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inTruST

increase Trust in Science and Technology

Improving science education and fostering a culture of trust and integrity in science.

Operationalisation of the Theory

A comparative analysis to support teachers in designing STEM lessons

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The inTrust Project

The inTrust project promotes ways of implementing action-oriented, interdisciplinary, and inquiry-based teaching behaviour. The aim is to change students' learning behaviour from one of consumption to one of action through competence-oriented aspects such as critical thinking, communication, collaboration and creativity. Learning, Teaching and Training workshops and inquiry-based learning scenarios provide an insight into different approaches and implementations in primary school and secondary school.

During the implementation activities, partner schools develop scenarios that deal with different aspects of inquiry-based learning (IBL) and are evaluated and implemented internally at each school and then externally by the project partners. 5 learning, teaching and training workshops will be held at the partner schools and universities, with teachers from all partner schools. The workshops deal with individual aspects of IBL, and each hosting partner school deals with the topic in which the school has particular expertise.

Results of the project will reflect three levels: (1) 15 open-source educational learning scenarios for IBL in STEAM subjects, (2) Professional development for teachers of STEAM subjects at primary and secondary school, which is achieved through the workshops and finally, (3) a report detailing the current state of IBL integration in school curricula of the consortium countries (Austria, Spain and Greece).

Abstract

Inquiry-Based Learning (IBL) has been widely recognised for its positive effects on learners' conceptual understanding, critical thinking, and active knowledge construction. Building on the findings of a systematic literature review on IBL (D2.1), this report presents the operationalisation of the theoretical framework adopted by the inTruST project through a comparative analysis of primary and secondary STEM curricula in Austria, Spain, and Greece. The eight science and engineering practices defined by the Next Generation Science Standards (NGSS) were used as a common analytical lens to identify how inquiry-related competencies are represented across national curricula in subjects including mathematics, biology, physics, chemistry, technology and design, and social/science education. A qualitative structured content analysis was conducted using MAXQDA, with teachers from all participating countries trained to code their respective curricula against the eight practices. The analysis reveals that practices such as analysing and interpreting data, constructing explanations, planning and carrying out investigations, and obtaining, evaluating and communicating information form a shared core across the three countries, while using mathematics and computational thinking, engaging in argument from evidence, and asking questions and defining problems are systematically underrepresented. Based on these findings, two complementary strategies for the design of Learning Scenarios are proposed: reinforcing well-established shared practices to ensure cross-country alignment, and deliberately targeting underrepresented practices to strengthen inquiry depth, argumentation, and computational thinking. The report concludes with a set of best-practice guidelines for teachers, structured

as a step-by-step process for designing inquiry-based STEM learning units, and provides an overview of the 16 Learning Scenarios developed within the first year of the project.

Aim of the Operationalisation

The overarching objective of the SLR is to establish a robust evidence base on the integration of IBL in primary and secondary education (Figure 1), with particular emphasis on science, technology, and design subjects. The work carried out is led by Kirchliche Pädagogische Hochschule Vienna/Lower Austria (kPH) in close collaboration with the National Technical University of Athens (NTUA) and the participating school partners (BG/BRG Schwechat, BG/BRG Gmünd, Escola A. Aguilera, Institut de Sales, and GTVS Dr Bruni Kreisky). The scope of the SLR encompasses the identification and refinement of relevant search terms, the selection of suitable academic databases, and the systematic screening and selection of peer-reviewed studies and relevant grey literature to understand the benefits/barriers associated with IBL.

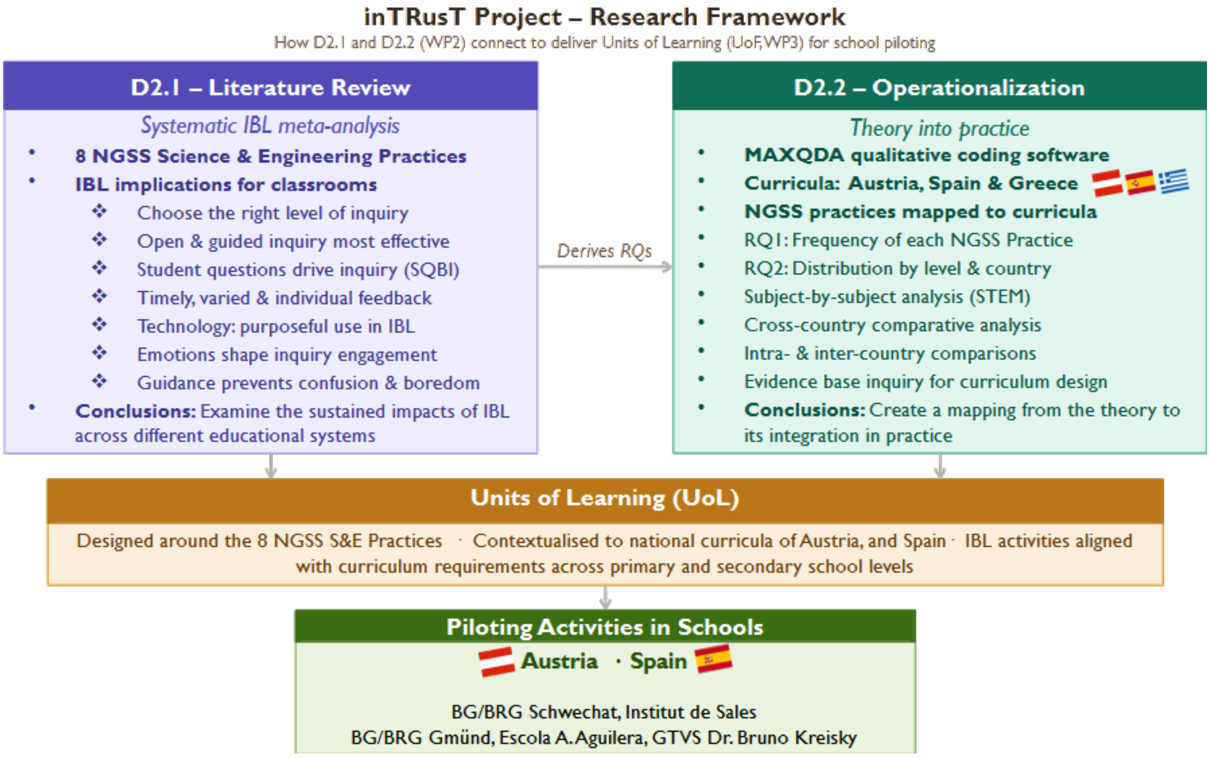


Figure 1: *Conceptual diagram illustrating the mapping from theory to practice within the inTRusT project, showing how the findings of the Literature Review (D2.1), centered on the 8 NGSS science and engineering practices and key IBL implications, informed the curriculum analysis conducted in D2.2 across Austria, Spain, and Greece, and guiding the design of the Learning Scenarios for the school piloting activities.*

Building on the outcomes of the SLR, this activity delivers a comprehensive analytical report outlining the current state of IBL in primary and secondary education. The scope encompasses the identification and critical analysis of the benefits and challenges associated with IBL implementation, as well as the generation of subject- and age-group-specific insights that capture variations in effectiveness across diverse educational contexts. Finally, the review underpins the development of evidence-based best practice guidelines, drawing on documented successful IBL initiatives and best practices, to support the design of targeted strategies for the effective adoption of IBL in diverse school settings and science curricula.

As illustrated in Figure 1, the operationalisation phase follows a sequential, three-stage process that maps theory onto practice. The starting point is the systematic literature review (D2.1), which synthesised the existing evidence on IBL and identified the eight NGSS science and engineering practices as a coherent framework for characterising inquiry-related competencies. The key findings and implications drawn from D2.1 then served as the analytical foundation for the comparative curriculum analysis carried out in D2.2, in which the curricula of Austria, Spain, and Greece were examined through the lens of these eight practices. The results of the curriculum analysis, in turn, feed directly into the design of the Learning Scenarios that will be piloted in the participating schools. During the second and third years of the project. By revealing which practices are emphasised and which are underrepresented across the three national curricula, the analysis provides teachers with an evidence-based rationale for selecting the focus of their learning units. In this way, the theoretical insights from the literature are translated into an analytical instrument, applied to the curricula, and ultimately used to inform classroom and teaching practices in Austria and Spain.

