FEDORA

Deliverable 5.6

Guidelines for RPOs, RFOs, HEIs and high schools on “Promoting futurized science education as key dimension of RRI”

Version 3.0

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Quality assurance

In order to ensure the quality and accuracy of this deliverable, we employed a review and validation process internal to the FEDORA Project. The deliverable was carried out by the task leader (KTU), revised and edited by the work package leader (UOXF).

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V1	01/08/2022	Shared with UOXF	UOXF provided feedback	Suggestions and edits were conducted
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Disclaimer

This deliverable contains original, unpublished work except where clearly indicated otherwise. It builds upon the experience of the team and related work published on this topic. Acknowledgement of previously published material and others' work has been made through appropriate citation, quotation, or both. The views and opinions expressed in this publication are the authors' sole responsibility and do not necessarily reflect the views of the European Commission.

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Abbreviations and acronyms

AB	Advisory board
D	Deliverable
FEDORA	Future-oriented Science EDucation to enhance Responsibility and engagement in the society of Acceleration and uncertainty
GO	General objective
HEI	Higher education institution
KPI	Key performance indicator
M	Month
MoRRI	Acronym for the project “Monitoring the evolution and benefits of Responsible Research and Innovation” funded by the EC Framework programme 7
NGO	Non-governmental organisation
R&I	Research and innovation
RFO	Research funding organisation
RPO	Research performing organisation
RQ	Research question
RRI	Responsible research and innovation
SDGs	Sustainable Development Goals
SLSE	Science literacy and science education
SO	Specific objective
SSH	Social sciences and humanities
S&T	Science and technology
STEAM	Science, technology, engineering, arts, mathematics
STEM	Science, technology, engineering, mathematics
T	Task
WP	Work package

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Executive summary

The deliverable outlines the guidelines for RPOs, RFOs, HEIs and high schools on "Promoting futurized science education as key dimension of RRI". It builds on the recommendations produced by WP1-5, interviews and discussions with RRI experts. The guidelines connect the AIRR principles of RRI, reflect on the MoRRI indicator SLSE1 and SDG4 targets 4.7, 4.3 and 4.4. The guidelines suggest that promoting science education as the key pillar of RRI, some changes have to be initiated by RFOs as institutional changes usually follow funding decisions. Therefore, based on research evidence from the FEDORA outputs in WP1-5, RFOs are expected to promote interdisciplinarity by revising HEIs/RPOs funding principles, engage in stakeholder dialogue to increase relevance of funded research to real life problems and promote futures studies in some national contexts. Consequently, RPOs could develop human resource management practices which favour interdisciplinary research and create "third spaces" which enable sense making and strange making practices. Finally, HEIs as science education providers should integrate futures thinking as a 21st century skill into curricula, balance creative thinking and system, critical thinking skills as learning outcomes, and rely on class activities and methods which speak the language of contemporary youth.

Introduction

This deliverable is an output produced by task 5.4 of the WP5 “Recommendations for proactive and anticipatory policy making” which develops policy briefs on futurizing science education on the basis of the research evidence from WP1-4. More specifically, D5.6 takes into account the research findings in the project frameworks 1-2-3 as well as recommendations produced by WP4 and analyses them from the perspective of the responsible research and innovation (RRI).

RRI is a normative concept denoting “a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)” (von Schomberg, 2012). There are four conceptual dimensions which outline the ethical and future-oriented perspectives of RRI as a process and a product, abbreviated to AIRR: anticipation, inclusivity, responsiveness and reflexivity (Stilgoe et al., 2013). Sustainability and care are also seen as emerging principles which constitute the RRI dimensions (Burget et al., 2017). The dimensions set demands to both individuals and industrial and academic institutions to apply forecast and anticipatory governance to benefit society.

As noted by Owen et al. (2012), the concept was introduced and operationalised by the European Commission in its funded research programmes: Framework Programme 6, 7 and subsequently Horizon2020. MoRRI indicators represent a result of the EC Framework Programme 7 funded project MoRRI - “Monitoring the evolution and benefits of responsible Research and Innovation” that was realised in 2014-2018. It aimed to offer a tool for the EU countries to measure progress of national R&I governance systems from the responsibility dimension. The indicators covered 6 pillars of institutionalising RRI, i.e. gender equality, science literacy and science education, public engagement, ethics, open access/open data, governance in 36 items.

The initially planned deliverable was meant to elaborate on the MoRRI indicator in the domain of science literacy and science education, i.e. **SLSE 1:** “Importance of societal aspects of science in science curricula for 15-18-year-old students to embrace the future and diversity dimensions" (Spaini et al., 2018). The attitudes that describe the importance of societal aspects of science were measured by conducting interviews discussing controversial science topics in 28 EU countries in 2016 and desk research. In interviews, 15-18-year-old students were asked the question "Does the curriculum address the controversial character of either one of the two topics GMO and nuclear energy?", which was further broken down to ask for societal, environmental and ethical aspects, topping the enquiry with a question on the degree of coverage (with the answer options 'substantially/superficially/not at all').

