on teachers' sense of efficacy and their overall views on inquiry learning. This is important, because teachers' sense of efficacy is directly related to teachers' readiness to use new methods in their teaching such as inquiry learning. Executed via questionnaires that were distributed at the beginning and end of the teacher training sessions, a study was conducted in 10 countries including nearly 500 participants to examine this linkage. It was found that teachers with higher teacher efficacy also had more positive attitudes toward IBL. But more than that, the teacher training sessions and the time in between sessions had a positive effect on both teachers' sense of efficacy and their attitudes towards IBL. Since within the trainings the teachers had the opportunity to have mastery experiences, learn from others and get feedback, their feelings of self-efficacy increased and thus the likelihood of them using inquiry activities for their pupils as well.

✓ **Teachers** can recognize the importance of the inquiry learning pathways in the same way they would engage their students during their own practice.

✓ **Teacher educators and researchers** can design such teacher training programs (or professional development programs) that focus on hands on, as well as minds-on, activities rather than lecturing.

Ark of Inquiry Teacher Perspective (Italy)

"The possibility to be trained as "pupils" and to do the activities in person was a huge advantage of the Ark of Inquiry training over other trainings I have participated in. I now feel more confident to apply this inquiry lesson in my own classroom."

Ark of Inquiry Best Practice (Cyprus)

After teachers' participation in the first phase of the training in Cyprus (teachers as "learners") in which they undertook the role of pupils during an inquiry activity, the majority of teachers (32/38, 84%) indicated that they were planning to implement a similar learning activity.

Rationale 2.3: Whole-school training for teachers fosters collaboration and greater understanding of how to use inquiry learning in the classroom

Effective and enjoyable inquiry-based learning often relies on "political and cultural aspects of teaching", which in many cases has stronger effects on learning outcomes than infrastructural or technical issues[13]. Beyond teachers' individual capacities, a collective capacity and a supportive environment is also needed to perform quality inquiry teaching and learning[14].

Schools as professional learning communities can efficiently integrate peripheric (local) and general (research-based) knowledge into their daily way of operation (how inquiry is practiced in and outside the classroom): this combination is inevitable if a sustainable improvement is desired[15]. Schools as professional learning communities also have high potential in capacity building[16]. Whole-school trainings therefore offer a whole-school approach in professional learning: beyond the power of peer support, teachers experience a culture of collaboration and engage in a cumulative knowledge building process while enjoying the various benefits of organisational learning. They share the responsibility of learning and (with their very presence and previous knowledge) enrich the learning journey of their colleagues.

In the Ark of Inquiry project, each partner country took a tailored approach to their own context, in that some countries undertook trainings at the school level and others at the individual teacher level. In Hungary, initially five schools volunteered to host and take part in teacher trainings: some of the schools had already been exposed to inquiry-based learning, others had only a few teachers with previous experience in inquiry teaching. They all experienced a gain in discovering new collaboration opportunities, strengthening elements of existing traditions linked to using inquiry, while stocking up on their capital in knowledge and prestige in their region. Didactical hints and practical tips from their colleagues engaged in other subject areas or age groups were refreshing to participants, while they felt empowered by the process of exchange and cooperation.

✓ **Teachers of Science and Science Teacher Societies** may encourage fellow teachers to engage in a whole school training program. They can prepare lists to inspire others: they can suggest for example, what other subject teachers may profit from collaboration with Math teachers, or collect their expectations about learning from others. Another source of inspiration may emerge from success stories of schools that took steps to become learning organizations by participating in whole-school professional development programs.

✓ **National Educational Authorities and Policy-makers** may consider research findings about the efficiency and sustainability of whole-school professional learning programs. The multi-faceted capacity-building potential of whole school trainings is remarkable, while also a cost-efficient way of implementing educational reform ideals.

✓ **Teacher Educators** may build on the peer support and the cumulative knowledge-building capacity of teachers they can work with in a whole-school training. Although it might be challenging to work with such diverse groups, diversity also promotes innovative approaches, while the school can serve as a comforting environment needed for emotional and mental support for professional behavioural changes involved in the learning process.

Ark of Inquiry Teacher Perspective (Hungary)

After participating in whole-school teacher trainings hosted by the Ark of Inquiry project in Hungary, two teachers noted:

"Being an Arts teacher, I was excited to see what I can learn at this training. Finally, it was thrilling to experience how inquiry works, but it was yet more delightful to get inspired to start projects with some of my colleagues who I haven't thought of collaborating with before. I can say I have found my space in STEAM inquiry teaching here."

"I have had some previous experience in inquiry-based teaching, which I love to practice. It was so empowering to me to see that I can contribute to the learning process of others! Then, it was also exciting to receive feedback from colleagues. As learners, we were free to make some mistakes too, and I feel that the reflections from fellow teachers really deepened my understanding of how inquiry works and how I can improve my own inquiry teaching."

Rationale 2.4: Approaching teachers as designers of activities enables the flexibility needed to apply inquiry learning across different contexts and cultures

In general, teachers are crucial factors in the implementation of any innovation[17]. Moreover, they have been found to frequently adapt innovations to local insights and needs[18]. One of the aims in the Ark of Inquiry project is to support inquiry learning in different countries across Europe. This means the project has to function in gradually and in some respects fundamentally different school systems. Even further, the Ark of Inquiry has been developed for both primary and secondary education as well as home usage, three totally different contexts. And lastly, teachers who participate in the Ark of Inquiry project will differ in terms of their prior experiences and appreciations of inquiry learning. The expectations, therefore, are that teachers will need to make local adaptations to the approach, systems and concrete materials of the Ark of Inquiry portal and materials.

In order to address these variations across the project, teachers were encouraged to use the different pedagogical scenarios created by the Ark of Inquiry project[19]. All of the scenarios were created with one theme in common: addressing the teacher as the designer of their own, custom-made activity for the learning context in their classroom. From case studies in the Netherlands, anecdotal evidence has been collected about the relevance and practical usability of the pedagogical scenarios. The evidence shows that teachers are in need of support to tailor inquiry activities and evaluation instruments to their needs. For instance, teachers guiding young pupils aged 7 have different needs than teachers who work with pupils aged 11. Accordingly, they have been adapting levels of inquiry activities by adding structure, skipping certain phases or by adapting presentation formats in the conclusion and discussion phase of inquiry. Other triggers to adapt materials with the help of the scenarios appeared to be: the need to turn activities aimed at individual pupils to into group activities, the need to take away structure and create more freedom for pupils to explore during the investigation phase, and the need to embed an inquiry activity into a real life context (adding an RRI component in the orientation and discussion phase). Collected materials of the teachers and interviews held with them after the implementation of the materials in their classrooms confirms that the pedagogical scenarios helped the teachers taking up their roles as designers, and existing materials were easy to use and redesign.