Introduction

In times of increasing societal challenges and rapid technological change, fostering students' understanding of and trust in science has become a central goal of STEM education. Understanding how curricula can support this aim is therefore essential for the development of meaningful and future-oriented learning environments.

In this chapter, we briefly outline the theoretical basis for the operationalization applied in this project, together with the curriculum analysis conducted during its first year. As this is an international study with a focus on STEM education and the overarching aim of increasing trust in science and technology, we selected IBL as the conceptual foundation for our work and for the development of Learning Scenarios. This approach provides numerous opportunities for teachers to design learning environments in which students can explore their own ideas, construct knowledge, reflect on their learning, and communicate outcomes. Various approaches to IBL exist, which will be briefly discussed in the next section.

Over the last decade, the American National Research Council has shifted its focus from IBL as a general pedagogical approach to a more detailed description of the practices that scientists and engineers engage in as part of their work. In this context, eight science and engineering practices were formulated that students from elementary to secondary education should be able to demonstrate.

For this project, both concepts are employed, as each contributes valuable perspectives to the development of the Learning Scenarios and to the comparison of the participating countries' curricula. Through IBL, students emulate the scientific research cycle, as illustrated in ***Figure 2***. Beginning with the formulation of research questions or the definition of a problem, students plan and conduct investigations, collect and analyse data, and communicate their findings. By engaging in these scientific processes, students are expected to develop scientific competencies as well as scientific literacy through learning about science. The NGSS emphasize hands-on, inquiry-driven activities that foster both the acquisition of scientific knowledge and the application of skills to address engineering problems. Learning activities implemented within an inquiry-based setting can thus be described and structured through the science and engineering practices. These practices are clearly defined and serve both as inspiration and as a guiding framework for the development of the Learning Scenarios and for the comparative analysis of curricula. Consequently, combining these two concepts appears to be a coherent and productive approach for this study.

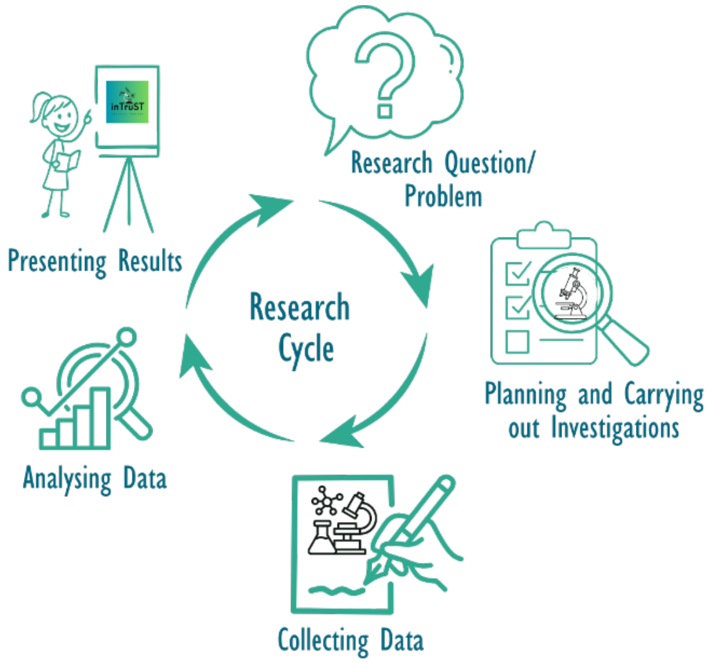


Figure 2: *The research cycle: From formulating a research question to inquiry and exploration to analysis, synthesis, and reflection, driving continuous scientific discovery and understanding.*

Inquiry-based Learning

Inquiry-based learning has proven to be effective in fostering students' critical thinking skills and conceptual understanding (Arifin et al., 2025; Mediana et al., 2025). From a constructivist perspective, the open environment and hands-on mentality of IBL settings provide the students with opportunities to construct their own knowledge. However, from the science education literature, we know that some aspects should be considered for the construction of IBL settings, which were also summarised in the umbrella literature review on IBL of this project (Loidl et al., 2026).

In addition to the positive effects of IBL on learning outcomes compared to traditional instructional settings, as demonstrated in numerous quantitative meta-analyses (e.g., Alfieri et al., 2011; Lazonder & Harmsen, 2016), IBL supports students' engagement with authentic, inquiry-oriented learning situations. From a pedagogical perspective, the structuring of IBL into distinct inquiry phases offers the advantage of breaking investigations and learning content into smaller learning units. These units are, on the one hand, manageable for students and, on the other hand, allow attention to be directed to specific aspects of scientific work and reasoning (Pedaste et al., 2015, p. 48). There are different educational concepts to implement IBL, as for example the 5E instructional model according to Bybee et al. (2006). In their model, they describe five phases of an inquiry process: Engage – Explore – Explain – Elaborate – Evaluate; However, there are also other examples to structure the different inquiry phases as "inquiry-based learning is not a prescribed, uniform linear process" (Pedaste et al., 2015, p. 49).

There are usually two common types of classification for inquiry activities in the science education literature. The first one distinguishes "four levels of inquiry – verification, structured, guided and open, respectively – depending on whether the source of the question, the data collection methods and the interpretation of results are given by the teacher or open to the students." (Rönnebeck et al., 2016, p. 187) The second type distinguishes between teacher-led instruction and learner self-direction (Rönnebeck et al., 2016, p. 187). The inquiry process is supported by either more or less guidance and scaffolds, in the best case according to the students' needs.

To contribute to fostering trust in science—and thereby to the development of scientific literacy—IBL should also place a strong emphasis on teaching that supports an understanding of the Nature of Science (NoS). This means that activities should not merely be replicated mechanically; rather, students should be encouraged to recognize and establish connections between the activities and the purposes they serve. By engaging in these activities, students may gain new insights into observable phenomena and build scientific knowledge (Rönnebeck et al., 2016).

Science and Engineering Practices

The eight science and engineering practices were developed by the National Research Council (NRC) in the Framework for K-12 Science Education (2012). This framework laid the foundation for the Next Generation Science Standards (NGSS), which were released in 2013. To effectively engage in these practices, students require not only inquiry skills but also a deep understanding of the practices themselves to grasp science concepts and ideas. Consequently, students should not only acquire scientific content but also be able to apply their knowledge to solve problems and investigate phenomena. The eight science and engineering practices are presented in Table 1, together with the pictograms used in the subsequent presentation of the results. The guiding principles underlying these practices are outlined in Appendix F of the NGSS science and engineering practices, reflecting the rationale behind their development. These key principles will be briefly summarized.

Table 1: The eight science and engineering practices and their assigned pictograms used in the presentation of results.

1 Asking questions (for science) and defining problems (for engineering)
2 Developing and using models
3 Planning and carrying out investigations
4 Analysing and interpreting data
5 Using mathematics and computational thinking
6 Constructing explanations (for science) and designing solutions (for engineering)
7 Engaging in argument from evidence
8 Obtaining, evaluating and communicating information

All students from the kindergarten to the end of secondary school should engage in all eight practices. Naturally, the complexity and depth of the practices vary across the different age-groups. However, as the students' capabilities progress, the students can engage in more depth with the practices and need less or different forms of support and guidance. For example, 'planning and carrying out investigations' is already part at elementary level, students conduct small experiments that have been prepared by the teacher. In higher educational levels, students may plan their own experiments to test a hypothesis. All eight practices are meant as being shared practices of science and engineering. By asking about the goal of an activity, one can find out whether the students are doing science or engineering, i.e. is the purpose of the activity to construct an explanation (science) or to design a solution (engineering)? Furthermore, the practices are not meant as teaching methods or as a curriculum. The practices simply describe what students should be able to do and are in line with practices that scientists and engineers engage in. When looking at the practices and comparing it to the research cycle, one may anticipate that the practices are not separate but overlap and interconnect (i.e. 'analysing and interpreting data' and 'mathematical and computational thinking'). Finally, "the engagement in practices is language intensive and requires students to participate in classroom science discourse" (NGSS, 2013, p.3). The practices provide valuable opportunities for language learning while advancing science education for all students, including language learners and those with language-related disabilities. When supported appropriately, these students can develop both their scientific understanding and language proficiency through engaging in complex language functions like arguing from evidence and constructing models.

