Ark of Inquiry: Inquiry Activities for Youth over Europe

Deliverable D2.6

Complete Population of the Ark of Inquiry Platform – Update

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Summary

The Ark of Inquiry project aims to build a scientifically literate and responsible society through inquiry-based science education. The project seeks to expand young people's awareness of Responsible Research and Innovation (RRI) by disseminating across Europe engaging inquiry activities in Science, Technology, Engineering and Mathematics (STEM) domains.

The current deliverable provides an update of Deliverable D2.5, which was submitted in February 2017. The deliverable presents an end-of-the-project overview of the available inquiry activities in the Ark of Inquiry platform (http://arkportal.ut.ee/) from the perspective of the selection criteria (Deliverable D2.1) and coverage of core elements of the Ark of Inquiry project (Dow). The specific focus is on highlighting the progress made since Deliverable D2.5 and discussing how the project has been able to bridge some gaps identified in Deliverable D2.5 related to the availability and distribution of inquiry activities.

The updated overview revealed that the inquiry activities available in the Ark of Inquiry platform as a whole represent an excellent coverage of the central components of the project and that the project has made significant progress in overcoming the shortages that were identified in Deliverable D2.5. In short, the Ark of Inquiry platform offers a broad array of engaging inquiry activities to pupils and teachers across Europe. Here are the main highlights:

1. By the end of January 2018, the Ark of Inquiry platform offers 759 (829[1]) inquiry activities. There has been a notable increase in the number of available activities since Deliverable D2.5.

2. Inquiry activities are available in 14 different European languages, with Albanian as a new language. The availability of inquiry activities across different language areas has improved substantially since Deliverable D2.5.

3. The inquiry activities have a good coverage off all major STEM domains, particularly physics, chemistry and biology.

4. The coverage of the whole targeted age range (7 to 18) is comprehensive; there are nearly 150 inquiry activities available for each individual age group.

5. The inquiry activities are available on three different proficiency levels, ensuring that pupils with different sets of skills and knowledge (even within a certain age level or range) can find inquiry activities that match their inquiry proficiency. Since

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[1]The sum of inquiry activities in different languages (827) is higher than 759 because some of the activities are available in multiple languages.

Deliverable D2.5, the availability of advanced level inquiry activities has improved notably.

6. The inquiry activities can provide a comprehensive inquiry experience for pupils, as 70% of the inquiry activities include all five inquiry phases and nearly 90% include at least four inquiry phases.

7. New data from WP5 sub-studies confirm that the inquiry activities cover RRI elements and topics relatively well. WP5 data also suggest that both girls and boys enjoy inquiry activities and perceive those as highly engaging, suggesting that inquiry activities have a potential to promote and restore pupils' interest in science.

8. The duration of the inquiry activities varies from 30 minutes to a whole semester. The average duration of two didactic hours ensures that the threshold to use inquiry activities is low and that the activities can more easily be fitted into the curriculum, whereas inquiry activities with a longer duration can provide more extensive and challenging inquiry experiences.

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1. Introduction

The Ark of Inquiry project aims to build a scientifically literate and responsible society through inquiry-based science education. The project seeks to expand young people's awareness of Responsible Research and Innovation (RRI) by selecting engaging inquiry activities in Science, Technology, Engineering and Mathematics (STEM) domains and to make these learning resources available to European learners, teachers and schools through the Ark of Inquiry platform.

The current deliverable provides an update of Deliverable D2.5, which was submitted in February 2017. The focus of this deliverable is to provide an overview of the inquiry activities that have passed the Ark of Inquiry selection criteria (Deliverable D2.1) and are shared at the end stages (M47) of the project with teachers and pupils across Europe via the Ark of Inquiry platform. The specific focus is on highlighting the progress made since Deliverable D2.5 and discussing how the project has been able to bridge the gaps identified in Deliverable D2.5 related to the availability and distribution of the activities. The methodology and procedures for selecting inquiry activities as well as the functionalities of the Ark of Inquiry platform have been described in Deliverable D2.5 and will not be repeated in the current document.

The deliverable can inform about the quality of the published inquiry activities, that is, to what extent the inquiry activities cover areas that are deemed important for the project. It can also be considered as an overview that helps teachers to get a general picture as to what kinds of inquiry activities are available in the Ark of Inquiry platform.

2. Overview of inquiry activities

By 15 January 2018, a total of 759 inquiry activities have been published in the Ark of Inquiry platform (http://arkportal.eu). This can be considered a notable increase from the already impressive 524 inquiry activities that were available in February 2017 when Deliverable D2.5 was submitted.

The following subsections give an overview of the 759 inquiry activities by reviewing them as a whole[2] against the results of Deliverable D2.5 and coverage of the main selection criteria (Deliverable D2.1) and in relation to the general goals of the Ark of Inquiry (DoW).
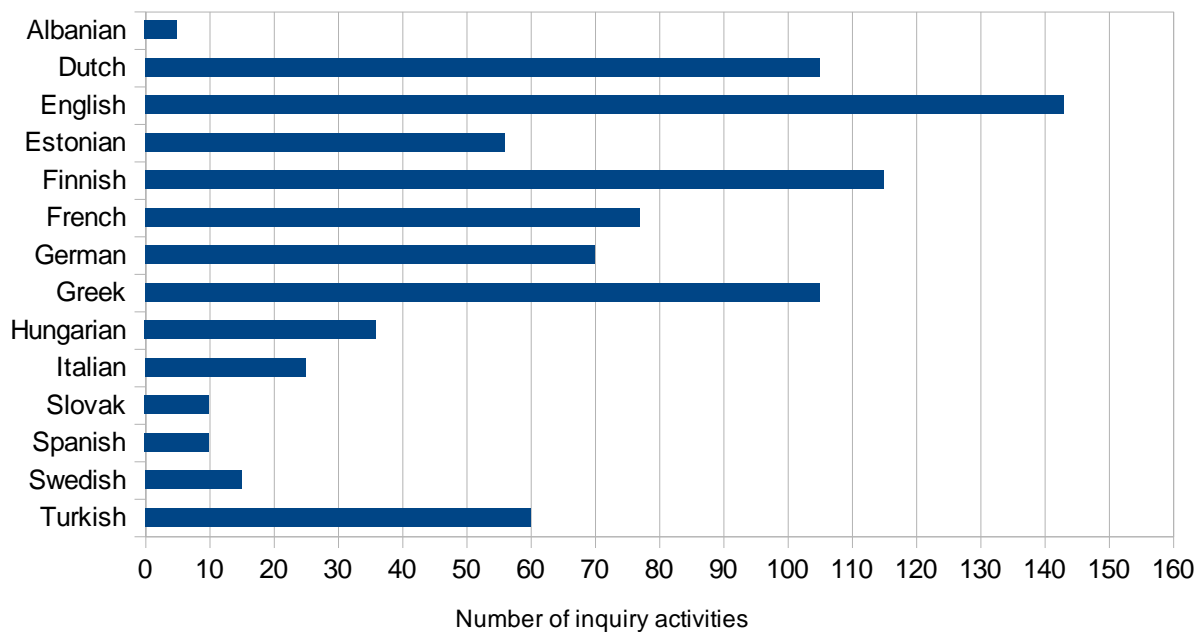
2.1. Language