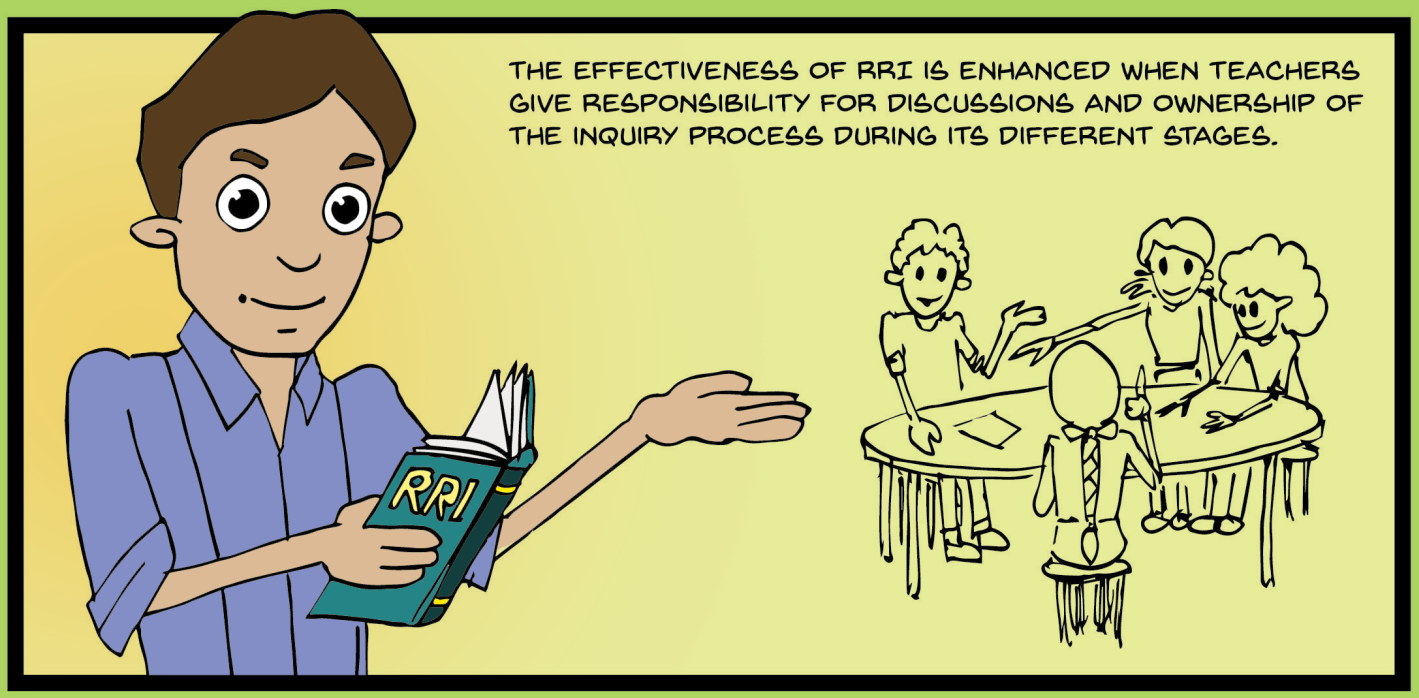
✓ **Teachers** are invited to view themselves as learning activities designers and use existing materials and scenarios as a starting point to tailor them to their own and their pupils needs.

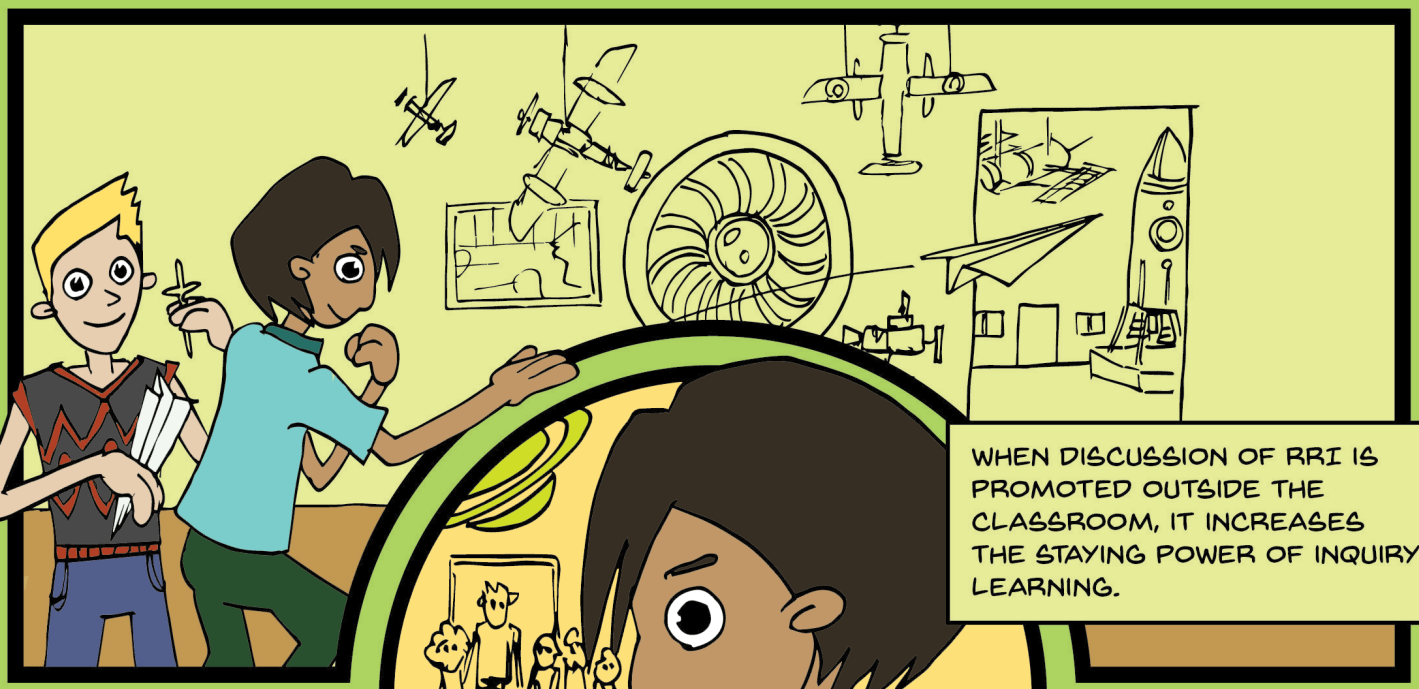
✓ **Teacher educators** are encouraged to point out the importance of (re)designing in teacher education, and to help teachers develop the skills to be able to do this and follow the implementation.

