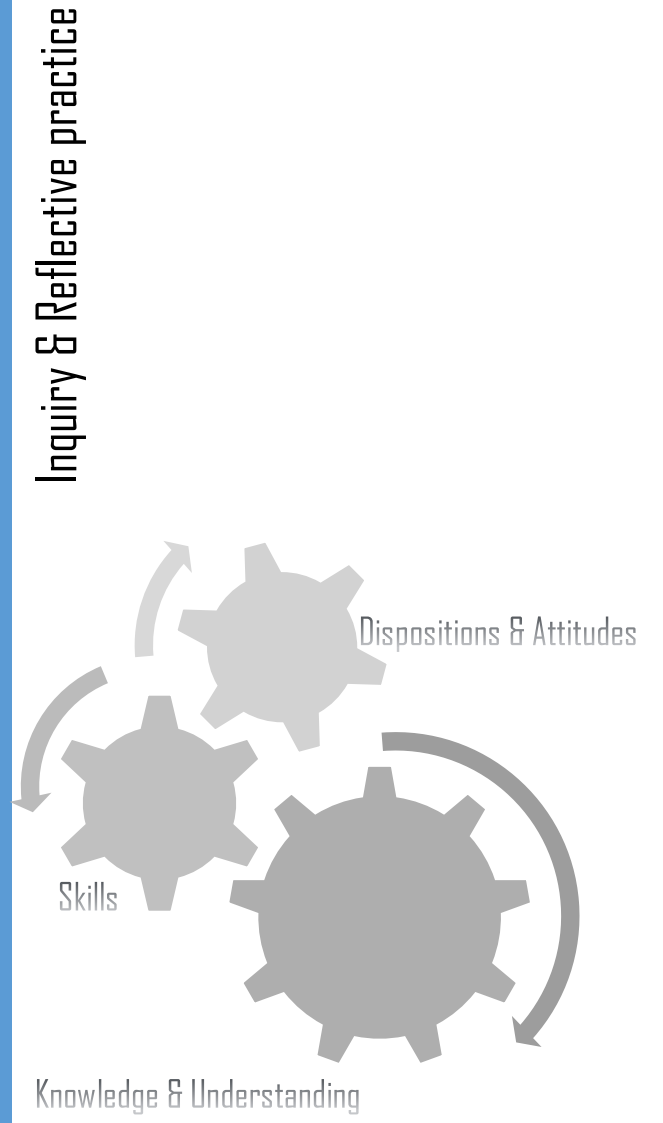
SUPPORTING STEM TEACHERS INQUIRY AND REFLECTIVE PRACTICE

The ELITe project framework for STEM teachers' competence development under an inquiry approach



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ELITe is concerned with supporting Science, Technology, Engineering and Mathematics (STEM) teachers' development of knowledge, skills and attitudes so that they can effectively address their roles as lifelong learners, facilitators of students' learning and members of educational communities. It aims to on the one hand highlight the links between inquiry skills practicing and STEM teachers' competence development, and on the other to inform curriculum development in STEM teachers' education.

Project: Enhancing Learning in Teaching via e-inquiries (ELITe)

Program: Erasmus +, Strategic Partnerships for school education, 2016-2019

Document title: Intellectual Output O9: Framework for STEM teachers' competence development under an inquiry approach

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The ELITe project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Co-funded by the Erasmus+ Programme of the European Union

Preface

This publication aims ***to inform curriculum design in Science, Technology, Engineering and Mathematics (STEM) teacher education, by providing a framework for teachers' competence development under an inquiry based learning approach***.

The framework – developed and validated in the course of the ERASMUS+ project ELITe in four national EU contexts, namely in Greece, the Netherlands, Bulgaria and Spain- ***aims support STEM teachers' development of knowledge, skills and attitudes*** so that they can effectively address their roles as ***lifelong learners***, ***facilitators of students' learning*** and ***members of educational communities***.

Whereas current prevailing approaches in initial and continuous training programs focus on subject knowledge, pedagogy and 'practice' (classroom-based training), the ELITe approach for STEM CPD calls for the ***need to address teachers' competence development goals***, articulated as knowledge, skills and attitudes needed by teachers to address their challenging roles. ***The core innovation element of the ELITe framework is the adaptation of the Inquiry Based Learning (IBL) methodology in STEM teachers' training***, on the basis of evidence from ELITe implementation on the links between inquiry skills practicing and STEM teachers' competence development. ***Contextual aspects*** affecting effective provision of CPD in the above mentioned countries have been taken into consideration, while ***challenges and needs in terms of renewing the thematic*** of STEM teacher trainings have been also addressed.