Designing of the MoRRI indicators also included desk research and analysis of the secondary data from other pan-European surveys such as Eurobarometer, She-figures, WoS and Unpaywall (Ryan et al., 2022). Monitoring the SLSE1 indicator covered data from two questions in the special Eurobarometer opinion poll (EB401, 2013) that (beside general questions on science and technology) focused on RRI and one question from the special Eurobarometer opinion poll 63:1 (2005). The two questions that were taken from EB401 (2013) dealt with population's interest in science and technology (as indicated by answers to the question 'How interested are you in development of science and technology?', answers ranging from "not at all interested" to "very interested" in the scale of 1-4, option 5 being "do not know") and informedness about developments in science and technology (as indicated by answers to the question 'How informed do you feel in developments of science and technology?', answers ranging from "not at all informed" to "very well informed" in the scale of 1-4, option 5 being "do not know"). The third question is QA10 from EB 63:1, which is called a textbook knowledge quiz. It outlines 13 statements and asks a respondent to answer whether the statement is true or false, with the third option of "don't know". The statements are as follows:

1. The Sun goes around the Earth
2. The centre of the Earth is very hot
3. The oxygen we breathe comes from plants
4. Radioactive milk can be made safe by boiling it
5. Electrons are smaller than atoms
6. The continents on which we live have been moving for millions of years and will continue to move in the future
7. It is the mother's genes that decide whether the baby is a boy or a girl
8. The earliest humans lived at the same time as the dinosaurs
9. Antibiotics kill viruses as well as bacteria
10. Lasers work by focusing sound waves
11. All radioactivity is man-made
12. Human beings, as we know them today, developed from earlier species of animals

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13. It takes one month for the Earth to go around the Sun

The MoRRI indicators report (Spaini et al., 2018) does not explain how the interview data were handled in combination with the desk research results to arrive at the current indicator.

Finally, the FEDORA project efforts are aligned with SDG4 "Ensure inclusive and equitable quality education and promote life-long learning opportunities for all" and its targets related to social, humanistic and moral purposes of education for sustainable development, to ensure equal access for all women and men to affordable and quality education and to foster vocational skills. The SDG4 targets are quoted below in the order of importance to the FEDORA objectives, followed by the UN indicators for monitoring their achievement (as approved by the United Nations General Assembly, 2017, considering the latest available version of the annual refinements of the Global indicator framework – United Nations Secretary-General, Inter-Agency and Expert Group on Sustainable Development Goal Indicators, 2022):

SDG 4.7: by 2030 ensure all learners acquire knowledge and skills needed to promote sustainable development, including among others through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development. The indicator for monitoring achievement of the target is 4.7.1: Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment.

SDG 4.3: by 2030 ensure equal access for all women and men to affordable quality technical, vocational and tertiary education, including university. The indicator for the target is 4.3.1: Participation rate of youth and adults in formal and non-formal education and training in the previous 12 months, by sex.

SDG 4.4: by 2030 ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes. The indicator for the target is 4.4.1: Proportion of youth and adults with information and communications technology (ICT) skills, by type of skill.

The deliverable contributes to one of the general and several specific objectives of the project:

GO4) Support the young generation to increase their personal and public engagement in science, their employability within a comprehensive view of "smart, sustainable and inclusive growth" (EC, 2016: 30), and their hope, trust, desire, visionary and proactive moods in this accelerated, multi-velocity, complex and uncertain society.

SO6) To flesh out, from the three knowledge bases, a research-based model for science education that prepares the young generation for the society of acceleration and uncertainty.

SO7) To equip, through the implementation of the model in educational contexts, 11-19 years old people with thinking (inter-multi-transdisciplinary, linguistic-argumentative-imaginative) and future-scaffolding skills needed to navigate and participate in science within the society of acceleration.

SO8) To improve, through the implementation of the model in different educational contexts (formal, informal and non-formal), scientific literacy, public engagement and the quality of the ways young people understand, react to and interact with science, and their motives for engaging in science-related activities.

SO10) To futurize science education, one of the dimensions RRI, and, in particular, the MoRRI indicators that refer to Science Literacy and Science Education.

SO11) To design policy recommendations to value Science Education as crucial dimension of RRI to align multi-velocity institutions and prepare effectively the young generation to become science co-creators and/or responsible citizens in a society of acceleration and uncertainty.

These objectives were approached by three actions under T5.4:

a) Meta-analysis of FEDORA policy recommendations produced by the other WPs from the MoRRI-SLSE indicators (SLSE1 in particular) and SDG4 (4.7, 4.3, 4.4) perspectives.
b) RRI expert written interviews.
c) RRI expert discussion organised in Brussels as part of the final project event in M33 to refine the measurement of SLSE1 based on the FEDORA results and align the FEDORA results with SDG4 targets 4.7, 4.3, 4.4.

In the next section the process of each action is described.

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1. Sub-tasks carried out

According to the description of T5.4, the following actions were planned:

1) KTU analyses policy recommendations produced by the other WPs from the perspective of the RRI concept, MoRRI-SLSE indicators and SDGs and produces guidelines for RPOs, HEIs and RFOs how to futurize science education as a core dimension of RRI.
2) The findings are discussed with the RRI community to address the project results such as developed modules and their implementation results from classrooms. Expert interviews (a small scale, 10-12 informants) with representatives of the RRI community (e.g. consortium members of the MoRRI, Super MoRRI and related projects) will be carried out by skype or any other ICT tool or face-to-face in public events such as conferences related to RRI.
3) A workshop explicitly organized to feed FEDORA results in refinement of the MoRRI indicators with the RRI community and with MoRRI related projects is organized in Brussels in M34.
4) Based on the results of their evaluations, meta-analysis of FEDORA outputs (e.g. modules, recommendations for policy briefs) will be elaborated to strengthen the dimension of futurizing science education in RRI. More specifically, suggestions to elaborate the MoRRI indicators related to SLSE 1- Science curricula are provided. The suggestions will be consistent with the SDGs related to social, humanistic and moral purposes of education for sustainable development, to ensure equal access for all women and men to affordable and quality education and to foster vocational skills (SDG 4.7; SDG 4.3; SDG 4.4). These outcomes will be presented and discussed in the final conference (M34) and summed up into guidelines to futurize RRI and, in particular, Science Education as a dimension of RRI (M36).