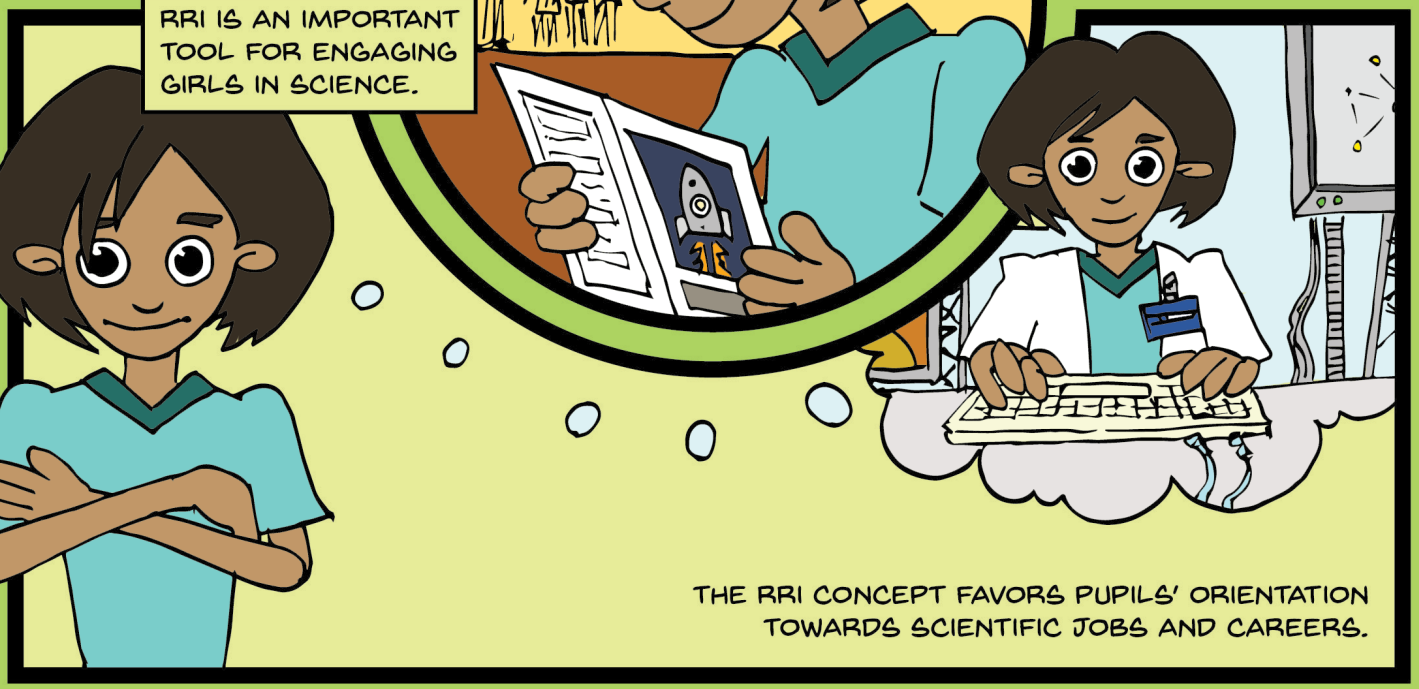
✓ **National Educational Authorities and educational policy-makers** are encouraged to recognize the importance of teachers as designers of tailored educational materials and invited to make this explicit in national agendas that guide teacher education.

Ark of Inquiry Best Practice (The Netherlands)

In the Netherlands, a special focus was made to train teachers to design their own inquiry activities. Teachers were asked to redesign an activity with the help of a worksheet, according to the phases of the inquiry model and the proficiency level of the pupils (level A, B or C). Follow-up after the implementation of the materials in their classrooms confirmed that the pedagogical scenarios helped the teachers take up their roles as designers, and existing inquiry assignments were easily analysed and redesigned with the help of the worksheet.


THE EFFECTIVENESS OF RRI IS ENHANCED WHEN TEACHERS GIVE RESPONSIBILITY FOR DISCUSSIONS AND OWNERSHIP OF THE INQUIRY PROCESS DURING ITS DIFFERENT STAGES.
RRI


WHEN DISCUSSION OF RRI IS PROMOTED OUTSIDE THE CLASSROOM, IT INCREASES THE STAYING POWER OF INQUIRY LEARNING.


RRI IS AN IMPORTANT TOOL FOR ENGAGING GIRLS IN SCIENCE.
THE RRI CONCEPT FAVORS PUPILS' ORIENTATION TOWARDS SCIENTIFIC JOBS AND CAREERS.

5

Key message number 3: Concepts like Responsible Research and Innovation (RRI) are effective in enriching the inquiry learning process

In recent years, the term Responsible Research and Innovation (RRI) has gained a considerable amount of attention in Europe. According to the European Commission (2014), RRI refers to societal actors working together during the whole research and innovation process in order to better align both the process and its outcomes, with the values, needs and expectations of European society[20]. Of the six strategic areas in which RRI can be profitably developed and implemented, the one that is most important to the Ark of inquiry Project is science education, although those of gender and are also relevant. As the project sought to incorporate RRI in its activities, one of the major challenges identified was how to help teachers and science educators promote the development of RRI awareness among their pupils.