This approach unifies the created learning units in such a way that teachers in each participating country can adapt the Learning Scenarios for their classrooms, thereby contributing to the development of their students' scientific literacy.

Aims and Scope of the Analysis

The aim of this report is, first, to establish a theoretical foundation for the development of Learning Scenarios. In addition, the operationalization of this theory is intended to provide a framework for the analysis of the curricula, while the results of this comparative curriculum analysis will in turn feed back into the theoretical framework and serve as implications for the design of the Learning Scenarios. We decided to analyse the curricula through the lens of the NGSS practices, as these encompass the central aspects of inquiry-based learning. This approach makes visible the specific foci that different countries emphasise in their STEM education, as well as the commonalities and differences among them. The Learning Scenarios can thus be designed either in alignment with cross-country priorities or to address underrepresented aspects of IBL. The following questions guided our research:

1. Which science and engineering practices are represented in the curricula of the participating countries?
2. In which ways do the curricula of the participating countries converge or diverge with respect to these practices? And what challenges and opportunities emerge from the comparative curriculum analysis?
3. What best practices for implementing inquiry-based learning (IBL) in STEM education can be derived from the findings of the comparative analysis?

Methodology

We conducted a qualitative structured content analysis to identify similarities and differences in the school curricula of the participating countries. This approach allowed us to identify a common ground for the development of the Learning Scenarios within the project. We used the eight science and engineering practices as a guiding framework, implementing them as deductive codes in the MAXQDA software for qualitative data analysis. As this project is an international project, we encountered school curricula from three different countries (Spain, Greece and Austria), as well as separate languages. Additionally, we designed learning units in six STEM subjects and for educational levels ranging from primary to secondary school. Due to the variety of languages and subjects, we relied on the participating teachers' expertise to analyse the curricula. The analysis process will be presented in the following sections.

Step 1: Teacher Training for the Curriculum Analysis

As the teachers and project members were the main actors in the analysis of the curriculum, we first introduced them to the design and purpose of this study. This was done at the project's Kick-Off Meeting in March 2025. Furthermore, we introduced teachers and project members from all participating countries to the eight science and engineering practices, which form the basis for analysing the curricula and developing the Learning Scenarios. Following the theoretical introduction, the teachers underwent our step-by-step training to familiarise themselves with the MAXQDA software. In a shared folder, the teachers were given access to a prepared MAXQDA file. After downloading the file, they coded their assigned subject-specific curricula. After coding the first parts of the curricula, the teachers compared their initial results, clarifying any questions or difficulties they had encountered. Finally, we asked the project members to code one grade level in each subject until the next meeting in May 2025, with some teachers from the organising team acting as multipliers and teaching their teacher colleagues how to code the curricula. Alongside the coding, the teachers used the software's paraphrasing tool to translate the respective paragraphs into English to enable comparison of the curricula.

Step 2: Validation of the Curriculum Analysis

At the subsequent meeting, the coded curriculum documents were compared. Teachers from different countries were grouped by subject (e.g. physics, chemistry, or biology) and discussed their findings before presenting the main results of their curriculum analyses to the entire project team. To ensure the validity of the coding, the importance of validating the analysed data was explicitly addressed, and two complementary validation approaches were introduced. Throughout the coding process, teachers worked collaboratively, either discussing their coding decisions jointly during live coding sessions or coding independently and subsequently comparing their assigned codes. This collaborative procedure supported the validation of the coded segments, as teachers were able to discuss differing interpretations of curricular aims and competencies and to justify their coding decisions. Through this process, divergent understandings of the science and engineering practices were identified and resolved. Following the second meeting (May 2025), teachers were asked to complete the coding of all subjects and grade levels by the end of July 2025.

Step 3: Examination of the Curriculum Comparison

Until August 2025, the teachers uploaded their MAXQDA files to a shared folder. The KPH Vienna/Lower Austria partners then merged all the files into one MAXQDA file and analysed the curricula in terms of how the codes were distributed among the different countries. The results are presented in the form of tables in the results section, which are organised regarding the educational levels and subjects. This representation of the results was primarily used to make them easily accessible to the teachers when planning their learning units. In September 2025, the results of the curriculum analysis were presented at the project's third meeting in Barcelona.

Results of the Comparison of Curricula

Before starting the analysis of the specific curricula, the STEM subjects of the participating countries were compared, as presented in the Table 2 below. As can be seen, primary schools in Austria cover only the first to the fourth grade, whereas in Spain and Greece, primary education ranges from the first to the sixth grade. Where possible, the curricula of all included subjects were coded for each grade level. For example, the Spanish curriculum specifies aims and competencies in some subjects for two school years combined and does not list them separately. In such cases, the columns of the tables presenting the results of the analysis combine those grade levels into a single column. In this chapter, we first report the results of the primary curricula, followed by the results of the secondary curricula for each subject separately.

Table *3***:** Overview of the STEM related subjects in the participating countries from primary to secondary school levels.

Subjects	Age 6-8	Age 9-10	Age 11-12	Age 13-14	Age 15-16
Mathematics	All	All	All	All	All
Physics			AUT, GRC	All	All
Chemistry				All	All
Biology			AUT	All	All
Technology (and Design)			AUT	AUT, GRC	GRC
Social/Science Education	All	All	ESP, GRC		

Primary Education

In the participating primary schools, the inTruST project aims to develop Learning Scenarios in the two subject areas of mathematics and science education. The term *social/science education* is used as an umbrella term for the respective country-specific subjects: *General Studies* in Austria, *Knowledge of the Natural, Social, and Cultural Environment* in Spain, and *Environmental Studies* in Greece. As these subjects share overarching similarities while differing in their structure and emphasis, they are briefly described below.

General Studies in Austria

General Studies is a subject taught in Austrian primary education, covering Grades 1 to 4 (students aged approximately 6 to 10). Students explore their immediate environment from six different perspectives: historical, natural science (biology, chemistry, and physics), technical, economic, socio-scientific, and geographical. By addressing questions about the world from these perspectives, students develop critical thinking skills, learn to make informed decisions, and take responsibility for their actions.

The fundamental goals of general studies are viewed as an essential contribution to a reflective general education (Greiner et al. 2019). The focus is on building subject-specific foundational knowledge. Learning in and through general studies also encompasses the development of a reflective attitude, the assumption of responsibility, and active participation in the shared school life. This practical competence can be concretely illustrated by the following operators:

- Assessing, evaluating, and judging opinions, statements, and actions, as well as making one's own decisions based on critical reflection
- Justifying and defending one's own point of view while taking different perspectives into account
- Recognizing and questioning one's own ideas and assumptions, and further developing and adopting values, knowledge, and behaviors in light of subject-specific concepts

A reflective education for the 21st century requires the acquisition of competencies in four dimensions: knowledge, skills, character, and metacognition, or "learning to learn" (Fadel et al. 2017). These personal, social, and learning-methodological competencies are anchored in the general part of the curriculum.

The educational mission of general studies establishes a clear link to cross-curricular competencies - namely personal, social, and learning-methodological competencies - as these represent a significant focus within the subject-specific areas of competence.

Knowledge of the Natural, Social, and Cultural Environment in Spain

Knowledge of the Natural, Social, and Cultural Environment is a multidisciplinary subject taught in primary education, covering grades one to six (students aged approximately 6 to 12). Students explore the environment, society, and culture, reflecting on sustainability and critically analysing human intervention through the lens of natural sciences, social sciences, history, geography, and cultural studies. This integrated approach should help students to develop critical thinking skills, respect for diversity, civic values, and environmental responsibility. Additionally, they build a foundation for secondary science and history education.