While implementing the project, the following sub-tasks were carried out:

i) Meta-analysis of FEDORA policy recommendations produced by the other WPs from MoRRI-SLSE indicators and SDGs perspective. The frameworks produced by WP1-3 as well as recommendations from WP4 and draft policy briefs of WP5 were analysed from the perspective of SLSE1 and SDG4 specific targets 4.7, 4.3, 4.4 in relation to different stakeholders (RPOs, HEIs, RFOs and schools). More specifically, this part of analysis was carried out on the basis of these deliverables:

- D1.2 "FR1 - Framework for aligning science teaching/learning in formal contexts with the modus operandi of R&I: new inter-multitransdisciplinary forms of knowledge organization for co-teaching and open-schooling",
- D2.5 "FR2 – Framework for aligning science education with society: the search for new languages and narratives to enhance imagination and the capacity to talk about the contemporary challenges",
- D3.3 "FR3 - Framework to futurize science education",
- D4.2 "FEDORA materials' effectiveness to develop thinking and future-scaffolding skills and to foster aware, responsible and proactive engagement with science: results and hypotheses from the first round implementations", and
- D5.5 "Policy Makers' Views on a Model of Science Education for the Society of Acceleration and Uncertainty – the FEDORA Concept".

In addition, information on elaborating MORRI indicators by other EC-funded projects was sought to reflect on the implications of the FEDORA results to SLSE1 and futurizing science education. In particular, D6.4 "Recommendations report on improvements to MoRRI indicators for European RRI initiatives" from the RRING project (Jensen and Tash, 2021) and D4.1 "Methodological aspects of science education assessment" from the PERFORM project (Heras et al., 2016) were taken as input for reflection. Moreover, consideration has been given to the methodology of originally developing SLSE1 in the MORRI project.

ii) RRI expert written interviews (N=15, n=10) were carried out in May 2023. The experts for the workshop were selected on the basis of two criteria: 1) a person has held leadership role(s) in EC-funded FP7 and Horizon2020 projects focusing on RRI (e.g. CheRRIes, FIT4RRI, GRACE, GRRIP, HEIRRI, MoRRI, Res-AGorA, RRING, SeeRRI, Super MoRRI, TeRRItoria etc.) and/or 2) a person has published research papers on RRI or has otherwise actively participated in the network of RRI community. Besides, persons who committed to support the FEDORA project at the proposal writing stage by letters of support were also included in the general sample. These criteria were considered as evidence for sufficient knowledgeability in the conceptual dimensions of RRI and their operationalisation and/or monitoring as usually there are contractual obligations for EC-funded projects to embrace implications to RRI indicators such as MoRRI. Moreover, as post-FP7 projects have to address the RRI dimension in their project findings, participation in the EC-funded projects was regarded as evidence for reflection on one's research results from the RRI perspective.

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15 experts were approached by publicly available emails requesting to take part in a fully anonymous written interview that contained one open-ended question that was worded as follows:

> *"In the policy brief of the project MORRI "Monitoring the evolution and benefits of Responsible Research and Innovation in Europe" Jack Stilgoe (2018) wrote, referring to Wilsdon et al. (2015): "Drawing an accurate picture of research and innovation with the aim of assessing and improving RRI therefore demands a broad set of indicators and a recognition that metrics will always be incomplete."*
>
> *Considering this principle, in your opinion, how well does MORRI indicator SLSE1 ("Importance of societal aspects of science in science curricula for 15 to 18-year-old students") capture dynamics of science literacy and science education in society? What could be elaborated in this indicator so that it reflects the quality of science literacy and drives science education for sustainable development?"*

The approached experts were informed that their answers would be treated absolutely anonymously and confidentially and will be used to sparkle the discussion during the FEDORA final meeting in Brussels on May 25, 2023 and feed into the present deliverable. 10 experts provided their views. Neither socio-demographic characteristics nor personal data were asked to encourage the experts' openness and any critical insights about SLSE1 indicator. From the dichotomous gender perspective, the approached persons can be identified as 8 males and 7 females. The received responses were coded as experts in sequence E1, E2, E3 etc. It was not expected that the experts make any relation between this indicator and FEDORA findings so that more general views could be elicited and used for elaborating SLSE1 with the input from FEDORA.

iii) RRI expert discussion organised in Brussels as part of the final project event in M33 to refine the measurement of SLSE1 based on the FEDORA results and align the FEDORA results with SDG4 indicators 4.7, 4.3, 4.4. The same two criteria as above were used to identify and approach the experts. Invitations to 18 experts were sent by publicly available emails, 8 experts agreed to come to the workshop.

Before the workshop the experts were provided with a link to the project website which contains many resources and outputs. Specifically, they were asked to read FEDORA's

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deliverables D3.2 "Future-oriented science education manifesto", D4.3 "FEDORA materials' effectiveness to develop thinking and future-scaffolding skills and to foster aware, responsible and proactive engagement with science: results and hypotheses from the first round implementations" and the project handbook "Pathways for a future-oriented science education" which contain brief summaries of each work package. At the meeting, the experts were presented with the key findings from WP1, 3 and 4 as they directly dealt with interdisciplinarity as an approach to developing young people's skills as well as their perspectives and experiences in science education.

The Advisory board members, prof. R. Duschl and dr. L. Tauginienė took part in the workshop alongside with the representatives of the project partners present in the final events. Altogether, the number of participants was 20. The workshop was carried out using the *World Cafe method*: the participants were divided into 4 groups, each group critically reflecting one of the three questions from the Eurobarometer questionnaires in relation to SLSE1 and one question related to the SDG4 targets (see Table 1 for the discussion questions), 15 minutes each, taking rounds (see Annex 1 for the scheduling of the workshop).