Within the context of the Ark of Inquiry project, RRI is specifically identified as a complement of inquiry learning that is able to enrich the overall inquiry experience. As such RRI is connected to the attitude and ability to reflect on, communicate and discuss processes and outcomes of inquiry in terms of its relevance, consequences and ethics for oneself, others and society[21]. Such a definition enables teachers and science educators, on the one hand, and pupils, on the other, to recognize during the inquiry process and thus to address a variety of RRI-related issues. Such issues include collaboration among peers, communication of the results of an inquiry activity, broader reflections about the inquiry process and its constitutive elements, identification of explicit as well as implicit moral issues related to an inquiry, and recognition of the social context of inquiry[22].

To help teachers and science educators achieve a better understanding as to develop RRI awareness and thus enrich the inquiry learning process, the Ark of Inquiry project identified several strategies that have yielded promising results:

✓ RRI helps teachers translate important matters into their classroom materials;

✓ RRI provides a framework within which the research process, its ethical/social dimension and sustainability can be suitably discussed;

✓ The effectiveness of RRI is enhanced when teachers give responsibility for discussions and ownership of the inquiry learning process during its different stages;

✓ Adequate flexibility is needed in the classroom for an effective application of the RRI concept during inquiry learning lessons;

✓ RRI is an important tool for engaging girls in science;

✓ When discussion of RRI is promoted outside the classroom, it increases the staying power of inquiry learning;

✓ The RRI concept favours pupils' orientation towards scientific jobs and careers.

Rationale 3.1: RRI helps teachers translate important matters into their classroom materials

Of late, the world of pedagogy is transitioning from a teacher-centred to learner-centred approach, wherein learning gains have improved when pupils do as opposed to when they are simply talked to or listening. Facts and formulae only become relevant if pupils can discover what these facts and formulae can do for them. Given the impetus to provide more opportunities for this nature of authentic learning experiences within the walls of the classrooms, teachers have resorted to incorporating real-world elements within lessons that allow pupils to make connections and hence engage with the content. In pedagogy, science pedagogy in particular, learning by doing enables pupils to engage not just cognition but also social and emotional faculties, using exploration and judgement. The concept of Responsible Research and Innovation (RRI) promotes the cultivation of scientific thinking during the entire process of research and innovation, thereby developing a new generation capable of driving innovative technology to address global challenges.

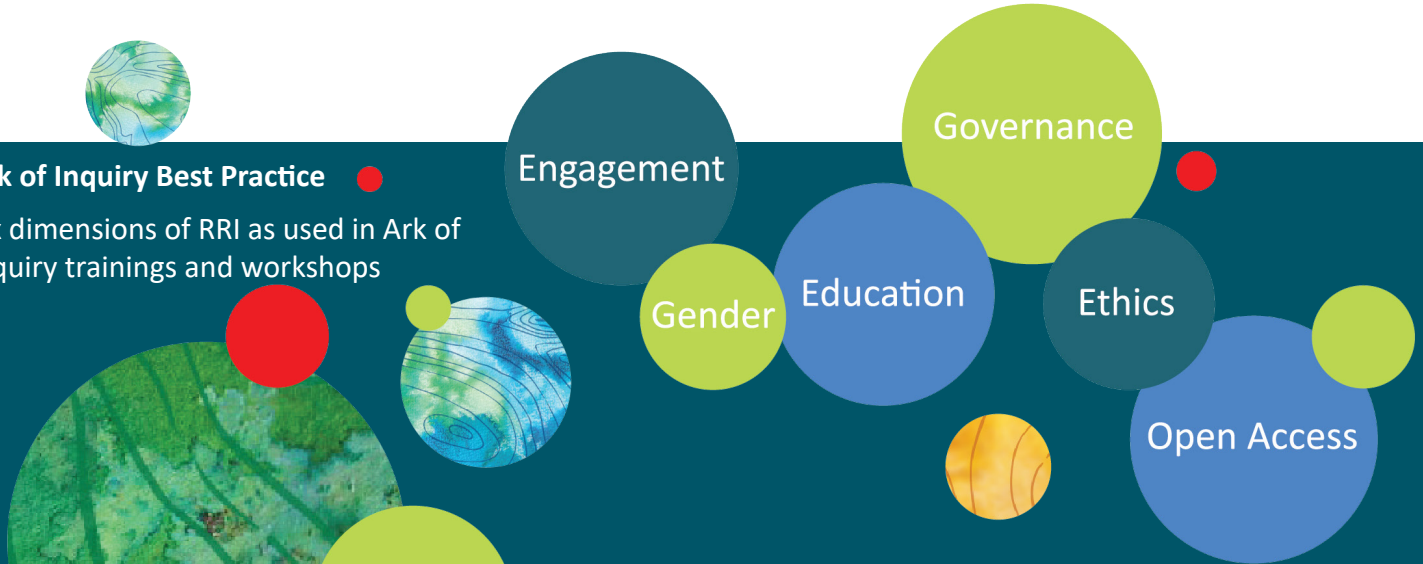
Throughout its four-year implementation, the Ark of Inquiry aimed to build a scientifically literate and responsible society by expanding youth's awareness of RRI through inquiry-based science education. As such, the project's inquiry model serves as a basis upon which elements of RRI can be easily integrated and elevated during a classroom inquiry learning activity. The phases of the inquiry model, particularly the orientation, conclusion and discussion phases, emphasises the role of the teacher in linking authentic, real-world ethical dilemmas to the inquiry activity in the classroom through guided reflection, communication and discussion. RRI within the project cultivates the attitude and ability needed to think through, present, explain and question the relevance, consequences and ethical issues surrounding inquiry and research process with an audience.

For example, during the teacher trainings in Cyprus, the teachers designed their own Inquiry Learning Spaces (ILS) on a particular topic for an elementary school pupil for the purposes of a Science Fair. One group of teachers designed a sequence of activities in the context of Electric Circuits for their pupils. In the Discussion phase, they were able to incorporate aspects of RRI relating to the relevance, consequences and ethics of the inquiry activities. These questions helped the pupil to understand in greater depth this topic and be better prepared as a citizen to think critically about scientific issues.

✓ **Teachers of Science and Science Teacher Societies** are recommended to incorporate time for reflection, communication and discussion in their lessons as often as possible and also guide their pupils in these processes. By following the inquiry model and using the pedagogical scenarios, activities that foster critical reasoning and scientific thinking allow youth to tackle real-world challenges and hence develop innovative solutions.

✓ **Teacher educators** can include components of RRI, particularly methods of embedding real-world, global ethical dilemmas, in their trainings to in-service and pre-service teachers.