One of the main aims of the subject is to encourage students to explore the relationships between people, society, culture, and nature. Pupils study topics such as ecosystems, animals, plants, weather, the human body, and the responsible use of natural resources. At the same time, they examine how communities are organised, how societies have evolved throughout history, and how geography influences ways of life in different regions of Spain and the wider world. By linking scientific and social perspectives, the subject promotes a more holistic understanding of contemporary global challenges.

The curriculum also places strong emphasis on sustainability, environmental awareness, and responsible citizenship. Students are encouraged to reflect critically on human intervention in the environment and to understand the importance of protecting biodiversity, reducing pollution, and promoting sustainable lifestyles. Activities often include practical investigations, collaborative projects, and discussions about current social and environmental issues, helping students to connect theory with real-life situations.

Cultural education is another essential component of the subject. Children learn about Spanish traditions, historical heritage, artistic expressions, and the cultural diversity that exists both within Spain and internationally. This helps foster respect for diversity, inclusion, intercultural understanding, and democratic values. Students are encouraged to appreciate different perspectives and recognise the importance of coexistence, equality, and social participation in modern societies.

Throughout primary education, the subject supports the development of key competencies such as critical thinking, communication, problem-solving, teamwork, and independent learning. Inquiry-based learning methods are commonly used, encouraging students to ask questions, investigate evidence, and draw conclusions from observations and research. In this way, children not only acquire factual knowledge but also develop the skills needed to become active, informed, and responsible citizens.

Furthermore, Knowledge of the Natural, Social, and Cultural Environment provides an important academic foundation for later secondary education subjects, particularly in science, geography, history, and civic education. By the end of primary school, students are expected to have developed a deeper understanding of the interconnectedness between humans, society, culture, and the natural world, as well as a growing sense of personal and collective responsibility toward their environment and community.

General Studies in Greece

The landscape of science education (STEM subjects) in Greece is undergoing a significant transformation since 2024, driven by the introduction of innovative curricula that emphasise IBL and practical experimentation. Recent academic initiatives, such as the new Primary Education Science Curriculum, strive to cultivate critical thinking and collaboration among students, addressing previously identified gaps in scientific literacy and pedagogical practices. Nonetheless, the implementation challenges remain evident; educators often grapple with resource constraints and the need for professional development to adapt to these evolving methodologies (Kotsis, 2024).

Formal education spans from ages 4 to 18, covering pre-primary (Nipiagogeio, age 4-6), primary (Dimotiko, Grades 1-6), lower secondary education (Gymnasio, Grades 7-9), and the upper secondary level (Geniko Lykeio, Grades 10-12). In primary education, the curriculum is designed to develop basic skills in literacy, numeracy, and critical thinking. The Greek curriculum encompasses a broad range of subjects across the different educational levels, providing opportunities for the development of interdisciplinary knowledge and competencies. In particular, the science curriculum includes subjects such as Mathematics, Environmental Studies, Information and Communication Technologies (ICT), Geography, Social and Civic Education, Science, as well as the Skills Labs (Table 4). At the lower secondary level, the science curriculum expands both in scope and depth, introducing more specialized subjects and further developing previously acquired knowledge. The curriculum comprises Mathematics, Natural Sciences (Physics, Chemistry, and Biology), Geography and Geology, Religious Education, Information Technology, and the Skills Labs (Table 5). In upper secondary education, which is non-compulsory, students following the general education pathway attend advanced courses in Mathematics, Physics, Chemistry, Biology, and Information and Communication Technologies (OECD, 2026).

The current primary education National Curriculum[1] is modelled on the basis of the Cross Thematic Curriculum Framework for Compulsory Education (DEPPS). As shown in Table 4, Mathematics receives the highest weekly allocation with five hours in Grades 1–2 and four hours in Grades 3–6, while the subject Environment is taught for three hours per week in Grades 1–2 and two hours in Grades 3–4, before being replaced in Grades 5–6 by the separate subjects of Geography (one hour) and Natural Sciences (three hours). The innovative "Skills Labs: A Flexible Zone of Interdisciplinary and Creative Activities", also included in DEPPS, is

[1] https://eurydice.eacea.ec.europa.eu/eurypedia/greece/teaching-and-learning-primary-education

allocated three hours per week in Grades 1–2, two hours in Grades 3–4, and one hour in Grades 5–6, while ICT is consistently taught for one hour per week across all six grades.

Table 4: STEM teaching and learning in primary education, Greece

Subject	Grade (Hours)					
	Grade 1	**Grade 2**	**Grade 3**	**Grade 4**	**Grade 5**	**Grade 6**
Mathematics	5	5	4	4	4	4
Environment	3	3	2	2	-	-
Geography	-	-	-	-	1	1
Natural Sciences	-	-	-	-	3	3
Skills Laboratories	3	3	2	2	1	1
ICT	1	1	1	1	1	1

In lower secondary education (Grades 7–9)[2], the school timetable includes distinct science-related courses such as Physics, Chemistry, Biology, Geology/Geography, Mathematics, ICT, and Skills Labs. Mathematics remains central with four hours per week throughout Grades 7–9, while Physics increases from one hour in Grade 7 to two hours in Grades 8–9, and Chemistry is introduced in Grade 8 with one hour, continuing into Grade 9. Biology is taught consistently at one hour per week across Grades 7–9, and Geology/Geography is offered for one to two hours in Grades 7–8 before being discontinued. In general, upper secondary education (Grades 10–12), the curriculum includes both general education science-related courses and science studies specialisation tracks. Weekly hours increase substantially in the specialisation stream: Mathematics rises to five hours in Grades 10–11 before reaching up to six hours in Grade 12 for specialisation students, while Physics and Chemistry each reach six hours per week in Grade 12.

Table 5: STEM teaching and learning in lower (Grades 7 - 9) and upper (Grades 10 - 12) secondary education, Greece

Subject	Grade (Hours)					
	Grade 7	**Grade 8**	**Grade 9**	**Grade 10**	**Grade 11**	**Grade 12**
Mathematics	4	4	4	5	5 (3)	2 (6)

[2] https://eurydice.eacea.ec.europa.eu/national-education-systems/greece/teaching-and-learning-general-lower-secondary-education

Physics	1	2	2	2	2 (2)	6
Chemistry	-	1	1	2	2	6
Biology	1	1	1	2	2	3
Geology/Geography	1	2	-	-	-	-
ICT	3	2	2	2	2	(6)
Skills Labs	1	1	1	-	-	-

Similarities and Differences in Social/Science Education

By comparing the distribution of codes in the primary-level science curricula, three practices were identified among the five most frequently assigned codes across all participating countries: *analysing and interpreting data*, *obtaining, evaluating and communicating information*, and *planning and carrying out investigations*. In particular, the practice *analysing and interpreting data* warrants special attention, as it appears among the three most frequently assigned codes in all participating countries. This finding suggests that this practice plays a central role in primary-level science education.

In addition, three further practices were identified among the top five codes in at least two countries: *asking questions*, *engaging in argument from evidence*, and *constructing explanations*. A comparison of the relative distribution of codes reveals that two practices are consistently underrepresented across all countries, namely *developing and using models* and *using mathematics and computational thinking*. An overview of the distribution of the five most frequently assigned codes across the participating countries is provided in Figure 3.

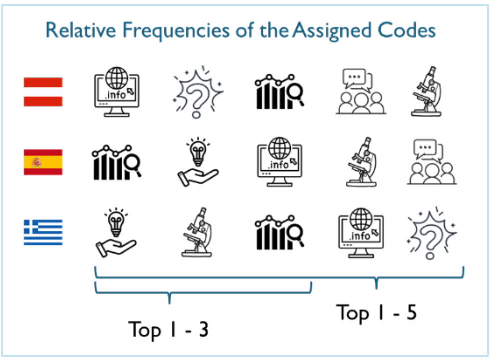


Table 1: Read from left to right for finding the most frequently assinged codes
to the less frequently assigned codes. Only the top five codes are

Similarities and Differences in Mathematics

In this section, the results of the mathematics curricula at Grades 1–4 and subsequently at Grades 5–6 are reported separately, as primary education in Austria comprises Grades 1 to 4, whereas in Greece and Spain it spans Grades 1 to 6. Consequently, Grades 5 and 6 of the Austrian secondary curriculum are compared with the primary curricula of Greece and Spain.