Table 1. Discussion questions for the RRI workshop participants

1. Interest in science and technology Discussion focus: which FEDORA's topics do you see most relevant to foster interest in science of the young generation and advance their science literacy? How can future be integrated as part of interest in science and technology?
2. Informedness about science and technology Discussion focus: How can FEDORA's results develop informedness of the young generation about science and technology? What scope/depth of informedness is expected to be indicative of a change in science literacy and education? (What quality should informedness contain?)
3. Textbook knowledge Discussion focus: how can FEDORA results inform curricula of science education? Why do you think they are important?
4. SDG: 4.3 ,4.4, 4.7 Discussion focus: how can futurized science education (curricula, didactics) contribute to equal access to education, skills and sustainable development in practice?

A moderator and an assistant from the project team's members were appointed for each World cafe group to take notes, identify emerging themes and ascribe discussion points to them. Consequently, reporting of the outputs took 10-15 minutes for each group (see Figure 1 for the outputs of the workshop), during which notes by the task leader were taken.

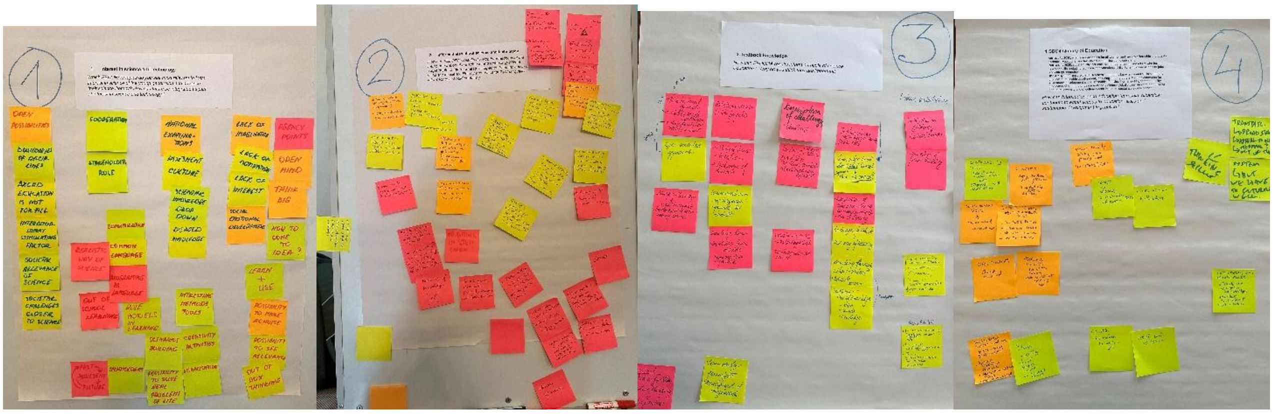

Figure 1. Outputs of the RRI workshop discussion

Content analysis method was applied to all the data generated under T5.4 to explore the role of science literacy and science education in society and RRI and identify implications of the FEDORA findings to SLSE1 and SDG4 targets. Analysis of the findings (section 2) from each subtask has led to formulating the Guidelines for RPOs, HEIs and RFOs how to futurize science education as a core dimension of RRI (section 3).

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2. Findings

The findings are reported following the sequence of the conducted actions.

Meta-analysis of FEDORA policy recommendations produced by the other WPs from MoRRI-SLSE indicator (SLSE1) and SDGs (4.7, 4.3, 4.4) perspectives

The MORRI indicator SLSE1 can be criticized for lack of explicitness in the methodology and the need for collecting primary data, which is costly. Reliance on secondary data such as Eurobarometer opinion polls can be informative, yet still meet criticism. The Eurobarometer questions are not specific enough as indicators for monitoring progress on the learning outcomes of science education, which was spelt as a warning in D63.2 of the MORRI project. The textbook knowledge quiz as a measurement of science literacy can also be criticized as it does not give a chance to the respondents to demonstrate a perspective on different lenses that could be applied to the recent developments in technologies such as artificial intelligence.

Recommendations based on the findings of the WP1 part studies (Pucetaite and Rauleckas, 2023) propose interdisciplinarity as a way of learning to navigate in the world by taking different lenses – different epistemological perspectives to real life problems, to be a "disciplinary nomad" at individual level, creating "third spaces" which create a context to practise sense making and strange making skills which are needed for science education at institutional level and aligning science policies and governance with institutional human resource management practices to motivate researchers to engage in interdisciplinary research and pedagogy. WP1 has also argued about lack of graduates' skills to apply scientific knowledge to real life problems and based on the findings proposed to foster the connection between formal and informal education, integrating scientific uncertainty and philosophy into science curricula to develop interdisciplinary competencies such as perspective taking and thinking big. In addition, based on literature review findings that mentioned social insensitivity as an obstacle for science education and literacy, the recommendations to educational institutions suggested offering curriculum differentiation for students' diversity. In other words, gender, cultural and socio-economic background of students are factors for students' perceptions and feeling of being informed about and interested in S&T developments. Following the Eurobarometer survey findings (EB401, 2013) which indicate that informedness about and interest in S&T have strong correlation, finding a way to engage students in science learning by their socio-demographic characteristics may result that they

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feel more informed about S&T developments, leading to stronger interest in S&T.

Recommendations from WP2 (Troncoso et al., 2023) to policy makers were built on the identified four 'new' languages which may lead to more effective science learning, communication and education: Languages for adaptation, Languages for foraging futures, Languages for uncharted territories, and Languages for interdependencies. Educational systems must accommodate experimental spaces which allow their participants to experiment and play with different perspectives in science, not being restricted by disciplinary boundaries. Understanding complexity of problems and challenges to society can be enabled by a non-binary thinking (e.g. disciplinarity vs interdisciplinarity) and professional identities which are not bound to one discipline. Continuous learning by teachers themselves to develop imagination and creativity is also recommended as a step to futurize science education. As European societies are profoundly changing and triggering an epistemic emotion is a pre-requisite for deep learning, D2.5 suggested some activities that challenge Western views to science and allow to empathise with emotions of students from different backgrounds. In addition, it offered some methods such as storytelling, exploring the surrounding with sounds and video or arts which help to "make memory" and practise sense making and strange making skills.