When Deliverable D2.5 was submitted, the Ark of Inquiry platform contained inquiry activities in 13 European languages. Thanks to some new activities in the Albanian language, inquiry activities are now available in 14 European languages. According to Deliverable D2.5, the availability of inquiry activities was limited in certain partner languages. This was considered as one of the two major shortcomings at the time of the deliverable. Since then, the situation has improved significantly.

As shown in Figure 1, currently, there are more than 100 inquiry activities available in Dutch, English, Finnish, and Greek languages, and the coverage is also good in Estonian, French, German, and Turkish languages. From those countries that had a relatively poor coverage in Deliverable D2.5, Turkey, in particular, has made substantial progress. Though the availability has also improved in Italian and Hungarian languages, the availability of activities in these partner languages can still be considered limited. Despite the two languages, the availability of inquiry activities in different partner languages as a whole can be considered very good. From the non-partner languages, the availability of Swedish language activities has also grown from 5 to 15. As the focus of the project has been on existing inquiry activities, shortcomings in some language areas could indicate that there are differences between countries in teaching traditions and adaptation (and history) of inquiry learning in education.

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[2]It is important to recognise that the range within each element of the selection criteria is so wide as a whole that a single activity that passes the criteria can (and shall) cover only part of the range (e.g., basic proficiency level physics activity for 13–15-year-olds). In order to accommodate various learners and teachers, coverage should therefore come from the collection of all activities.

Figure 1. Availability of inquiry activities in different European languages (note: the sum of inquiry activities in different languages (827) is higher than 759 because some of the activities are available in multiple languages)

It is, however, important to note that an inquiry activity being in a foreign language does not render it useless. First of all, there is a large variation in language dependency between inquiry activities, that is, some activities can be used with little effort in a foreign language, whereas others require some or considerable amount of adaptation. Secondly, language dependency is in many cases subjective and teachers and schools might actually seize different language activities as an opportunity to integrate content and second language learning (see Deliverable D2.4 for more details on the language issue in general and some potential solutions). Training and implementation has shown that while teachers and pupils tend to prefer inquiry activities that are in the local language, they can and are willing to use foreign language inquiry activities as well. As shown above, the availability of inquiry activities is good in languages such as English and German (and depending on the country, many others as well), which can be used, in principle, in most of the European countries; in other words, German and English inquiry activities, and particularly those in English, can supplement the collection of local inquiry activities in all countries. At least Dutch, Greek and Swedish language activities can also be used in multiple countries.

Because language seems to be a factor in the use of inquiry activities in different countries (more so in some countries than others), in the following section where other aspects of the inquiry activities are investigated, the results will be represented first as a whole and then by language.

2.2. Domain
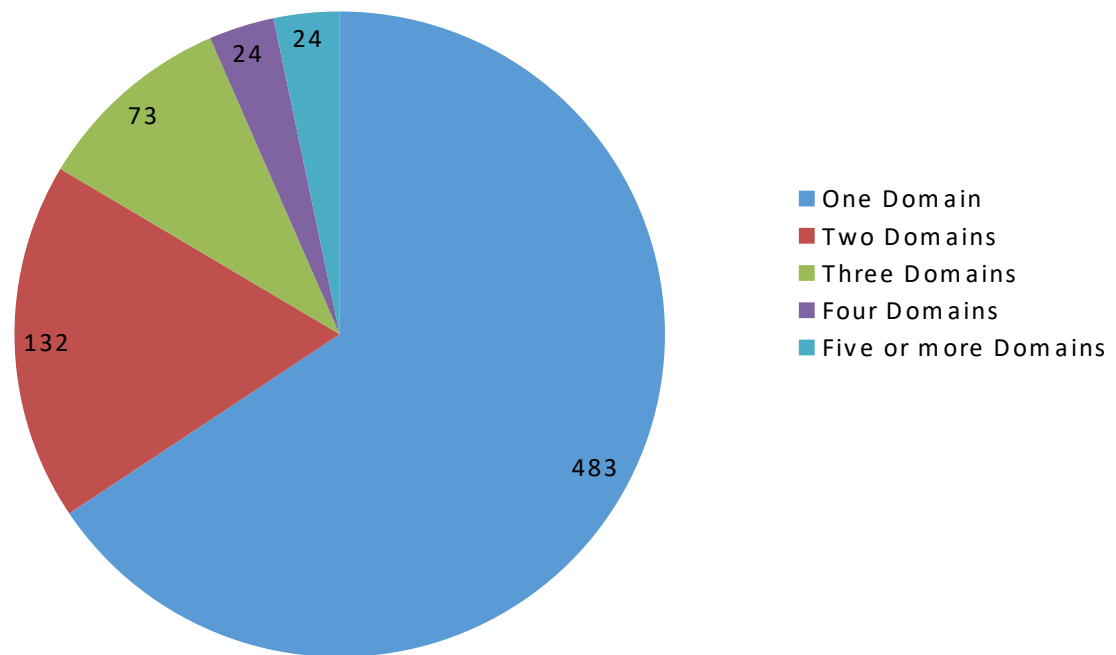
Figure 2. Number of domains covered within individual inquiry activities