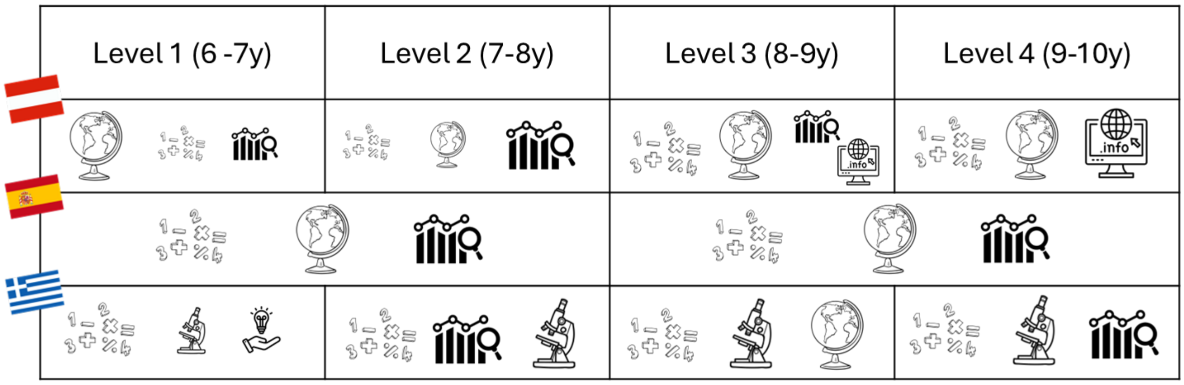
In addition, in both Austria and Greece, the aims and content of mathematics are specified separately for each grade level, while in Spain the aims and content of the subject are formulated jointly for every two grade levels (see Table 5 and Table 6 for further clarification).

Mathematics in the levels 1 - 4

Our analysis indicates that the Greek mathematics curriculum differs slightly from those of Spain and Austria. While the curricula for Grades 1 and 2 in Austria and Spain primarily emphasize the practices *using mathematics and computational thinking*, *developing and using models*, and *analysing and interpreting data*, the Greek curriculum places a stronger focus on *planning and carrying out investigations* and *constructing explanations*. It is also noteworthy that, from Grades 3 to 4, the Austrian curriculum additionally highlights the practice *obtaining, evaluating and communicating information* in mathematics. This practice does not appear among the three most frequently assigned practices in the other participating countries.

Despite these differences, a shared pattern can be identified across the curricula. In Grades 1 to 4, three practices emerge as particularly prominent in all examined countries: (i) *using mathematics and computational thinking*, (ii) *analysing and interpreting data*, and (iii) *developing and using models*. In contrast, the practices *engaging in argument from evidence* and *asking questions* are consistently underrepresented across the curricula.

Table 2: Distribution of Codes in the Mathematics Curricula of the participating



Mathematics in the levels 5 – 6

Similar results to those identified for Grades 1–4 were also found for mathematics in Grades 5–6. In total, N = 278 codes were assigned to the respective curricula (Austria: n = 40; Greece: n = 147; Spain: n = 91). As expected, the practice *using mathematics and computational thinking* was the most frequently coded practice across all countries (N = 114). The second and third most frequently assigned practices varied by country (see Table 6).

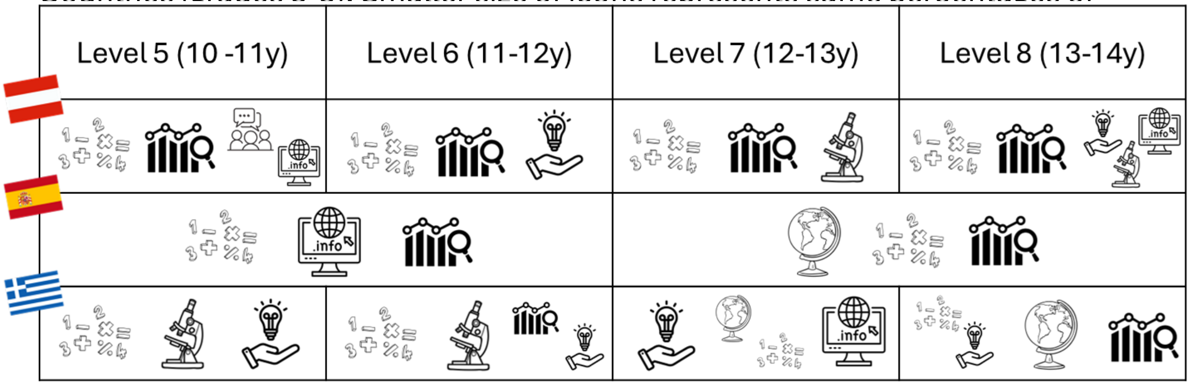
While both Spain and Austria place a strong emphasis on *analysing and interpreting data* and *obtaining, evaluating and communicating information*, the Greek curriculum places greater emphasis on *planning and carrying out investigations* and *constructing explanations*. The latter practice also occurs frequently in the Austrian curriculum.

With regard to underrepresented practices, differences between the countries were also evident. Although Greece places strong emphasis on *planning and carrying out investigations*, this practice was coded only once in the Spanish curriculum and twice in the Austrian curriculum, compared to N = 34 instances in the Greek curriculum. Furthermore, *asking questions* appears to be underrepresented in mathematics education overall (Greece: N = 0; Austria: N = 1; Spain: N = 6).

In addition, the practices *engaging in argument from evidence* and *obtaining, evaluating and communicating information* were not coded in the Greek curriculum. The former practice is also underrepresented in the Austrian (N = 4) and Spanish (N = 2) curricula, whereas the latter was coded at least N = 16 times in the Spanish curriculum and N = 4 times in the Austrian curriculum.

In summary, the most frequently assigned practices in mathematics education—although differing in their relative prominence across countries—are *using mathematics and computational thinking*, *analysing and interpreting data*, and *planning and carrying out investigations*. In contrast, the practices *asking questions* and *engaging in argument from evidence* are underrepresented across the curricula.

Table 3: Distribution of Codes in the Mathematics Curricula of the participating Countries (grades 5-8). Smaller size of icons represents same percentages of



Secondary Education

At the secondary level, we examined the curricula of the following STEM subjects: mathematics, technology and design, biology, physics, and chemistry. As in the previous chapter, the distribution of assigned codes—representing the eight science and engineering practices according to the NGSS (2013)—is presented for each subject in secondary education and compared across the participating countries.

Mathematics in the levels 7 – 8

In the Spanish mathematics curriculum, aims and topics are defined jointly for Grades 7–9. By contrast, the Austrian and Greek mathematics curricula provide separate descriptions for each grade level (see Table 6). Across all countries, *using mathematics and computational thinking* constitutes a shared central focus of the curricula (see Table 6).

In the Spanish curriculum, however, a comparatively high number of codes is assigned to the practice *developing and using models*. This practice is likewise emphasized in the Greek curriculum at Grades 7 and 8. In addition, *constructing explanations* appears to play a more prominent role in the Greek curriculum than in those of the other participating countries.

In contrast to the lower grade levels, the practice *planning and carrying out investigations* gains increasing importance at higher grade levels in the Austrian curriculum, a trend that is not observed in the Greek curriculum. Overall, at least four practices appear among the three most frequently assigned codes in at least two countries: *using mathematics and computational thinking*, *analysing and interpreting data*, *developing and using models*, and *constructing explanations*.

Conversely, *engaging in argument from evidence* is underrepresented in the Austrian mathematics curriculum, while *asking questions* is underrepresented in both the Austrian and Spanish curricula. In the Spanish curriculum, *planning and carrying out investigations* is the least frequently assigned practice, accounting for only N = 2 out of a total of N = 155 codes, and thus represents another underrepresented practice. An overview of the code distribution in the mathematics curricula is provided in Table 3.