The recommendations produced by WP3 in D3.3 (Rasa et al., 2023) addressed several issues among which young people's powerlessness, detachment and polarization-oriented thinking were in focus. The recommendations were targeted at policy-makers, curriculum developers and teachers education and proposed to use futures thinking to incorporate future concepts in science curricula and teacher education programmes. This is needed to develop human agency and empower both students and teachers. It is maintained that imagined futures should be based on values, dream and choices to activate agency. Moreover, personal, gendered, cultural, religious, socio-economic dimensions of futures thinking were argued to be understood and addressed to enable science literacy. The research findings of this WP demonstrate that dichotomous thinking is a reality that accounts for the lack of imagining alternatives of future. Consequently, this undermines possibilities of inclusive education as "future-oriented education cannot be a singular future" (p. 34).

D3.3 has strong implications to establishing futures literacy as an essential competency for the 21st century, and making education accessible and inclusive rests on critical, creative and empathetic thinking as well as the capability to cooperate and engage in an interdisciplinary dialogue with the diversity of languages. In general, society's diversity cannot be embraced in education if democratic dialogue skills are missing. Marginalised social groups may be given voice by searching for solutions via science activities in formal and informal environments That helps to build relevance of science education, better understand nature of science and enable participation in the scientific discourse in a society. Hence, interdisciplinary projects are seen as a pathway to the mentioned outcomes.

Based on findings from the first round of trial classes under WP4 where the open-schooling and interactive, participatory approach, originally developed interdisciplinary topics with resources that use new languages and rely on future studies were applied, D4.2 (Tasquier and Barelli, 2023) documents significant impact on the skills of futures and systemic thinking, perception of variables constituting complex systems and articulating to oneself their own role in impacting them (i.e. developing agency as part of identity), voicing their emotions in relation to change and expectations to policy makers (i.e. choosing an authentic way to express oneself), conceptualising and re-conceptualising the phenomena by switching language registers from scientific to narrated. Furthermore, some of the trialled classes went beyond just one set of thinking skills or feelings and aimed at balancing, e.g. systemic and creative thinking, making sense of the variety of epistemic emotions without polarising them into positive and negative ones, being authentic and acting as a group member, developing students' understanding of interconnectedness between different science disciplines and promoted both individual and collective motivation for action taking for social, environmental causes and public values. The results of the second round of trials will be available in M36. The trial was based on the frameworks produced by WP1-3 as well as two competence areas (i.e. Embracing complexity in sustainability and Envisioning sustainable futures) of the GreenComp, the new European sustainability competence framework (Bianchi et al., 2022), which can be regarded as a recommendation for redesigning learning outcomes of science education. It also integrated SDG4 targets (in particular, inclusivity from the gender and culture perspectives) and SLSE1 and SLSE3 (science communication).

Finally, D5.5 of WP5 (Erduran and Chan, 2023) outlines the results from the Delphi study with policy makers in national settings and offers consensus-based recommendations to be extrapolated by policy-makers beyond national contexts. The strongest agreement between participants translates into respective recommendations for policy makers on promoting futurized, accessible and inclusive science education. These findings supported the findings from the other WPs. To specify, based on the findings, science education could promote competencies for imagining the future and addressing future challenges by integrating interdisciplinarity, promoting imagination and including socio-scientific issues into curricula. Policy-makers also agreed on the need of critical thinking, problem-solving skills and creativity to address future challenges. Critical thinking, interdisciplinarity and imagination were also considered as the skills which help students to envision futures. To promote students' ability to think about their own and global future a feeling of agency found the strongest agreement. Policies to stimulate these developments were expected to promote collaboration between stakeholders, align educational goals with resources and revise teacher training programmes. Collective acting for positive global future was also seen as dependent on the extent of informedness about problems and impacts of individual actions on e.g. eco or social systems. Dialectic activities between different stakeholders is one of the key recommendations for developing future-scaffolding skills via science education policies.

The results of the FEDORA actions directly relate to MoRRI SLSE1 and SLSE3 by arguing the need and possibility to develop critical and systems thinking skills alongside futures thinking and imagination and enabling young people to deal with complex societal problems and challenges in the context of technological progress. They offer approaches and resources to facilitate enactment of interdisciplinarity in science education, aligning it with the modus operandi of R&I. They propose new languages in the form of narratives, visualisations, audio and video resources, engaging in learning activities in the spaces which do not bear single discipline artefacts. They expand the understanding of science literacy with the futures thinking skills and futures consciousness and have potential to enrich indicator SLSE1, in line with the UNESCO Futures Literacy programme (Miller, 2018) and the EC GreenComp (Bianchi et al., 2022). The results feed the SDG4 targets by proposing the ways of building inclusivity via science education as well as research performance and funding. They argue for dialectical science education and multi-perspective communication, creating an opportunity for voicing diversity of (marginalized) social groups and enacting participatory principles which are pre-requisites for democratic governance and creation of relevance of science to everyday life.

RRI expert written interviews

The answers provided by the RRI experts in the written interviews criticized the present SLSE1 on several grounds: a narrow age group in focus, lack of rigor in capturing quality and dynamics of science education, uni-directionality in science communication presupposed by

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its current focus/object, lack of contextualization to a particular society or institutional level (although acknowledging that MORRI are national level indicators), e.g.:

E1: *"…it is a very narrow and inaccurate indicator as it is only about a reduced age group (which is not yet in the policy decision level/age) and therefore, it will be more a qualitative indicator of the future society literacy or just interest in science. Furthermore, it is very open to interpretation of what are the societal aspects of science leaving low options for comparability among countries, regions*".