Since the Ark of Inquiry targets inquiry activities in STEM domains, it is interesting to see the coverage of domains among the whole set of materials. The inquiry activities cover a total of 19 domains. The majority (81%) of the activities focus on one or two domains (Figure 2), while activities covering as many as 8 domains are also available. Most of the activities focus on the domain of Physics (Figure 3). Chemistry and Biology are also well covered. From the other core STEM domains, Technology, Mathematics, and Engineering have a weaker coverage, but substantial progress has also been made in these three domains since Deliverable D2.5. The 'Other domains' category consists of 8 domains (Astronomy, Evolution, Statistics, Geophysics, Social Sciences, Anatomy, Logic, Arts), each of which was covered in less than 10 inquiry activities. In all, a rather diverse range of domains is covered, with both single disciplinary and cross-disciplinary activities. In these results, there have been no notable changes since Deliverable D2.5.
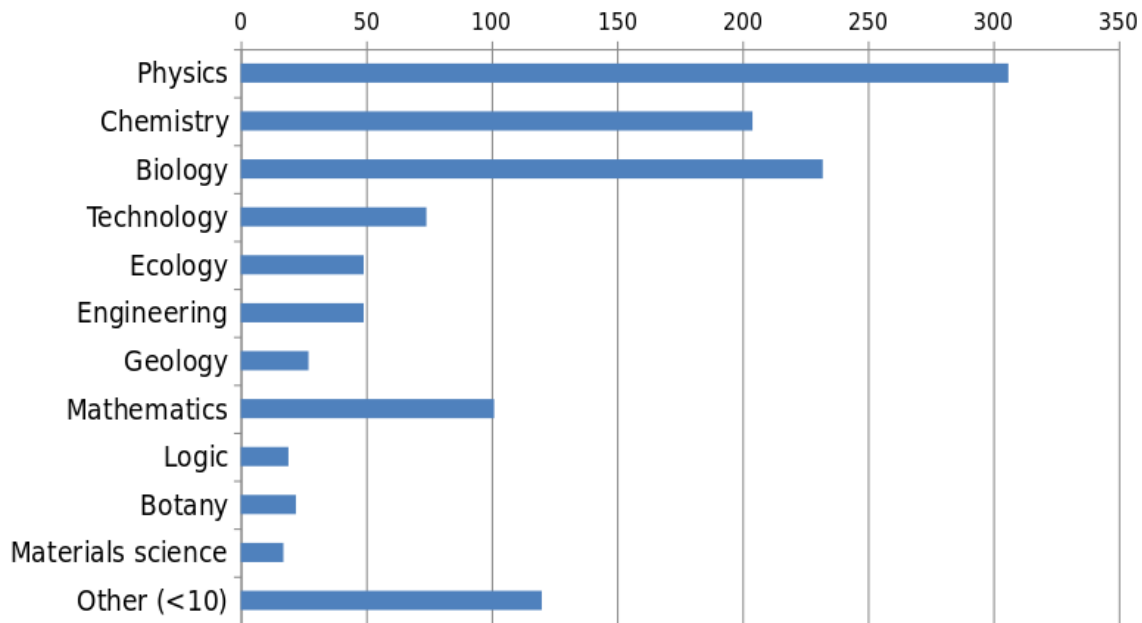
Figure 3. Frequency of individual domains' coverage by the inquiry activities

Table 1 presents distribution of domains across activities in different languages. Overall, coverage of science domains seems to be independent of language. However, it is clear that in those language areas where more inquiry activities are available, the coverage across different domains is also broader.

Table 1. Frequency of individual domains' coverage by the inquiry activities across different languages

	Albanian	Dutch	English	Estonian	Finnish	French	German	Greek	Hungarian	Italian	Slovak	Spanish	Swedish	Turkish
Physics	1	58	82	18	58	12	23	54	9	6	8	8	1	25
Chemistry	0	24	34	31	42	3	21	17	13	8	2	2	6	8
Biology	2	22	43	22	30	40	18	27	11	12	3	3	7	16
Technology	0	8	25	0	14	0	13	11	2	1	0	0	8	1
Ecology	0	3	10	4	19	5	4	4	2	4	1	1	1	1
Engineering	1	15	7	2	6	0	10	9	2	0	2	2	0	0
Geology	0	0	5	5	8	2	0	6	0	0	0	0	0	2
Mathematics	3	13	22	2	25	1	8	42	3	5	8	8	3	0
Logic	0	0	8	0	11	0	0	0	1	0	0	0	4	0
Botany	1	1	7	0	1	0	1	5	3	2	0	0	0	0
Materials science	0	2	4	0	10	0	0	1	0	0	0	0	0	0
Other (<10)	3	7	22	4	27	8	5	34	4	2	2	2	1	3