Sciences in Secondary Education

As primary education in Spain and Greece covers Grades 1–6, whereas in Austria it spans only Grades 1–4, differences in the subjects taught emerge from Grade 5 onwards. In Spain, natural sciences are taught in combined subjects together with humanities at Grades 5 and 6. In Greece, physics, chemistry, and biology are likewise taught within a single, integrated subject at Grades 5 and 6. In Austria, by contrast, natural sciences are taught as distinct subjects from the beginning of secondary education (biology in Grades 5–8, physics in Grades 6–8, and chemistry in Grade 8).

In the following sections, the three subjects biology, chemistry, and physics are compared with the combined science subjects in Greece and Spain at Grades 5 and 6, as well as with the respective individual subjects at Grades 7 and 8 across the participating countries. As in the preceding sections, tabular overviews are provided to display the most frequently assigned codes for the STEM subjects. In addition, these tables facilitate clearer navigation across the different subjects taught in the participating countries.

Sciences in the Levels 5-6

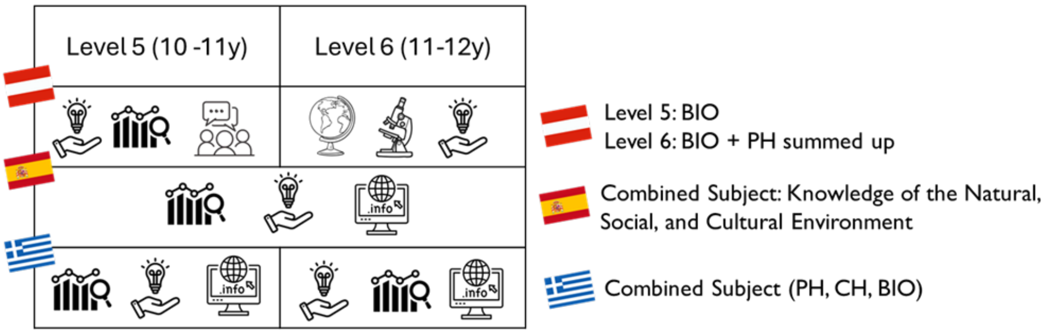
In sum, a total of N = 254 codes were assigned to the science curricula across all participating countries. In Spain, natural sciences are taught within the combined subject *Knowledge of the Natural, Social, and Cultural Environment*. The main practices emphasized in the Spanish curriculum are *analysing and interpreting data*, *constructing explanations*, and *obtaining, evaluating and communicating information*.

Similarly, in Austria, the first two practices are also emphasized in biology education at Level 5, along with the additional practice *engaging in argument from evidence*. It should be noted, however, that only a small number of codes (N = 12) were assigned in total within the Austrian biology curriculum, although all practices are mentioned at least once.

To facilitate a comparison of the practices primarily emphasized in natural sciences education in Austria, physics and biology were combined for Level 6. While *constructing explanations* remains among the three most frequently assigned practices, *developing and using models* and *planning and carrying out investigations* replace *analysing and interpreting data* and *engaging in argument from evidence*.

In the Greek curriculum, the dominant practices are largely similar to those identified in the Spanish curriculum. In Spain, however, the practices *asking questions*, *developing and using models*, and *engaging in argument from evidence* are underrepresented. Among these, *engaging in argument from evidence* is the least frequently mentioned practice across all three countries combined (N = 9). The second most underrepresented practice in science education overall is *using mathematics and computational thinking*, with a total of N = 11 occurrences.

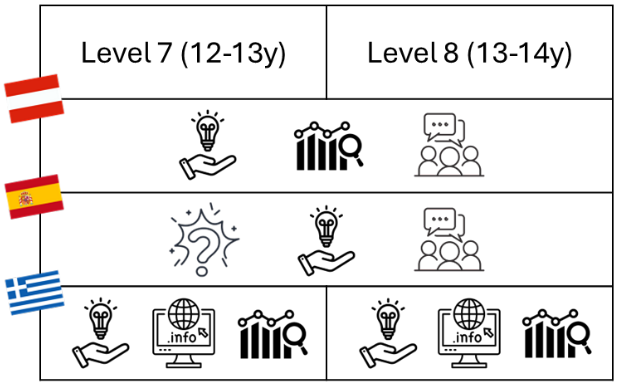
Table 4: Distribution of Codes in Sciences in the Levels 5 & 6.



Biology in the levels 7-8

From Grade 7 to 8, all participating countries teach biology as a distinct subject. One practice appears to dominate across all countries, namely *constructing explanations*. With regard to the second most frequently assigned practice, differences emerge among the countries. While Spain assigns a similarly high number of codes to the practice *asking questions* as to *constructing explanations*, Greece places little to no emphasis on *asking questions* in biology education. Spain also emphasizes the practices *engaging in argument from evidence*—as does Austria—as well as *developing and using models*. In the Austrian and Greek curricula, another key practice is *planning and carrying out investigations*, while the Greek curriculum additionally highlights *obtaining, evaluating and communicating information*. Across all countries, *using mathematics and computational thinking* is an underrepresented practice in biology education. The three most frequently assigned practices in the biology curricula are also presented in Table 5.

Table 5: Top three Practices in the Biology



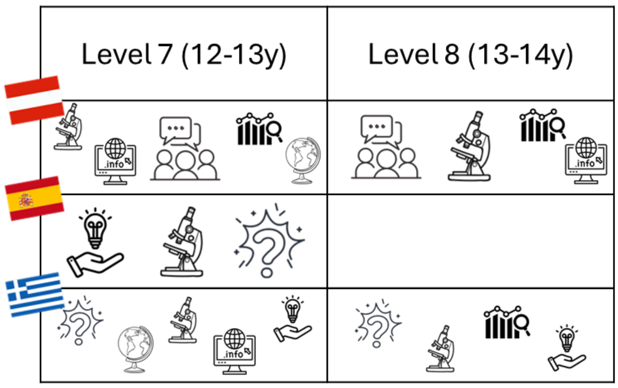
Physics in the levels 7-8

Physics is taught as a separate subject in Austria and Greece, whereas in Spain physics and chemistry are taught as a combined subject and only at Grade 7. A comparison of the countries presented in Table 6 shows that *planning and carrying out investigations* is emphasized across all curricula. While the Austrian curriculum places a stronger focus on *engaging in argument from evidence*, the Greek and Spanish curricula emphasize *asking questions* and *constructing explanations*, respectively.

Interestingly, both Austria and Greece also stress the importance of *developing and using models* in Grade 7. In Spain, this practice receives even greater emphasis and represents the fourth most frequently assigned code. In addition, the Austrian and Greek curricula underline the practice *obtaining, evaluating and communicating information*, which ranks as the fifth most frequently assigned code in the Spanish curriculum.

To summarise, the five most prominent practices identified above are shared across all participating countries. However, the practice *engaging in argument from evidence* is particularly underrepresented in the Greek curriculum, whereas it ranks among the top three practices in the Austrian curriculum. In contrast, *asking questions*, *using mathematics and computational thinking*, and *constructing explanations* were not coded in the Austrian physics curriculum. Overall, the practice *using mathematics and computational thinking* is underrepresented across all physics curricula.