E6: "*SLSE1 captures only a fraction of the dynamics of science literacy and science education in society*"; E7: "*Hardly SLSE1 captures dynamics of science literacy and science education in society*"; E8: "*…SLSE1 would capture science education in the society to some extent, but does not capture quality and/or dynamics of science literacy at all*"; E10: "*In my opinion, this indicator is a very general one and does not reflect the depth of literacy nor knowledgeability in a certain field of science*".

E3: "*It [SLSE1] is a precondition, that does not guarantee visioning and implementation of responsible science communication. Science communication should be more bi-directional in the first place*".

E3: "*The indicator SLSE1 is a country level indicator that does not necessarily reflect the institutional efforts on science communication. So in that sense it hardly reflects the quality of science literacy and science education*". E5: "*The SLSE1 indicator is general and must be contextualised and interpretated*".

More specifically, some experts saw potential flaws with operationalization of the object it attempts to measure, i.e. "importance" and "societal aspects" or even the concept of science education which varies by different educational systems in cross-national contexts, e.g.:

E8: "*First, as the indicator "provides information on the extent to which societal aspects of science and technology are mentioned in the curricula as important aspects for teachers to include in their teaching." (MORRI D3.2 https://super-MoRRI.eu/MoRRI-2014-2018/), it is not clear how measurement of the "extent" and "important" would be accomplished and what concrete "societal aspects" would be covered. Thus, clarification of the measurement procedures and conceptualization of the terms would be useful*". E10: "*From a contextual viewpoint, not every country uses the term "science education" in a native language and rather focuses on specific disciplines in their education systems, so I wonder how national questionnaires ensure robustness of measurement and cross-country comparability*".

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As a result, it may be the reason SLSE1 becoming less relevant to monitor progress of RRI in national contexts and will likely be eliminated, which also has implications for the purpose of elaborating it on the one hand as quality data is missing and collecting primary data is too costly e.g.:

> E9: "*Generally, I would recommend to take a very flexible approach re the MoRRI indicators. MoRRI had the objective to develop indicators for the national level. It was a not very useful step of the Commission when they required SwafS projects (and others) to apply MoRRI indicators to the meso and micro levels of projects. In addition, to my knowledge, the successor project of MoRRI is most likely to drop many of the original MoRRI indicators. This includes SLSE1 (due to data quality and availability issues, and due to limited explanatory power). And thirdly, the broader policy landscape has changed since the development of the FEDORA project, entailing a demise of RRI and the RRI keys*".

The policy changes relate to the rise of the concept and policy of open science that is mentioned by another expert:

> E1: "*…the 2019 [UNESCO] Recommendation on Open Science, much more broad concept that Science education or literacy. The expert groups are working on suitable indicators for the monitoring framework and capacity building*".

The suggestions for improving the indicator varied from relying on SDG4 through focus on futures thinking skills to elaborating the marker itself (e.g. shifting the focus of measuring from the perception of importance to the range of subjects studied and / or scientific agency (e.g. if and how scientific knowledge helps (is applied by) a person to solve real life problems), i.e. moving from monitoring cognitive to transversal skills such as values and capability to act in different contexts based on scientific knowledge, e.g.:

> E1: "*The intergovernmental programme for the Management of Social Transformations (MOST) is also working closely with the Future literacies programme understood as the skill that allows people to better understand the role of the future in what they see and do. Being futures literate empowers the imagination, enhances our ability to prepare, recover and invent as changes occur*". E5: "*The central point is to empower pupils to get involved in addressing societal challenges and forming the future (which is well alligned with the purpose of RRI).*". E7: "*Perhaps the focus should be not on importance, but inclusion of societal aspects of science in*

curricula in general (e.g. multiple subjects) and deriving short- and long-term achievements (e.g. participation in contests, pursuance of scientific career)".

These suggestions are in line with the methodological arguments proposed by the PERFORM project, i.e. how to assess the learning outcomes of science education in relation to RRI values. These include respective dimensions and criteria: inclusiveness of all participants (balanced participation and fostering dialogue among participants), gender (gender equality in participation, approaching critically gender issues), engagement (emotional and cognitive engagement), critical and creative thinking (questioning and reframing, systems thinking, connecting topics with experience, seeking other points of view), and ethical aspects (understanding of the nature of science (NOS), social relevance of topics addressed, participants acceptance of process/outcomes, connecting scientific topics with values). The indicators suggested by the PERFORM project can be effectively measured at institutional level, yet they are difficult to be captured via secondary data and a cross-national perspective.

Besides, the Education for Sustainability concept proposed by UNESCO in 2019 was referred as a substitute for SLSE1 and other MORRI indicators, e.g.:

> E1: "*Education for Sustainable Development (ESD) empowers learners through providing knowledge, skills, values and attitudes, and building necessary competencies, including system thinking, anticipatory, normative, strategic and collaboration competencies, and critical thinking, so that they can take informed decisions and make responsible actions for environmental integrity, economic viability and a just society with empowered people of all genders, for present and future generations, while respecting diversity*".

The same point was stressed in the RRING project's D6.4 (Recommendations) which argued that MORRI indicators cover just the EU Member States and require granulation, while UNESCO Recommendation on Science and Scientific Researchers is targeted at almost 200 countries and monitors policy measures and indicators across at least 10 areas of RRI. Therefore, they suggest that impact of future research initiatives should be linked to this set of recommendations. As noted by the RRING team, MORRI indicators have also proven inadequate for institutional level, which was the reason why Super MORRI was granted funds to adapt the indicators to organisations.

RRI expert discussion organised in Brussels as part of the final project event in M33 to refine the measurement of SLSE1 based on the FEDORA results and align the FEDORA results with SDG4 targets 4.7, 4.3, 4.4.