✓ **National educational authorities and policy-makers** can endorse curriculum changes and trainings for educators that incorporate RRI elements in order to develop the next wave of scientific thinkers to drive innovation.



Ark of Inquiry Best Practice

Six dimensions of RRI as used in Ark of Inquiry trainings and workshops

Rationale 3.2: RRI provides a framework within which the research process, its ethical/social dimension and sustainability can be suitably discussed

As already stated, RRI applied to inquiry learning can give teachers the opportunity to encourage pupils to reflect on the research process and make meaningful connections between the topic under investigation and its broader ramifications in everyday life, particularly as regards the ethical and social dimensions of research.

In Estonia, for example, the hesitation that pupils showed in approaching hypothesis generation during an inquiry activity triggered on several occasions a discussion led by the teacher, in which pupils could reflect on the nature of the research process and draw the conclusion that mistakes are an essential ingredient of it. For example, during an inquiry activity on the human circulatory system, pupils had the chance to experience for themselves the effect of physical exercise on their heart and at the same time discuss the consequences that different life styles can have on one's own body. In another case, an inquiry activity in which students inquired into reflexes provided the experiential basis for a discussion centred around how the assumption of alcohol slows down one's reaction time while driving a car.

In an RRI-based inquiry activity in Austria, pupils were asked how to creatively use the Raspberry Pi microcomputer[23] and develop original solutions or inventions to problems that matter to them or to invent things that could be useful to have in the near future. They also had to discuss the sustainability and ethics aspects of their newly invented application: i.e. Where do you get the components for your invention from? How are the components produced and under which circumstances? How does this affect the environment?

In another RRI-based inquiry activity, "The Camera non obscura" pupils tried to control a camera with the Raspberry Pi. Then the students discussed where the invention could be applied (i.e. for alarm systems, for art installations, etc.). Some of the students developed their own ideas on what to do invent. At the end, pupils were able to discuss and better understand the ethical implications of the invention (i.e. the societal consequences of surveillance).

✓ **Teachers** can familiarise themselves with engaging inquiry experiments from an RRI-perspective, such as those that use the Raspberry Pi microcomputer, in order to actively promote discussions with pupils on ethics, society and sustainability during the lesson.

✓ **Teacher educators and researchers** can design professional development programs that encourage science teachers to remain open to finding connections with RRI-issues in inquiry activities.

Ark of Inquiry Pupil Perspective (Austria)

After completing the RRI-based inquiry activity "The Camera non obscura", a pupil remarked, "Now I really got an idea of what will be possible in the future and how I can contribute to developing it."

Rationale 3.3: The effectiveness of RRI is enhanced when teachers give responsibility for discussions and ownership of the inquiry learning process during its different stages

A crucial element for the effective/fruitful application of RRI concerns the engagement of pupils in making meaningful decisions during the course of an inquiry lesson. Meaningful decisions are identified in those situations in which pupils – sometimes with the help of the teacher – are given the responsibility for taking the lead in the inquiry lesson during its different phases.

An example that illustrates this comes from Estonia concerning an inquiry activity conducted by a second-grade teacher where the pupils buried different items in the ground in September (right at the beginning of the school year) and then to unearth them in May to see by how much the different materials have degraded in the soil. Throughout the various inquiry phases, the teacher tried to engage her pupils in making meaningful decisions and in particular during the investigation phase. Here, after seeing the items they were to bury, the teacher asked the class where they wanted to dig the hole in the big garden that extended for a few hundred meters from the school building. A discussion amongst the pupils followed, concluding as a group that the place should be where the ground is soft and where it would be unlikely that people would tramp on it. The pupils then discussed and decided how to remember the exact location of the hole in May; how to dig the hole itself; and, how to remember to remind the teacher of the need to return to the inquiry activity in the springtime. Each of these discussions within themselves could even be considered as "micro-inquiries", as the pupils had to decide upon a number of issues as each question arose during the inquiry lesson.

As the example shows, the teacher has also an important role in engaging the pupils to take ownership of the decisions during the inquiry activity and making them feel a sense of ownership. Giving responsibility to pupils during the inquiry process is a big challenge, though. Constraints of various nature may discourage teachers – especially those that have less experience – to adopt a different style during the inquiry lessons, a style that is more welcoming towards pupils' own contribution. Nonetheless, by taking ownership and responsibility of their inquiry learning process, the pupils were able to comprehend more effectively the implications of their decisions.

✓ **Teachers** can encourage pupils to take the lead in making meaningful decisions in all phases of an inquiry activity.

✓ **Teacher educators** can help teachers design inquiry activities that place more emphasis on pupils' responsibility for making meaningful decisions in all phases of an inquiry activity. They can also support teachers – especially those who have less experience – in developing the kind of attitude that tries to accommodate pupils' contribution.

✓ **National Educational Authorities and Educational policy-makers** can promote policies that would place more emphasis on developing pupils' ownership of their learning process.

Ark of Inquiry Teacher Perspective (Estonia)

The same teacher that was mentioned above said that including pupils in the inquiry process is crucial, because – as she put it - "you have to give the children this joy", that is, the joy of inquiring. She also added that letting pupils try and sometimes fail is part of the learning process. During the conceptualization phase, for example, she remarked: "they [the pupils] also have to understand that sometimes you've got a hypothesis, but you can't prove it, and the other thing is that you reject it and that's not bad or wrong either and can happen in [real world] science as well".

SEPTEMBER 2016: PUPILS ARE INVOLVED IN DIGGING A HOLE WHERE THEY ARE GOING TO BURY A FEW ITEMS TO SEE HOW FAST THEY ARE GOING TO DEGRADE IN THE SOIL.

STUDENTS TAKING RESPONSIBILITY DURING THE INVESTIGATION PHASE OF AN INQUIRY ACTIVITY

MAY 2017: 9 MONTHS LATER, THE PUPILS ARE GOING TO DISCOVER WHICH ITEMS HAVE DEGRADED FASTER AND WHICH SLOWER.

AFTER SOME TIME, THEY FIND THE FIRST ITEM, WHICH GETS PASSED FROM PUPIL TO PUPIL.

THE PUPILS SHARE RESULTS WITH THE TEACHER.