2.3. Age
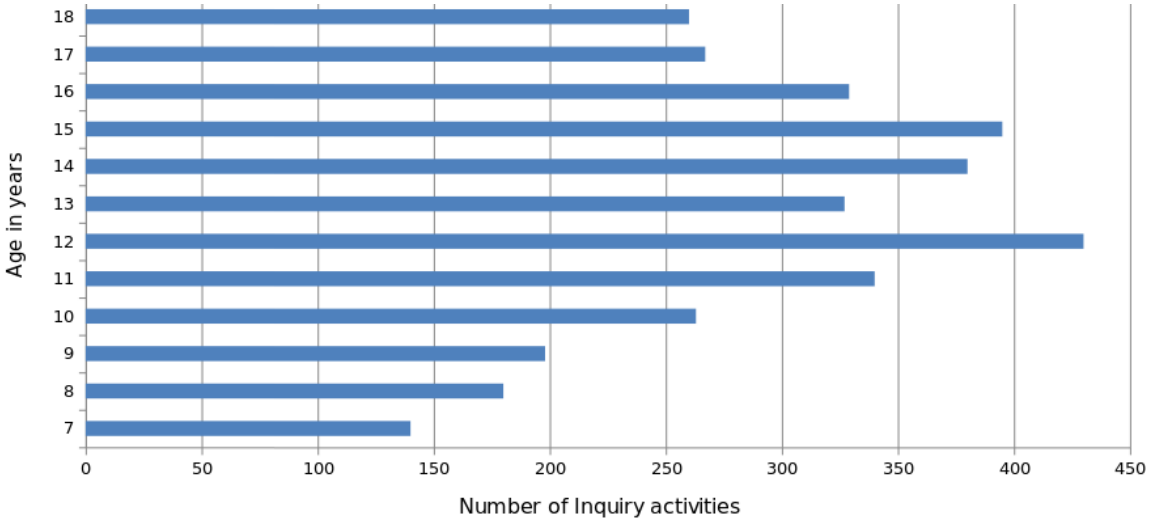
Figure 4. Number of inquiry activities available in each age within the targeted age range of the Ark of Inquiry

The coverage of different age levels was already good in Deliverable D2.5, with at least 100 activities available for each category. Figure 4 shows that the distribution of inquiry activities across the entire targeted age range (7–18) has become even better ever since. Even for 1st graders (7-year-olds), for whom the availability is the weakest, there are almost 150 inquiry activities available. Furthermore, compared to Deliverable D2.5, Table 2 shows that the age coverage is now pretty good in almost all partner countries.
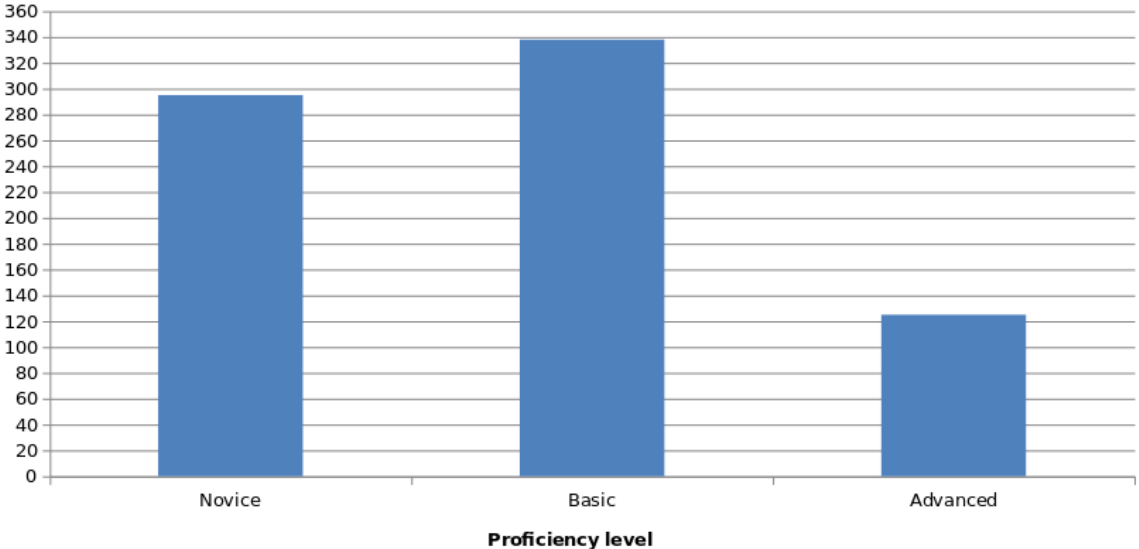
Table 2. Number of inquiry activities available in each age across different languages

| AGE	Albanian	Dutch	English	Estonian	Finnish	French	German	Greek	Hungarian	Italian	Slovak	Spanish	Swedish	Turkish
7	0	25	29	4	40	25	5	11	11	7	0	0	4	4
8	1	34	33	8	41	36	5	17	11	9	0	0	5	4
9	0	36	34	10	52	36	8	20	5	9	0	0	4	7
10	1	40	43	12	52	37	16	41	10	16	0	0	4	12
11	1	44	48	16	69	50	18	47	10	18	3	3	3	43
12	1	66	63	38	70	49	19	73	12	22	4	4	3	46
13	0	32	51	36	39	37	21	52	7	14	5	5	2	51
14	0	36	63	38	37	42	44	64	15	15	8	8	2	46
15	0	56	66	42	35	37	41	58	16	13	6	6	2	42
16	0	48	60	45	16	35	44	55	14	12	5	5	2	7
17	0	42	43	34	16	32	36	45	13	4	1	1	0	2
18	0	42	40	34	16	32	35	43	12	4	1	1	0	2

2.4. Proficiency levels

In order to make inquiry learning engaging and productive, it is important to match the learner's level of inquiry proficiency with suitably challenging inquiry activities. In the context of Ark of Inquiry this is supported by distinguishing the levels of inquiry proficiency. Inquiry proficiency, one of the central concepts in the Ark of Inquiry project's inquiry framework, refers to pupils' experience, skills and capacity regarding inquiry learning; and in the context of Ark of Inquiry, inquiry activities are divided into the following three proficiency levels: A – Novice; B – Basic; and C – Advanced.