At the World Café table 1 "Interest in S&T" where discussion centred on the FEDORA's topics which seem most relevant to foster interest in science of the young generation and advance their science literacy and the ways that future could be integrated as part of interest in S&T, the discussants found interdisciplinarity as one of the key topics and approaches to make science education relevant, enable addressing real life problems, reduce tensions and stress arising from challenges when learning sciences. Relevance of science to practical life was among the key themes when discussing approaches to science education, in particular when binding science and society, helping society to deal with challenges. Interdisciplinarity was seen by the experts as an approach that empowers young people to deal with problems without being restricted to a single discipline of knowledge and possibility to make a choice of what professional path to follow. Yet, as noted by the experts, interest in how science can serve the future must be supported by respective resources which help young people to apply scientific knowledge to real life problems, combine past, present and future perspectives, use language of technologies, which is generally missing in the present classes. In this respect, cooperation between schools and HEIs with stakeholders outside the academic realm, out of school learning are perceived as necessary. These methods and approaches could help society to address the issues of young people's lack of motivation to study science, lack of interest in it, lack of imagination on how to apply scientific knowledge in practice and promote socio-emotional development of the young generation.

Table 2 "Informedness about S&T" discussion that revolved around the applicability of the FEDORA's results to developing informedness of the young generation about S&T and the scope/depth of informedness that could indicate a change in science literacy and education yielded suggestions about considering the role of the human in science, including agency as a learning outcome into measuring academic achievement, and the FEDORA's findings could rely on UNESCO's futures literacy programme to promote futures thinking skills as a learning outcome and indicator of feeling informed about S&T. Imagination was often referred to as a skill that should be considered as a marker of informedness. For example, introducing societal challenges and taking an imaginative approach to solving them with technological assistance, e.g. virtual environment was proposed as a way to engage students in science learning and measure change in their perceptions. Moreover, such an approach would be seen as connecting past, present and future. On the other hand, fostering imagination should balance with framing, which must be delicate as there are many layers of knowledge to be crossed. Science literacy could rest on ethics as a dimension of science. Ethical reasoning could be trained via imaginary exercises on e.g. ethics of artificial intelligence. Informedness may also capture the capability to distinguish between good and bad science as a facet of critical thinking. Agency was suggested to be stimulated and evaluated through the process and outcomes, which would require teachers to consider also the process of learning. It would mean revising planned activities and actions during the classes so that they become opportunities to challenge their knowledge of science. Still another suggestion for monitoring change in science literacy and education included students' STEM careers pursued after graduating. Finally, language for describing students' problems and challenges was perceived as missing alongside textbooks taking an anti-historical perspective and encouraging students to ask right questions instead of learning right answers.

Discussion at table 3 "Textbook knowledge" that asked the participants to consider the ways the FEDORA project could inform curricula of science education has yielded a suggestion to rely on the three blind spots identified by the FEDORA project which translate into the needs for an interdisciplinary approach in science education, new languages and a historical perspective in science education. Science education should form an understanding about the nature of science as shifting and temporal. Meeting these needs requires problem- or project-based learning with problems that are faced by society raised in the textbooks. To offer a solution to a problem, the metaphor of lenses was seen as helpful. Therefore, according to the discussants, curricula should reflect methods rather than topics. The participants lingered on the problem of language that textbooks use: it is perceived as less and less recognizable by contemporary students. Rise of ChatGPT in general questions the use of textbooks for science education. Studying science should rely on cases, fiction movies, short videos, podcasts so that more than one sensation is used in the learning process. Learning spaces that are free from curricula could enable this learning.

Finally, table 4 which related science education with SDG4 by asking the discussants to reflect on the ways futurized science education could contribute to equal access to education, development of skills and sustainable development in practice, saw new languages as a facilitator for equal access to science education. Science education by single disciplines and respective organization of knowledge into disciplines were perceived as a game of power: boundaries of disciplines maintain science as elitist. The experts maintained that science education should not be a linear process, it should develop horizontal (transversal, also "soft", although this term was not liked), critical thinking, solution thinking and anticipatory skills. Developing agency in students should also consider cultural background which socializes persons into gender roles. Gender education was seen as necessary at primary school, firstly, as prevention against stereotyping.

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In the wrap-up discussion scientific citizenship was mentioned as a constituent of science curricula to develop the agency skills. A possibility to experience to move from theory to evidence and back to practice in the process of learning was related to active learning. To foster sustainable development and its goals, emphasis on the AIRR principles should be placed, which, in the discussants' perspective, align well with the FEDORA's findings: anticipation is related to future-scaffolding skills, responsiveness with agency, reflexiveness with redefining problems and taking a problem-based approach to dealing with challenges, inclusiveness with collective action taking as the agency capacity. Another important aspect highlighted in the discussion was having choice: students were considered to have different needs, even with regard to reading books, which enables agency and voice. Interaction should be dialectic. Science education is expected to give broad skills, although at table 1 discussants noted that broad education is not for everyone. Hence, dealing with uncertainty in the changing world is another skill that must be learnt through science education, and keeping an open mind was seen as a prerequisite for the ability to change.

To sum up, the FEDORA outputs are rich in developing evidence-based guidelines on futurizing science education as a core dimension of RRI. As evidenced by the RRI expert discussion, FEDORA findings integrate the AIRR principles which are at the core of the RRI concept: anticipation is embodied by combining futures and creative thinking with critical and systems thinking; inclusion is enacted by participative activities and polylogue between educational institutions and their stakeholders; responsiveness is addressed by individual and collective agency; and reflexivity is attained by mastering to integrate numerous identities, taking different lenses when analysing complex issues, crossing boundaries between disciplines, using new languages, narration and storytelling. These skills bring other dimensions of RRI into effect: they ensure equality of diverse (i.e. going beyond gender equality) students, researchers and teachers; practices of enacting interdisciplinarity go beyond formal ethics management systems by building informal practices of treating everyone with respect and dignity, diminishing the possibility of power games and exclusion by communicating science in languages that are understood by diverse public audiences; participatory skills contribute to normalising stakeholder dialogue and building effective governance processes and public engagement in science through, e.g. citizen science activities.