Rationale 3.4: Adequate flexibility is needed in the classroom for an effective application of the RRI concept during inquiry learning lessons

The application of the RRI concept to science education can give teachers the opportunity to encourage pupils to reflect on the research process and make meaningful connections between science and everyday life. However, this cannot be expected to happen without providing teachers with an adequate degree of flexibility and discretion. Often already overloaded with tasks and targets to hit, teachers may not be able, even if they want to, to allow themselves to be more flexible and consequently take risk.

Flexibility is crucial for teachers to successfully include pupils during inquiry lessons and so prompt the kind of active participation that is so crucial to RRI. However, curriculum demands and limitations are often a major constraint preventing them from adopting a more flexible style.

During the teacher trainings in Estonia, it was observed that time is one of the most limiting factors that can impair the effective application of RRI during inquiry activities in the class. In line with several informal surveys elsewhere, teachers time and time again pointed to time limitations as a major obstacle, regardless their age and years of experience. Also in Estonia, it was observed that during an inquiry lesson teachers are often forced to artificially increase the "pace" to be able to finish the activity within the prescribed time. This was especially true for lessons that lasted only 45 minutes and which did not allow enough time for pupils to draw conclusions on their own, undermining this crucial part of the original purpose of inquiry learning in the first place. Limited time also left out the opportunity for pupils to discuss the broader implications of the topic treated, such as those promoted within an RRI approach. Conversely, in an observed case where the inquiry activity was spread out over the course of three days, giving pupils the proper amount of time to carry out tasks independently in each inquiry phase, the opposite held true. This can be considered as a success story as pupils could work at their own individual pace and could independently make key and meaningful decisions concerning how to proceed in the inquiry activity. The teacher himself had more time at the end of the inquiry activity to fully engage pupils in reflecting on the nature of the inquiry process. It must be said, though, that a larger amount of time was possible because the activity in question was part of an elective course.

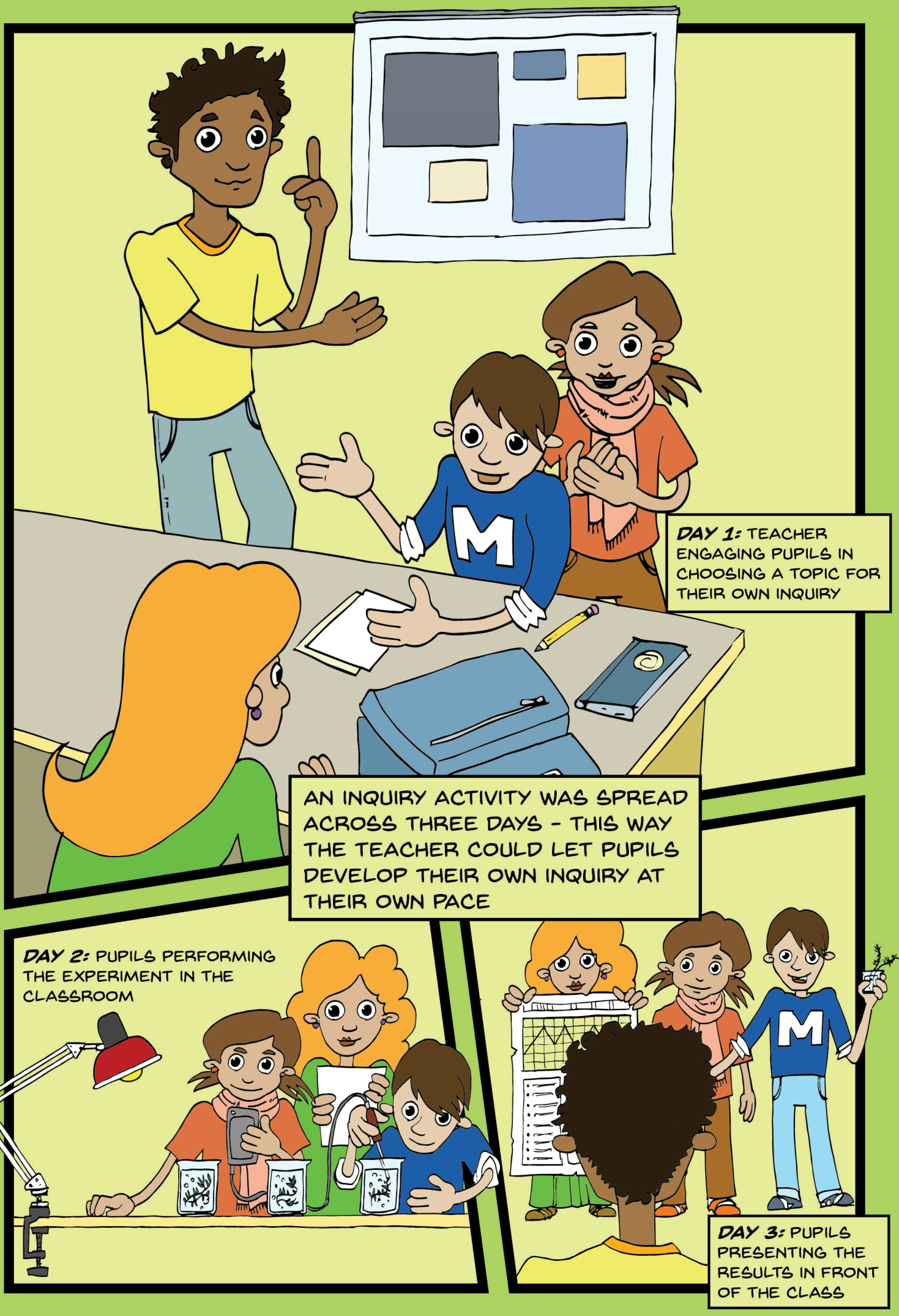
✓ **Teachers** can try to maximize their flexibility in planning inquiry lesson plans whenever possible.

✓ **Teacher educators** can help teachers strategize about methods and techniques they can use to introduce more flexibility into their given and often rigid curriculum requirements.

✓ **National Educational Authorities and Educational policy-makers** can support and introduce policies that would give teachers more flexibility to carry out inquiry activities and follow a pupil-led learning process.

Ark of Inquiry Teacher Perspective (Estonia)

"[When I have the flexibility to dedicate more time to an inquiry activity,] I enjoy what's going on in the lesson...the intuition, instantly taking advantage of the actual situation… [and] the lesson turning out to be something else, actually turning out much better. Lately it happens more and more that it's better than the [original] lesson plan – this is why you [need flexibility to] let go of the plan in a lot of places, because you just go along with the pupils and this is where the real learning actually happens".