Table 6: Distributed Practices in Physics

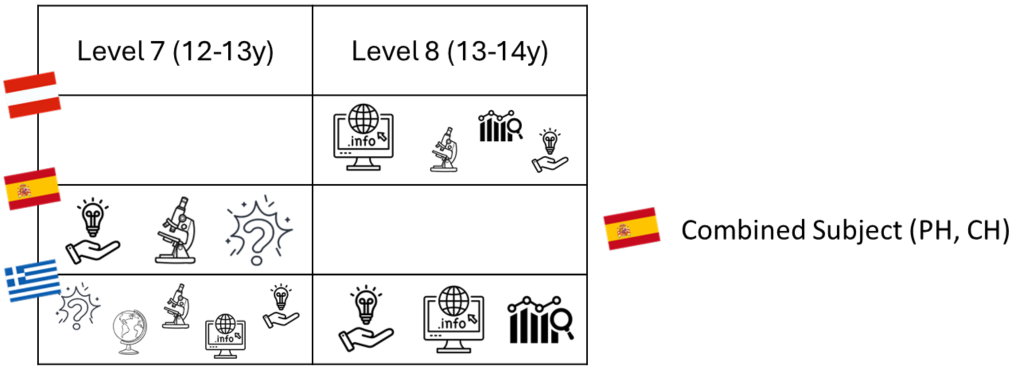


Combined Subject (PH, CH)

Chemistry in the levels 7-8

In Spain, chemistry education is delivered as part of a combined subject together with physics at Grade 7. In Austria, chemistry is taught only in Grade 8 of lower secondary education, while in Greece it is covered in Grades 7 and 8. When comparing the practices emphasized in the curricula, *constructing explanations* emerges as a common practice across all three countries, as shown in Table 7. Both the Austrian and Greek curricula place a strong emphasis on *obtaining, evaluating and communicating information* as well as on *analysing and interpreting data*. Another practice addressed in all countries—although to a lesser extent in Greece—is *planning and carrying out investigations*. Practices that are underrepresented across the chemistry curricula include *using mathematics and computational thinking*, *engaging in argument from evidence*, and *asking questions*.

Table 7: Distribution of Practices in the Chemistry Curricula.



Technology and Design in levels 5-9

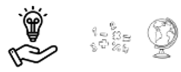
Technology and Design is taught in Austria from the beginning of lower secondary education, but only until Grade 8, and therefore holds a more prominent role than in the curricula of Spain and Greece. Across all grade levels in Austria, the most frequently occurring practices are *defining problems, developing and using models, obtaining, evaluating and communicating information*, and *designing solutions*. In Grades 6–8, a stronger emphasis is placed on the practices *planning and carrying out investigations* as well as *engaging in argument from evidence*. Practices that are underrepresented—or not represented at all—in Technology and Design in Austria include *using mathematics and computational thinking* and, with the exception of Grade 7, *analysing and interpreting data*.

In Spain, the focus in technology education lies predominantly on the practices *designing solutions*, *defining problems*, and *obtaining, evaluating and communicating information*. These practices are closely followed by *analysing and interpreting data*. Slightly more than 10% of the assigned codes (n = 13 out of a total of N = 116) were attributed to the practice *using mathematics and computational thinking*. All remaining practices occur with slightly less than 10% representation in the Spanish technology curriculum.

In Greece, a strong emphasis on *designing solutions* and *developing and using models* was identified across all three levels (Grades 7–9). In Grade 7, the practices *obtaining, evaluating* *and communicating information* and *planning and carrying out investigations* are additionally emphasized. Notably, the practice *using mathematics and computational thinking* increases in prominence at higher grade levels and was identified as a key practice in Grades 8 and 9.

Overall, the cross-country comparison reveals an underrepresentation of mathematical aspects within the subject of Technology and Design in Austria compared to the other two participating countries. In contrast, the practice *engaging in argument from evidence* is particularly prominent in Austria, while it does not appear among the central practices in Spain and Greece. A common focus across all countries can be observed in the practices *defining problems, designing solutions*, and *obtaining, evaluating and communicating information*, see Table 11.

Table 11: Distribution of Practices in the Technology (and Design) Curricula.

	Level 5 (10 -11y)	Level 6 (11-12y)	Level 7 (12-13y)	Level 8 (13-14y)	Level 9 (14-15y)
					
					
					

Discussion of the Results and Implications

Uncovered Challenges and Opportunities

The analysis of the curricula regarding the science and engineering practices showed that there are similarities in each subject and across the various levels of education to focus on in the Units of Learning in inTruST. Next to the similar practices that the curricula of the participating countries focus on, we also discovered shared underrepresented practices in each subject. As displayed in Figure 1, teachers have two options for the design of the Units of Learning: a) Units of Learning can be designed with a focus on the most emphasised science and engineering practices in the curricula of the participating countries, or b) Units of Learning can be designed with a focus on underrepresented science and engineering practices in the curricula of the participating countries. In the next two sections underlying considerations for those two options will be explained.

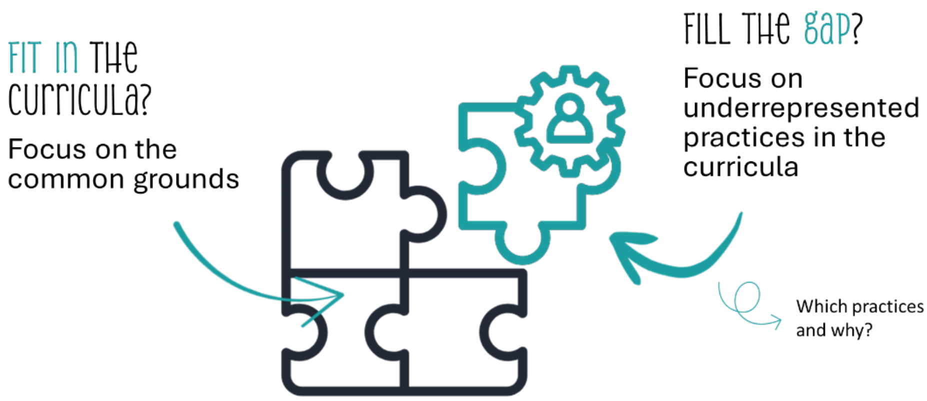


Table 8: Two options to Proceed in the Development of the Units of Learning.

Learning Scenarios with a Focus on Emphasised Practices

From the comparison of the curricula, we know which practices the different countries emphasise in the STEM subjects. Since the units of learning will be tested in all participating countries and may also be published for external use by teachers, it is sensible to focus on common practices. This approach ensures that the materials align with the national educational objectives of each country and reinforce the core competencies valued across all three systems. By doing so, the developed materials can be easily adapted and implemented in multiple classrooms, as they meet subject-specific standards of all participating countries. This facilitates the adoption of innovative teaching materials without conflicting with teachers' established teaching traditions. Moreover, focusing on shared practices demonstrates a strong consensus among the countries, which may help address international challenges and align with recommendations from bodies such as the OECD.

Learning Scenarios with a Focus on Underrepresented Practices

Focusing on underrepresented practices has many positive aspects. Firstly, neglected practices are brought to the forefront, allowing a comprehensive STEM education by filling gaps. Secondly, implementing new practices in the classroom requires new methods and concepts. This fosters innovation and the professional development of teachers. Students may also benefit from these new methods and ideas, which could result in higher motivation and engagement. Thirdly, underrepresented practices such as 'computational thinking' could help prepare students for real-world challenges such as climate change and digitalisation. Fourthly, strengthening all practices in STEM education and diverse subjects helps to establish a solid foundation for further education in STEM subjects.

Implications for the Design of Learning Scenarios in inTruST

In this chapter, we outline implications for designing learning units along with exemplary considerations for designing a learning unit. The following steps (also presented in form of FIGURE) are intended as best practice advice based on considerations from the literature and insights gained during the first year of the inTruST project. The order of the steps can, of course, be varied.

STEP 0 Defining the Scope according to Curriculum Requirements: Subject, Age of Students, Topic, Number of Lessons and Duration of the Lessons.

Before we can start with developing the learning units, various formalities must be considered, such as the subjects involved, the age of the students, the topics and teaching goals of the (inter-)national curricula, the number of lessons that are available for the unit of learning etc. Teaching lessons are planned in respective subjects and for a defined grade level. In accordance with the teaching plan for the whole school year, teachers select a topic in line with the national curriculum and the curricula of the participating countries prior to identifying the learning objectives.

STEP 1 Identifying Core Science and Engineering Practices for the Learning Unit and Defining Learning Objectives.