The main distinctive features between the inquiry proficiency levels are problem-solving type (well- vs. ill-defined problem space), learner autonomy (from teacher-led to pupil-led), and RRI awareness (gradually expanding the amount and scope of interaction/discussion). At the lowest, Novice level (A), activities aim mainly at engaging learners in and introducing them to structured inquiry activities. At the Basic level (B) the inquiry activities become semi-structured and guide learners towards independency related to knowing how to inquire, reflect on and discuss issues related to the activity. At the Advanced level (C) learners can already shape their own inquiry activities and reflect and discuss outcomes in collaboration with various stakeholders.
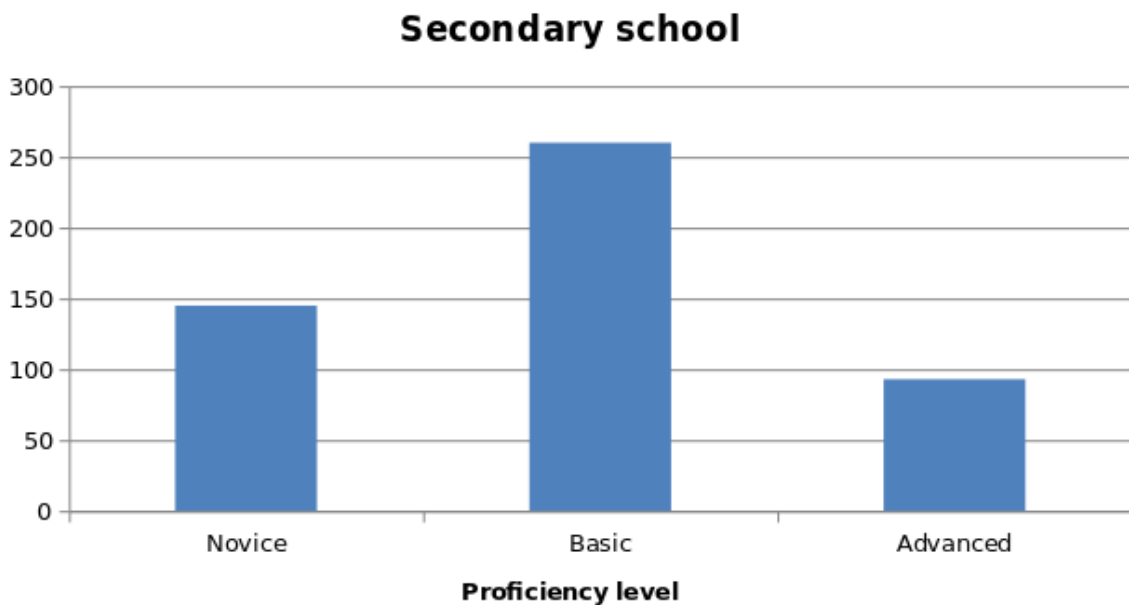

Figure 5. Number of inquiry activities on each proficiency level across the whole age range

In Deliverable D2.5, lack of advanced level inquiry was listed as the second major shortcoming; at that time, only 8% of the activities were categorized as advanced. Since Deliverable D2.5, the availability of advanced level inquiry activities has more than tripled. Currently, 17% of the total of 759 inquiry activities are on advanced level, which can be considered as a good number. From the total, 38% are novice and 45% are basic level activities.
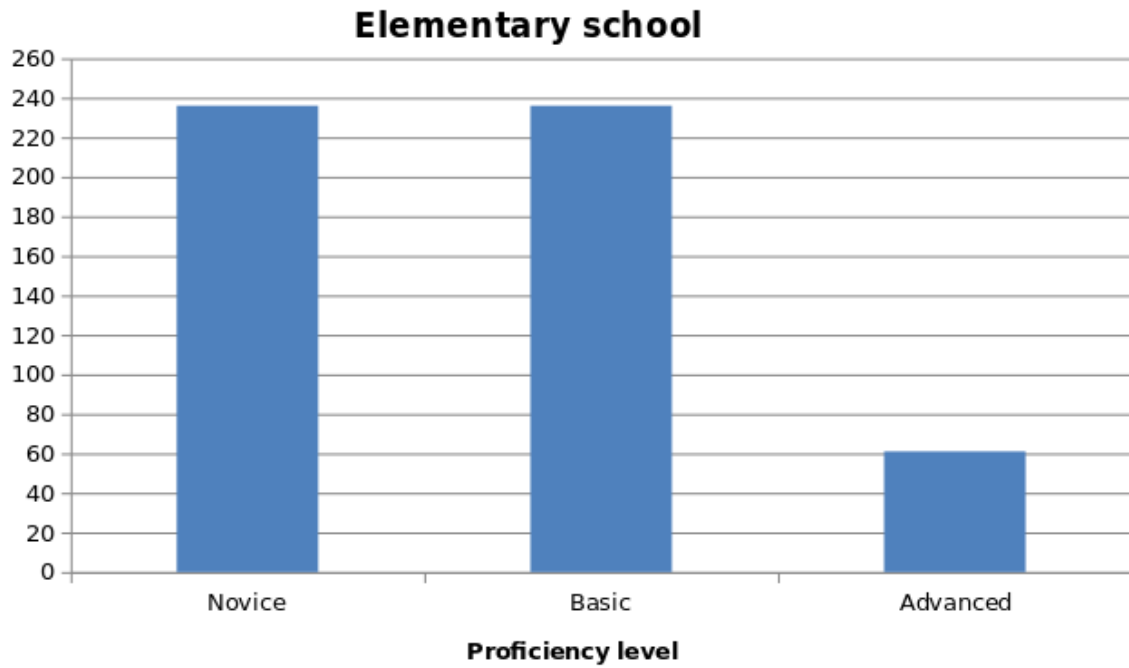
Figure 6. Number of inquiry activities on each proficiency level for elementary school

Figure 7. Number of inquiry activities on each proficiency level for secondary school

The availability of advanced level activities has improved on both elementary and secondary level. As can be seen from Figures 6 and 7, 11% of the activities on elementary level and 18% on the secondary level are advanced. Furthermore, as can be seen from the figures, on elementary level the distribution of novice and basic level activities is fairly equal, whereas on secondary level, basic level activities dominate. This makes sense, as it can be expected that older pupils are capable of conducting and already seeking more challenging and open-ended inquiry tasks than younger pupils.