DAY 1: TEACHER ENGAGING PUPILS IN CHOOSING A TOPIC FOR THEIR OWN INQUIRY
AN INQUIRY ACTIVITY WAS SPREAD ACROSS THREE DAYS - THIS WAY THE TEACHER COULD LET PUPILS DEVELOP THEIR OWN INQUIRY AT THEIR OWN PACE
DAY 2: PUPILS PERFORMING THE EXPERIMENT IN THE CLASSROOM
DAY 3: PUPILS PRESENTING THE RESULTS IN FRONT OF THE CLASS

Rationale 3.5: RRI is an important tool for engaging girls in science

The decline of interest in the sciences by today's European youth is even bigger in girls. Global trends indicate that there are less than 30% women working in STEM research[24]. This gender difference has its roots in adolescence with girls being less likely to retain sustained engagement or participation in the sciences[25], often due to traditional science teaching being characterized by conventional lectures and memorizing facts. The application of different teaching strategies, such as those that are pupil-centred, inquiry-based, and participatory, can help improve girls' self-confidence and improve their performance in STEM subjects[26].

Early school-based interventions through education can significantly contribute to increasing engagement and participation the STEM subjects. To attract more girls to these scientific fields of study, incorporating elements of RRI to scientific discourse in the class is crucial[27]. The Ark of Inquiry project addresses this gender imbalance in participation in the science classrooms through its inquiry model[28]. Studies show that when girls make connections to real-life issues and therefore to the larger and real world context, they are more likely to be oriented towards these STEM subjects. This is encapsulated within the project's inquiry framework, particularly the orientation and discussion phases, through the conscientious use of relatable examples, collaboration, dialogue and reflective discourse. These targeted interventions, especially the inquiry activities, were perceived to be highly engaging by boys and girls and therefore could in turn have a resounding impact on addressing this gender disparity down the road.

During Ark of Inquiry teacher trainings in Finland, it was observed that over the course of five different inquiry activities in various STEM disciplines (biology, chemistry, geology and physics), the interest level in the topic self-ranked by girls both before and after completing the inquiry activity, suffered a smaller decrease in interest or in fact increased. Both girls and boys maintained a relatively "high" ranking of interest in the activity (above 5 on a 7-point scale) before and after, but the girls' interest in the subject matter, particularly that of electricity simulation, a traditionally "male" STEM subject, increased whereas the boys' interest level remained the same. The cause of these observations is stipulated to be in the way the subject matter was taught, i.e., through the application of RRI and an inquiry learning approach.

✓ **Teachers of Science and Science Teacher Societies** have an important responsibility in creating a class culture that is conducive to equal participation of girls and boys. To achieve that, teachers can design their lessons by incorporating the components of RRI present in the inquiry model, specifically embedded within the orientation and the discussion phases. The Ark of Inquiry checklist (see below) has more information that would help in stimulating motivation and participation of all pupils within the classroom.

✓ **National Educational Authorities and Policy-makers** can support incorporation of RRI to aspects of the national curriculum of STEM subjects, which would have a bearing on fueling pupils' interest and participation in these fields.

✓ **Teacher educators** can work with pre-service and in-service teachers to design classroom activities that incorporate RRI elements.

✓ **Parents** can supplement classroom inquiry activities by adopting RRI elements at home or other non-formal learning environments. Parents can ensure that sustained interest in the sciences through extension of discussions outside the class.

Ark of Inquiry Best Practice (Global)

The Ark of Inquiry project elaborated on the pedagogical scenario on "Empowering Girls in Science" to create a checklist of strategies for teachers on how to better engage girls in the science classroom. The infographic includes simple strategies, online resources, and examples for teachers on how to include girls in science and is currently available in seven of the project languages.

Rationale 3.6: When discussion of RRI is promoted outside the classroom, it increases the staying power of inquiry learning

It is clear from many research reports that pupils' learning can be enhanced by the contribution of activities outside the classroom. The application of inquiry learning connected with RRI can multiply this effect. This can occur in teaching and learning environments where pupils are encouraged to find real life experiences and opportunities beyond their formal course assignments as given by teachers. In these situations, the learning constraints are broken apart from the schools and teachers and pupils are more willing to learn because learning comes outside of a school environment that can be perceived as binding and not playful[29].

At the DNA Learning Centre in France, studies of more than 200 pupils aged 13 to 15 have shown that there is an increase of more than 37% in knowledge acquisition when teaching is done outside the school setting[30]. It nevertheless requires an active role of the teacher or the accompanying person, who must ensure that the most comfortable pupil actually helps the person who has the most difficulty, and that the pupil accepts this aid and no one pupil simply takes charge to solve the problem alone and for the whole group. It is therefore a teaching practice that demands a high level of attention from the teacher as well as a great technicality .

In Turkey, during a nature park visit, it was observed that pupils' inquiry investigation skills dramatically increased when they explored the living things and their real environments. In particular, when pupils worked collaboratively in groups to find evidence for the problem statement as defined in the conceptualisation phase, applying an RRI approach that involved discussing sustainability implications helped them better understand why and what they were doing. During such collaborative problem solving, pupils are engaged in informal and more meaningful discussion processes than experienced when in a traditional classroom setting, that enhanced their comments and ideas about the data they collected during the investigations.

Informal learning environments outside the classroom allow pupils to interact with several societal actors (e.g., researchers, science museum staff, citizens, policy-makers, businesses, etc.) by engaging with real world research and innovation process. In such environments, RRI can be more easily understood by pupils, but teachers as facilitators also have an important role in organizing visits to informal learning environment as part of their efforts to promote RRI and to increase the staying power of inquiry learning.

✓ **Teachers** can enhance their teaching and learning activities by using informal learning activities and promote RRI beyond the classroom settings.

✓ **Teacher educators** can support teachers in designing learning modules for informal learning settings and testing them to see the effects on pupils' cognitive affective and psychomotor developments.

✓ **National Educational Authorities and Educational policy-makers** can re-design and/or develop curricula to include more opportunities to incorporate informal learning settings, based on the research results.

✓ **Science centres, museums, and researchers** can work with other stakeholders to develop and promote meaningful educational programs for schools that incorporate RRI elements.