In step 1, the teachers define learning objectives and simultaneously select science and engineering practices in focus for each lesson of the learning units. Due to the international character of the project, the learning objectives as well as the science and engineering practices should be selected in accordance with the diverse curricula of the participating countries. The selection of the science and engineering practices in focus was guided by the results of the curriculum analysis: Teachers decided to focus either on the most frequently selected practices or on underrepresented practices in their subject-specific curricula (see considerations in the section above). As a rule of thumb, we think it beneficial to focus on one or two practices per teaching lesson. Following the formal considerations for the development of the units, the teachers brainstormed first ides for achieving the learning objectives, such as contents for the teaching lessons and possible research questions as well as first ideas for student exercises. The first ideas were presented and discussed with the inTruST-Team in the first two meetings of this project.

STEP 2 Choosing the Appropriate Level of Inquiry-Based Learning.

To design the units of learning, teachers choose an appropriate level of Inquiry-Based Learning (IBL) that enables students to achieve the learning objectives. Some practices are more easily addressed in certain phases of the research cycle than others. Therefore, some practices are more easily achievable in open inquiry (level 3) than in guided or structured inquiry. However, although not visible at first glance, the practice of ‘asking questions and defining problems’ may not only be important in the open inquiry level, where students begin by formulating a research question. Asking questions can be part of all the phases of the research cycle. For example, students might be confronted with data from an experiment and tasked with identifying further research questions for a follow-up investigation. Another example could be to pose questions about phenomena students observe during an investigation. However, some phases of the research cycle are more naturally suitable for the implementation of a specific practice than others. Therefore, the choice of an IBL level and the practices should be carried out carefully.

STEP 3 Consider Pedagogical and Didactical Methods.

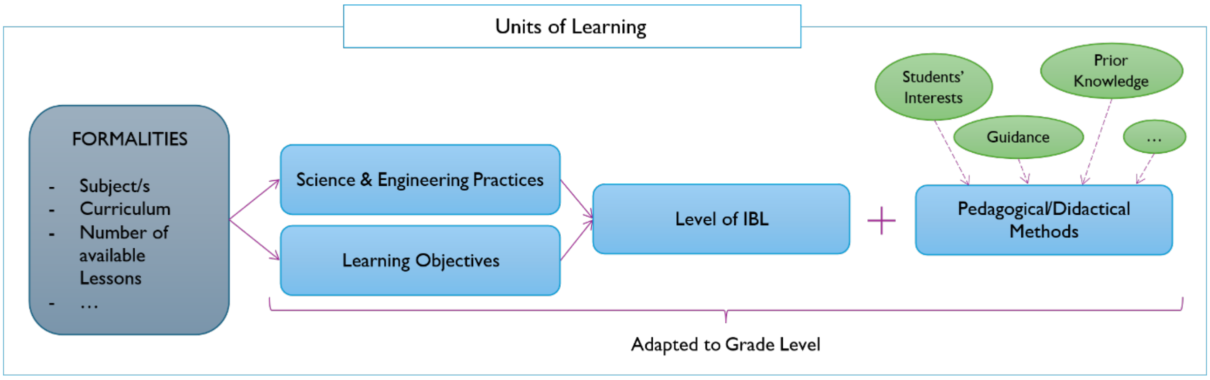
Finally, pedagogical and didactical methods, as well as the teachers' experiences, should be used to complete the learning units. In general, learning environments should build on students' prior knowledge and provide guidance where gaps exist in their processing of the content. As discussed in the literature review on IBL, individual guidance has proven highly effective in supporting students in IBL settings. Furthermore, topics and contents should be selected based on the students' interests. Ideally, students should have the opportunity to set their own focus for an investigation. Fruitful learning environments benefit from well-designed materials that help students to structure their work, track their learning progress, and document interesting findings and results. There are numerous methods and elements that teachers may consider when designing their learning units. Some of these methods, tips, and strategies can also be found in the umbrella literature review of this project.

STEP 4 Evolve from Subject-Specific Learning Units to STEM Learning Scenarios.

An attentive reader may have noticed that we start from a subject-specific perspective. However, STEM learning environments particularly benefit from interdisciplinary instruction or even project-based learning. To move beyond subject-specific teaching, educators can intentionally connect their learning units to other STEM disciplines. This not only strengthens the integration of knowledge but also enhances students' interdisciplinary problem-solving skills. Such an integrated approach allows for a deeper exploration of complex topics from multiple perspectives, fostering more sustainable learning outcomes.

Learning Scenarios Developed in inTruST

In sum, 16 learning units ranging from elementary to secondary level were designed in various STEM subjects. Given the project timeline, the curriculum analysis as well as the umbrella literature review were conducted concurrently with the teachers brainstorming their initial ideas for their learning units. However, the teachers met in person at their first meeting to discuss and align their chosen topics and learning objectives. Additionally, they familiarized themselves with the eight NGSS science and engineering practices and the various levels of IBL during the first project meeting in Schwechat (Austria), and planned their Learning Scenarios accordingly.



To develop the teaching units, the teachers used a prepared template, provided by the project lead, where they documented all relevant information for their Units of Learning. In the first and second meetings in Schwechat, the teachers presented their ideas for the Units of Learning, which served as the basis for the first feedback session. In the third project meeting in Viladecans (Spain), all team members provided feedback on the assigned Units of Learning regarding the NGSS science and engineering practices chosen, as well as anticipated challenges and potential improvements for implementation, among other aspects. Currently, the provisional Units of Learning are being pilot-tested and evaluated. The revised Units of Learning will be a significant outcome of the inTruST project, helping to build trust in science and technology. All Units of Learning will be uploaded upon their final revision.

Summary of Practices Across Curricula

Across the analysed curricula in Austria, Spain, and Greece, several science and engineering practices emerge as consistently prominent. Most frequently represented across subjects and educational levels are analysing and interpreting data, obtaining, evaluating and communicating information, planning and carrying out investigations, and constructing explanations. These practices form a shared core of STEM education across the participating countries and are particularly dominant in science subjects and social/science education at primary level.

In contrast, the practices using mathematics and computational thinking, engaging in argument from evidence, and asking questions and defining problems are systematically underrepresented across many subjects and levels. Notably, using mathematics and computational thinking is marginal in science and technology curricula, while engaging in argument from evidence appears strongly in Austrian curricula but is largely absent in Greece and Spain.

The comparative analysis reveals both convergence and divergence among national curricula. While all countries emphasize inquiry-related practices linked to investigation and explanation, they differ in how systematically argumentation, questioning, and mathematical reasoning are integrated. These differences point to both opportunities—such as leveraging strong national practices across borders—and challenges, particularly in addressing underrepresented practices essential for scientific literacy and trust in science.

From these findings, two complementary strategies for implementing inquiry-based learning in STEM education can be derived: designing Learning Scenarios that reinforce shared, well-established practices, and deliberately targeting underrepresented practices to strengthen inquiry depth, argumentation, and computational thinking. Both approaches are viable and context-sensitive pathways for enhancing IBL implementation across diverse educational systems.

Limitations

Several limitations need to be considered when interpreting the results of this study. First, the analysed curricula differ considerably in their structure, level of detail, and formulation of aims and competencies, which affects the direct comparability of coded practices across countries. In some cases, curricular content is specified for combined grade levels or integrated subjects, potentially obscuring grade-specific emphases. Second, the frequency of assigned codes reflects the explicit presence of practices in curricular documents, but does not necessarily indicate their pedagogical weight or actual classroom implementation. Third, the curriculum analysis relied on the interpretation and coding decisions of teachers from different national and disciplinary backgrounds, which—despite joint training and validation procedures—may introduce subjectivity. Finally, the study focuses on formal curricula and does not account for enacted curricula or instructional practices, which may differ substantially from curricular intentions.

Use of AI

AI Tool	**Purpose of Use**	**Description**
Microsoft Copilot (GPT-based)	Language editing and summarisation	Microsoft Copilot was used to support the linguistic revision of the report, including grammar, style, and clarity, as well as to assist in summarising selected sections of the document. All content was reviewed and validated by the authors.
Mistral	Background research support	Mistral was used for exploratory research purposes, such as comparing formal and structural aspects of national curricula (e.g. grade ranges, subject organisation, and terminology). The tool supported orientation and comparison but did not generate final content for the report.

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