Table 3. Number of inquiry activities on each proficiency level across different languages

|	Novice	Basic	Advanced	TOTAL
Albanian	3	2	0	5
Dutch	53	35	15	103
English	58	68	16	142
Estonian	33	21	5	59
Finnish	60	50	6	116
French	26	25	26	77
German	29	22	16	67
Greek	29	48	23	100
Hungarian	10	13	13	36
Italian	5	15	5	25
Slovak	8	1	0	9
Spanish	8	1	0	9
Swedish	8	5	2	15
Turkish	7	36	13	56
TOTAL	337	342	140	819

Despite the overall good progress in increasing the number of advanced level activities, Table 3 shows that this progress applies mostly to certain language areas. The availability of advanced level activities as well as the overall distribution of activities across the three proficiency levels is particularly good in French, German, Greek, and Hungarian languages. Availability of advanced level activities is also good in Dutch and Turkish. Within the partner countries, availability of advanced level activities is the weakest in Finnish, Estonian, and Italian. In contrast, there seems to be a shortage of novice activities in Turkish. Despite the above, it is important to emphasize that the proficiency distributions and lack of activities on some level should not be taken and interpreted too literally. The reason is that in many situations teachers use the activities as a template and modify those (including the proficiency level) according to their needs (e.g., skill level of pupils) before implementation. Deliverable D2.4 provides explicit guidelines for teachers on how to alter the proficiency level of activities.
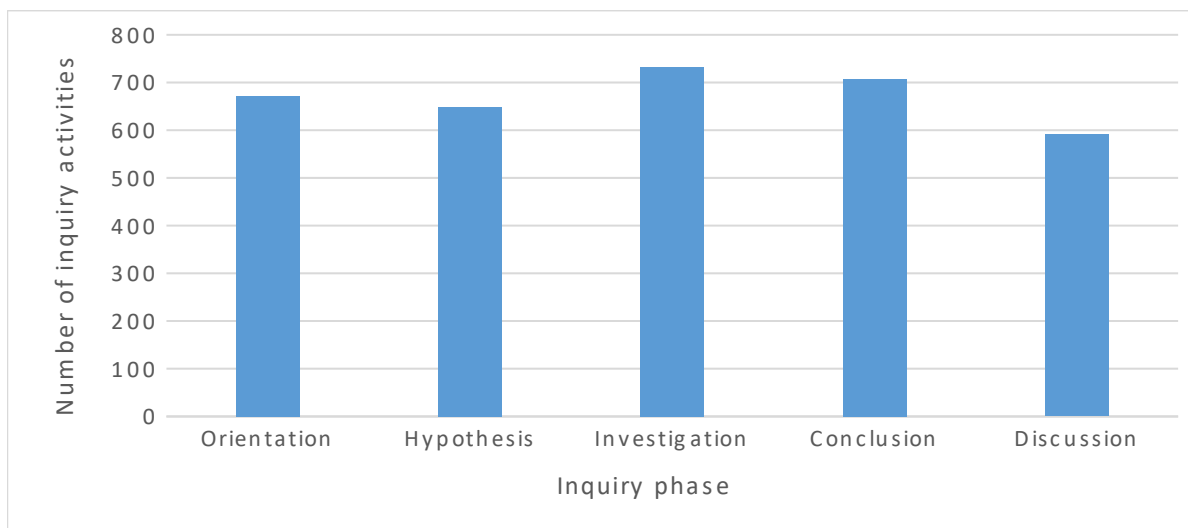
2.5. Inquiry phases

Inquiry learning is a process that is often complicated for learners (e.g., Veermans, van Joolingen & de Jong, 2006), and dividing the process into phases can make it easier to be explained and understood, especially when learners are not yet very proficient. In the Ark of Inquiry the inquiry process is divided into five distinct phases (Orientation, Conceptualisation, Investigation, Conclusion, and Discussion) according to the Pedaste et al. (2015) inquiry cycle model (see Deliverables D1.1 and D2.4 for more details on the inquiry phases; please note that "Pedaste et al. inquiry learning model" or "Pedaste et al. model" has been used in some previous deliverables to denote the "Pedaste et al. inquiry cycle

model" used in this deliverable). According to the selection criteria (Deliverable D2.1), an activity needs to cover at least one of the five inquiry phases. This relatively loose criterion stems from the fact that existing inquiry activities that were not designed with these particular phases in mind will not necessarily comply with all phases of the Pedaste et al. inquiry cycle model. Another reason is that an activity that covers only one (or two) inquiry phases may cover/address that phase particularly well and setting a stricter criterion would mean exclusion of these activities from the Ark of Inquiry. In general, though, activities covering multiple phases are highly recommended and desired, because multiple phases can ensure that learners get a good and comprehensive learning experience in a process that a) resembles scientific inquiry, b) helps to improve their inquiry skills and proficiency (i.e. the ability to generate and evaluate and discuss scientific evidence and explanations), and c) promotes their understanding of the process of conducting science in a better and more responsible manner. Regarding the last point, the Orientation phase and the Discussion phase are considered particularly important in the context of Ark of Inquiry, because it is in those phases that the RRI aspects can be thoroughly addressed in the most natural way.
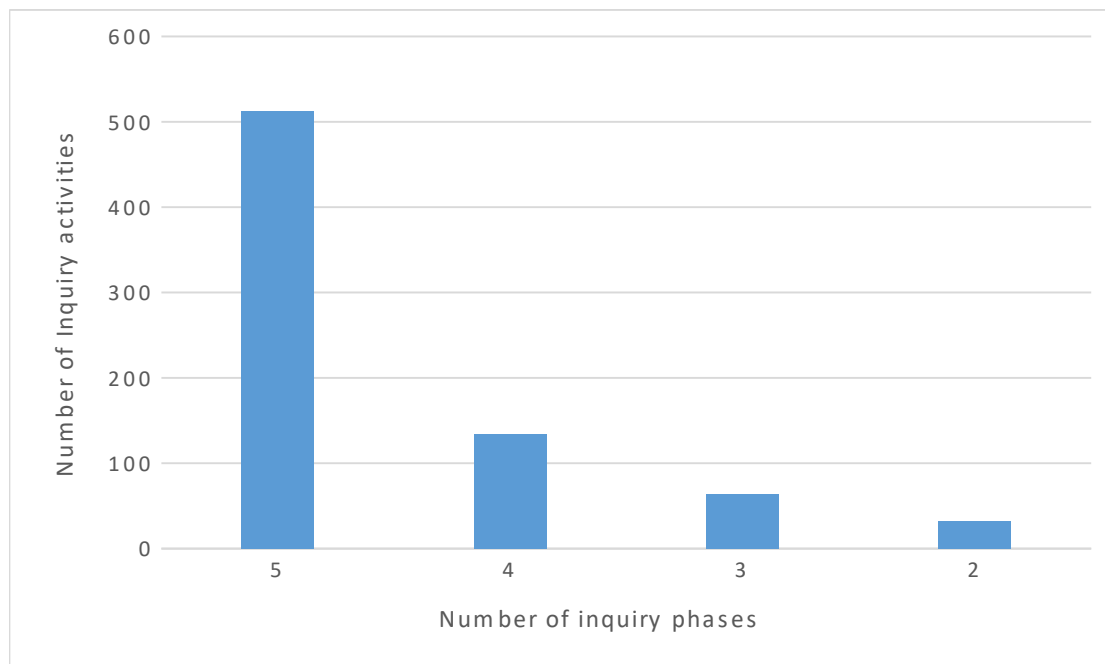
Figure 8. An overview of the amount of inquiry phases covered in individual activities