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3. Guidelines for RPOs, HEIs and RFOs how to futurize science education as a core dimension of RRI

As RPOs and HEIs usually follow science policy and the decisions that are made by its implementing bodies such as RFO, the FEDORA guidelines to futurize science education as a core dimension of RRI will start from this addressee.

Guidelines for RFOs

1. Promote interdisciplinarity by revising HEIs/RPOs funding principles

As identified in WP1, RPOs and HEIs direct their management and administration practices following the direction set by RFOs. As long as they set research rewards based on disciplinary fields, institutions will not likely enact interdisciplinarity as a normal practice and individuals will be less motivated to combine multiple professional and scientific identities, engage in multi-teaching and diversify teams.

2. Engage in stakeholder dialogue to increase relevance of funded research to real life problems

Inclusion for achieving SDG4 targets will not be built if discursive practices are absent from the science governance system. As implied by the recommendations from WP5, multi-stakeholder discussion when setting strategic research programmes and encouraging RPOs to seek partnership in R&D to engage in iterative recontextualization and reconceptualization based on evidence. Merging research findings into science education would develop inclusion, responsiveness and reflexivity as part of the educational system.

3. Promote futures studies in some national contexts

As evidenced by WP1 and WP3, not all European countries have integrated futures thinking skills and futures literacy as learning outcomes of their curricula. One of the reasons is lack of expertise in researching futures. This could be specifically targeted at national levels to strengthen capacity produced by science education to anticipate futures based on research evidence. UNESCO futures literacy and the EC GreenComp framework could serve as a reference point for realising this recommendation.

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Guidelines for RPOs

4. Develop human resource management practices which favour interdisciplinary research

As evidenced by WP1, RPOs are still inert in organizing their research on the disciplinary basis, recruiting and rewarding their employees for achievements in disciplinary fields. On the one hand, this practice depends on principles for research funding from RFOs, on the other hand, it is part of science culture that is constructed by institutions themselves. Redesigning their structures from departments to e.g. research groups focused on problem-solving, rewarding performance that addresses societal challenges could be one way to promote interdisciplinarity and engage in agency as a marker of responsiveness.

5. Create "third spaces" which enable sense making and strange making practices

As suggested by the findings from WP1, gaining the benefits from interdisciplinarity needs redesigning spaces where a common language between persons with different identities, epistemological, cognitive and emotional skills could be forged. These spaces are needed to mitigate fears arising from unsafety of trying new lenses. They could serve for reflexivity and team building based on common values and public interest.

Guidelines to HEIs

6. Integrate futures thinking as a 21st century skill into curricula

HEIs can help to enact anticipation as an RRI dimension via science education by including futures thinking in their pedagogies and class activities. As noted by WP3 outputs, not every national educational system includes futures thinking and literacy as a marker of academic attainment. Foresight, capability to imagine numerous futures, apply scientific knowledge to achieve a desirable scenario are the competencies which HEIs can foster.

7. Balance creative thinking and system, critical thinking skills as learning outcomes

Neither creative thinking nor critical thinking alone is sufficient to address complex problems which HEIs graduate will have to address. The FEDORA findings call to overcome stereotypical dichotomies in science education and integrate different types of thinking to strengthen reflexivity of RRI. The results of WP4 evidence that class activities which target development of an imaginary and calculative mindset help students to build their own identities by finding and articulating their own strengths and promote inclusiveness by cooperation with others who have different strengths. Such learning activities contribute to inclusion, interpersonal responsiveness and reflexivity by developing empathy and imagining impacts of one's own and group activities.

8. Rely on class activities and methods which speak the language of contemporary youth

As indicated by the findings of WP2-4 and the RRI expert workshop in WP5, textbooks must relate history of science to contemporary challenges and speak out about this relationship in a language of visualisations, audio and video records, mockumentaries and comics, apply the advantages of AI and other technologies. This approach in science education would rest on the dimensions of responsiveness, reflexivity and inclusion of RRI.

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ANNEX 1. Agenda of the RRI experts' workshop in Brussels, on May 25, 2023

14:00-14:30 Welcome coffee

WORKSHOP WITH THE RRI COMMUNITY, 14:30 – 17:30
Moderators: dr. Eglė Vaidelytė and dr. Raminta Pučėtaitė, Kaunas University of Technology, Lithuania

14:30-14:35 Tadas Tumėnas, Lithuanian RDI Liaison Office in Brussels (LINO)
of the Research Council of Lithuania

14:40-15:00 *Basis/outline for FEDORA output discussion from RRI perspective*,
work packages 1, 3 and 4 leaders:
dr. Raminta Pučėtaitė, Kaunas University of Technology, Lithuania;
dr. Antti Laherto, the University of Helsinki, Finland;
dr. Giulia Tasquier, the University of Bologna, Italy.

15:00-16:00 World Café discussion on *Aligning FEDORA outputs with MORRI indicator SLSE1 and SDG4*, dr. Eglė Vaidelytė, Kaunas University of Technology, Lithuania

16:00-16:10 Comfort break

16:10-17:10 *Collecting expert input for elaborating MORRI indicators*, dr. Raminta Pučėtaitė, Kaunas University of Technology, Lithuania

17:10-17:30 Wrap-up,
dr. Eglė Vaidelytė and dr. Raminta Pučėtaitė, Kaunas University of Technology, Lithuania

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