Ark of Inquiry Pupil Perspective (France)

After engaging in an Ark of Inquiry educational workshop at the DNA Learning Centre in France, a recurring pupil testimony is "It was nice and it happened so quickly, a pity that it is no longer".

Rationale 3.7: The RRI concept favours pupils' orientation towards scientific jobs and careers

The European Research Area (ERA) highlights in its priorities the importance of an open labour market for scientists and researchers. The ERA tries to remove the barriers which block scientists and researchers' mobility, training, and attractive careers in European Union and in Developed Countries such as the USA. The European Commission strongly dwells on upon science and technology based careers of young people, predicting that Europe will need around one million more researchers in the coming years in order to stay competitive on the global stage[32]. For that reason, in all educational sectors, an improved teaching and learning environment with innovative educational methods should be provided and teachers and pupils would benefit from being better informed about European opportunities so that they choose science and technology-based careers.

The Ark of Inquiry project has taken on an important task in working to raise awareness of pupils to Responsible Research and Innovation (RRI) and in building a scientifically literate and responsible society through Inquiry-Based Science Education (IBSE). By engaging pupils through an inquiry learning approach and applying principles of RRI, as evidenced in other parts of this document, there a "ripple" that could result in positive changes in these pupils' interests and motivation toward pursuing science and technology-based research careers.

For example, during an Ark of Inquiry activity based on earthquakes in Turkey, pupils collected their own real-time earthquake data as seismologists to check against the data provided by the Bogazici University's Kandilli Observatory and Earthquake Research Institute[33]. The pupils built strong links with the seismologists as they sought to understand their research; further, a common pattern observed among all levels of pupils (primary, secondary and high schools) was the increased level of awareness about STEM-related jobs. As pupils enjoyed and took active roles during the inquiry learning cycle, they became motivated and excited about a possible future STEM career. They realized that they enjoyed working in groups, conducting experiments, designing new models based on the previous studies they made and they grew confident in themselves that this could be how they made a living in the future.

✓ **Teachers** can foster discussions about science and technology careers when pupils are working on RRI-based inquiry activities

✓ **Teacher educators** can develop innovative and creative inquiry activities with the help and support of scientists and researchers that increase pupils' interest in choosing a career in science and technology.

✓ **Pupils** can seek out RRI-based inquiry learning activities that allow them to work with real scientists to better understand the role they play in society.

✓ **National Educational Authorities and Educational policy-makers** can redesign or develop innovative educational policies that would increase pupils' interest toward careers in science, technology and innovation.

Ark of Inquiry Pupil Perspective (France)

A university student in life sciences writes: "I was looking for a job more literary-oriented, with a share of creativity but away from the sciences, with human contact, something that was varied, that makes me move a little. It was complicated. It was during inquiry-based scientific workshops in biology class that I discovered the diversity of scientific professions, including the orthoptist who studies the eye. I inquired and made contact with an orthoptist and after discussing and researching, I realized that it might just fit me! Today I am only in second year, but studies and internships confirm my conviction that this job is for me! My patients range from the newborn to the aging person. The pathologies are very varied, and one has the possibility to work as a liberal, as an employee in a structure or in between."

6

Lessons Learned and Next Steps

Much has been learned through the activities of Ark of Inquiry, both country-specific and cross-cutting for the European context. In trying to "rethink" about science teaching in Europe via inquiry learning, three broad concepts emerged: Tools, People and Ideas. These three concepts formed the foundation of the lessons learned, as encapsulated by the three Key Messages. But the lessons learned from the project are not only directed at its target audiences of teachers, researchers, policy-makers, and so on. There are also lessons to be noted for analogous projects that are running in science education and related disciplines.

For one, an already common lesson learned for European projects, there is no "one size fits all" approach to be taken when implementing activities on such a wide breadth and depth of scale as the Ark of Inquiry project. With 13 partners in 12 countries, working to reach directly or indirectly nearly 25,000 individuals in 10 different European languages, compromises and allowances needed to be made in the style, structure and approach of the training sessions conducted across the continent. Echoing well teachers' need for flexibility as discussed in rationales 2.4 and 3.4, to engage teachers as learners required much flexibility to adapt to the country- and even region-specific needs within each country, in order to ensure that the trainings were targeted to their intended audiences.

Another lesson learned as relevant for other similar projects was the need to plan early on how to sustain the accessibility of the project resources once the project had finished. In the case of the Ark of Inquiry, partners will assume responsibility for the continuation of training efforts (if any) in their own country while the portal and other resources will remain available to all for at least four years, hopefully more. Projects, European Commission-funded or otherwise, that are created at a European level need to consider the unique capabilities and commitment possibilities of the partners joining on a project and also be willing to adapt, as noted in the lesson learned above, to country- or institution-specific circumstances to assure for the smooth continuation of the availability of project resources for all who are concerned.

A final lesson learned for similar projects is to "think big": in the sense that while the needs and requirements of winning a particular project proposal tend to be quite (necessarily) specific, one should always think about how the project could have an impact in a greater sense, outside the scientific discipline, outside the target audiences, outside the geographic mandate. There is always a spillover effect for the activities that a project like the Ark of Inquiry does that can serve, if identified and steered in the right direction, to serve a greater purpose. Such a purpose can be found in the European Commission's Grand Societal Challenges or the UN's Sustainable Development Goals. If applied correctly, project activities can also contribute to such "bigger" initiatives and enhance, at minimal to no cost, the intended impact of the project in additional ways that aim towards a more sustainable and liveable future for us all.

The Ark of Inquiry project has accomplished a lot over its four-year implementation period and it is not planning on stopping there. Efforts have already been made to formally expand the project into the non-participating countries of South-East Europe (such as Albania) and the resources created by the project will remain available online as discussed above. Some project partners have translated all or parts of the Ark of Inquiry portal into their country language and the portal itself was designed in such a fashion that teachers and others can still join online and access, add and share inquiry activities on their own. Further, many of the resources and lessons from this project are already being applied and incorporated into other EU-funded projects and partner-specific initiatives, either ongoing or in the pipeline. Thus, the Ark of Inquiry project consortium is confident that partners' combined efforts will not simply be lost to the sands of time but will continue to serve their intended purpose – to help teachers apply inquiry-based learning and RRI towards the creation of a new science classroom for Europe, and perhaps, beyond.

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