Figure 9. Number of times that an inquiry phase is included in an activity

As shown in Figure 8, the majority (70%) of the inquiry activities consist of all five inquiry phases and single-phase activities are completely absent, which can be considered an excellent outcome. This is a clear improvement since Deliverable D2.5 (61% of activities had all five phases), and it suggests that the new activities added since D2.5 are of good quality. As shown in Figure 9, the Orientation, Conceptualisation, Investigation and Conclusion phases are present in nearly 90% of activities (Investigation and Conclusion in almost all activities), and only inclusion of the Discussion phase is slightly less frequent – it is included in 80% of inquiry activities. All these numbers have gone up since Deliverable D2.5. Overall, the excellent coverage of inquiry phases suggests that inquiry activities distributed through the Ark of Inquiry can offer a comprehensive inquiry experience for pupils. Because the overall coverage of inquiry phases is good, inspection across different languages has been left out from this section.

2.6. Responsible Research and Innovation (RRI)

Responsible Research and Innovation (RRI) is a central theme in the European Union vision. RRI initiatives in science education aim to boost the interest of children and youth in STEM and to prepare them to take responsibility in the research and innovation processes as researchers or citizens in the future. While formal science education aims at effectivity and efficiency of science education in school in the short run, RRI aims to foster science use outside of formal education in the long run and connect science education to globally recognised issues (e.g., the following seven Grand Challenges identified by the EU: sustainable agriculture, climate action and resource efficiency, global poverty, inclusive and secure societies, health and well-being, sustainable transport, and clean energy). In this light, it is positive to see that many topics of the inquiry activities cover the areas of the Grand Challenges (e.g., pollution, CO_2 emission, sea pH level, ecology, greenhouse effect, environmentally conscious transportation, solar energy, alternative energy).

RRI also requires a greater consideration of the interactions among science, technology and society in the school science curriculum in order to raise awareness of RRI and to meet the needs, interests and aspirations of young citizens at the same time. For this purpose, the Ark of Inquiry project advocates emphasis on three aspects that can help to foster pupils' awareness of RRI and in the longer run prepare them to take part in RRI: reflection, communication and discussion (Deliverable D1.6). In the section on inquiry phases it was already argued that, besides the general nature of the inquiry, the Orientation and Discussion phases were identified as phases that would be the most appropriate for implementing dimensions of RRI in the inquiry activities. The Orientation phase is included in 90% of the inquiry activities, Discussion is included in 80%, and both Orientation and Discussion are available simultaneously in 76% of the inquiry activities (all these numbers are higher compared to D2.5) – this suggests that the majority of the inquiry activities are likely to be able to contribute to the RRI goals of the project. Because many of the existing inquiry activities have not been designed explicitly from an RRI perspective, Deliverable D2.4 (*Pedagogical Inquiry Scenarios for Re-Use of Inquiry Activities*) provides guidelines and suggestions for teachers as to how they can increase RRI elements in each inquiry activity.

Besides the above, the incidence of the RRI aspect in the Ark of Inquiry project's inquiry activities was studied as part of Study 5 of Deliverable D5.4. In the study, 40 activities (in Finnish and English) were analysed to find out how well they cover different 21st century skills, including RRI. According to the results, RRI aspect(s) were found in all analysed activities, with stronger RRI emphasis in more advanced and open-ended inquiry activities.

2.7. Gender

Over the past years, research has documented a consistent decline in pupils' interest in science and science careers. This holds true for girls, in particular. One of the goals of the Ark of Inquiry (and European Commission) is to make science more attractive to women in order to attract more women to science and science careers. Though the particular focus is on empowering girls in science, the global aim of the project is to promote gender inclusive science education (that is, empower girls in science without negatively affecting boys). One of the six pedagogical scenarios in Deliverable D2.4 is devoted to providing guidelines and practical examples for teachers on how to empower girls in science and how to avoid gender stereotypes in teaching. This work has been extended within the project in UNESCO's Gender-inclusive guidelines[3]. These materials are available to teachers in the Ark of Inquiry platform, in the Teachers' Toolbox section.

Inquiry activities' potential to engage pupils (girls n = 1255; boys n = 1253) was investigated in the context of WP5 (Evaluation; Study 6 of Deliverable D5.4), where data on pupils' engagement and interest while working on various inquiry activities was collected in several

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[3]https://sisu.ut.ee/sites/default/files/ark/files/infographic_gender_guidelines_final_version_a4.pdf

partner countries. According to the results, both genders find inquiry learning and activities highly interesting, and the interest even increased during the activities. It was found that girls expressed a significantly higher on-task interest than boys at the beginning of the activity. However, this gender gap was diminished during the activity, and no significant differences were found at the end of the activity. These results suggest that inquiry activities can promote and restore pupils' interest in science, independent of the gender.

2.8. Learning time
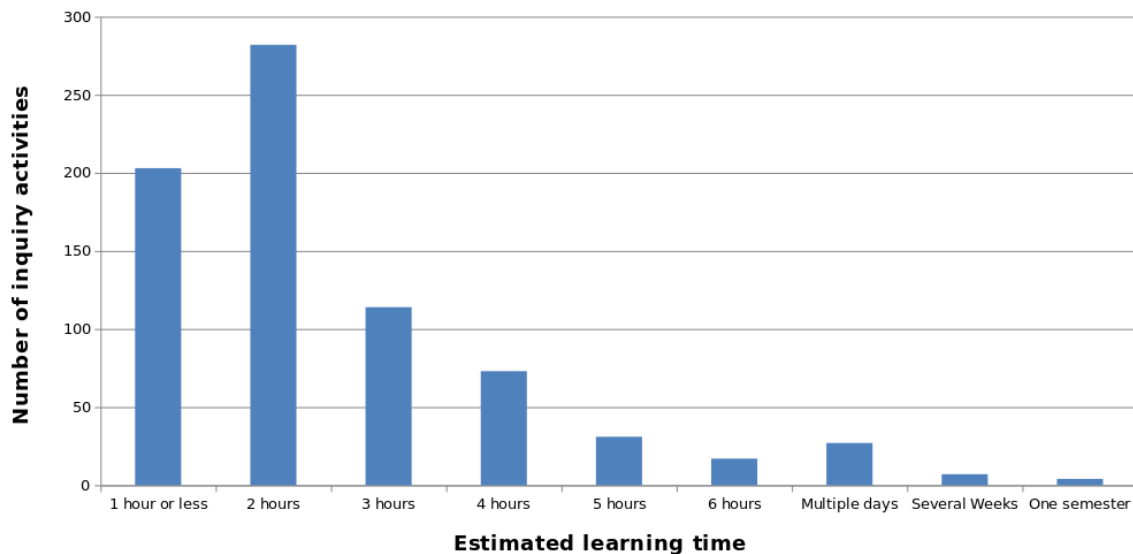
Figure 10. Distribution of inquiry activities by learning time

The median duration of inquiry activities is two didactic hours (90 minutes[4]). However, there is a large variation in the learning time between the activities, the shortest lasting less than one didactic hour (45 minutes) and the longest the whole semester (see Figure 10 for more details). The estimated learning time of an activity will likely be a factor for teachers and learners in deciding whether to engage with a certain activity. Inquiry activities with a shorter duration might be preferred by less experienced teachers and pupils because they may offer a lower threshold to get familiar with inquiry learning and can be more easily fitted into the curriculum. Activities with a longer learning time might enable the pupils to learn more about the inquiry process than the shorter ones. The longer ones might also address the RRI aspect better (although that obviously depends on the content), but in any case, the variance in range provides an option for teachers and learners to engage in projects with different durations based on the available resources, time, and goals.

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[4]If teachers use pedagogical scenarios and put extra emphasis on the Orientation and Discussion phases, the durations in Figure 10 are likely to be underestimations.

3. Discussion

The current deliverable has presented an updated end-of-the-project overview of the inquiry activities that are available in the Ark of Inquiry platform. The overview revealed that the inquiry activities as a whole represent an excellent coverage of the central components and aims of the project and that the project has made substantial progress since Deliverable D2.5. Here are the main highlights:

1. By the end of January 2018, the Ark of Inquiry platform offers 759 (829) inquiry activities for teachers and pupils across Europe. There has been a notable increase in the number of available activities since Deliverable D2.5.

2. Inquiry activities are available in 14 different European languages, with Albanian as a new language since Deliverable D2.5. The availability of inquiry activities across different language areas has improved substantially since Deliverable D2.5.

3. The inquiry activities cover well all major STEM domains, particularly physics, chemistry and biology.

4. The coverage of the whole targeted age range (7 to 18) is comprehensive; there are nearly 150 inquiry activities available in each targeted age group, and even 400 for some age groups.

5. The inquiry activities are available on three different proficiency levels, ensuring that pupils with different sets of skills and knowledge (even within a certain age level or range) can find inquiry activities that match their inquiry proficiency. Since Deliverable D2.5, the availability of advanced level inquiry activities has improved notably.

6. The inquiry activities can provide a comprehensive inquiry experience for pupils, as 70% of the inquiry activities include all five inquiry phases and nearly 90% include at least four inquiry phases.

7. The duration of the inquiry activities varies from 30 minutes to a whole semester. The average duration of two didactic hours ensures that the threshold to use inquiry activities is low and that the activities can be more easily fitted into the curriculum, whereas inquiry activities with a longer duration can provide more extensive and challenging inquiry experiences.

8. New data from WP5 sub-studies confirm that the inquiry activities cover RRI elements and topics relatively well. WP5 data also suggest that both girls and boys enjoy the inquiry activities and perceive them as highly engaging, suggesting that inquiry activities have a potential to promote and restore pupils' interest in science.

Given that the focus of the project has been on existing inquiry activities, it can be considered surprising that the inquiry activities available in the Ark of Inquiry platform extensively cover the main goals and pedagogical principles of the project. Compared to the outcomes of Deliverable D2.5, the project has made clear progress regarding inquiry activities in all major areas during the final year; among other things, the project has been able to overcome, to a large extent, two main shortcomings that were identified in Deliverable D2.5, namely, the shortage of the availability of activities in specific partner languages and the lack of advanced level activities as a whole. This suggests that, overall, the 759 inquiry activities that are currently available in the Ark of Inquiry platform offer a broad array of engaging inquiry activities that can promote pupils' awareness of RRI across Europe and beyond. This provides an excellent starting point for the continuation of the project and for the accumulation of the inquiry activity repository in the future after the project is formally completed.

4. References

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