The developmental process of the ELITe framework followed the following methodological steps:

- *Identification of the space for intervention* for supporting STEM teachers' competence development in 4 EU contexts, through documentary analysis and educational stakeholders' negotiation process
- *Definition of outcomes indicators* for evaluating the impact of professional learning activities targeting competence development on the basis of the EC (2013) teachers' competence framework
- *Development of the ELITe inquiry based approach* for STEM professional learning activities, through example digital scenarios for teachers' training in new thematic areas
- *Evaluation of the ELITe approach* through pilot implementation for providing evidence on the links between inquiry skills practicing and teachers' competence development.

It is hoped that this publication contributes to contemporary efforts of STEM teacher training providers ***towards modernizing STEM professional learning provisions in European educational contexts***, so that they can ***address current challenges – contextual, methodological, thematic and outcome related***- in STEM teachers' Continuous Professional Development (CPD).

Introduction

The work reported in this document is predicated on the premise that teachers' competence development is crucial to educational reform and school improvement focused on enhancing students' learning outcomes and achievement. This proposition has been highly acknowledged in current educational discourse across Europe (OECD, 2010) and is supported by research findings that indicate the significant, positive correlations between teacher quality and student achievement (Caenna, 2011).

Science, Technology, Engineering and Mathematics (STEM) teachers' Continuous Professional Development (CPD) in particular is currently a prevailing area of policy focus at EU and national levels. STEM education is considered vital for future citizens in acquiring and developing competences needed for living and working in the 21st century (EC, 2015). As reflected in the EC COUNCIL RECOMMENDATION on key competences for lifelong learning of 22 May 2018 [2]:

> "*In the knowledge economy, memorisation of facts and procedures is key, but not enough for progress and success. Skills, such as problem solving, critical thinking, ability to cooperate, creativity, computational thinking, self-regulation are more essential than ever before in our quickly changing society."*

One of the main recommendations in this communication is the need:

> "*to support the development of key competences paying special attention to: fostering the acquisition of competences in sciences, technology, engineering and mathematics (STEM), taking into account their link to the arts, creativity and innovation and motivating more young people, especially girls and young women, to engage in STEM careers*".

Contemporary large scale surveys provide evidence that the EU national educational systems have taken steps towards ensuring the provision of CPD for teachers' competence development. As reported in the 2018 Eurydice document "*Teaching careers in Europe: Access, Progression and Support*" in the large majority of education systems CPD is considered a professional duty; additional supporting measures for developing and improving professional practice are available to teachers in most countries; and thirty-two education systems have developed a teacher competence framework to varying degrees. However, 2018 TALIS results indicate a mismatch between STEM teachers' needs for CPD and the actual content and learning modes of professional learning activities, as well as low participation rates of teachers in the kinds of professional development that has shown to be effective-***results that call for a need to re-conceptualize and reconsider STEM CPD provisions***.

Against this background, ***this document proposes a framework for STEM teachers' competence development under an inquiry based learning approach***, developed and validated in the course of the ELITe project in four national EU contexts - namely in Greece, the Netherlands, Bulgaria and Spain in the period 2016-2019. The ELITe framework:

- Adopts a ***place-based approach*** for STEM teachers' professional learning, *taking into consideration national policy requirements and practice needs*
- Propagates the ***adoption of the inquiry-based learning (IBL) methodology in professional learning activities***, highlighting the *links between inquiry skills practicing and STEM teachers' competence development*
- Considers ***content areas that reflect current policy orientation on the broader aims of STEM education***, proposing exemplar *digital learning scenarios that address them*
- Is oriented towards ***facilitating the assessment of STEM teacher's competence development***, proposing *outcome indicators* for evaluating the impact of professional learning activities on STEM teachers practice.

The content of this document has been informed by results of activities conducted in the frame of ELITe, reported in the following Intellectual Outputs of the project:

- Policy envisions and requirements for STEM teachers' competence development: State of affairs in 4 EU countries.
- Context-based indicators for evaluation STEM teachers' competence development
- Systemic opportunities and challenges for STEM teachers' competence development in 4 EU national contexts
- Evaluation and validation report of the ELITe's learning in teaching approach via e-inquiries.

The document is structured as follows:

First, presented is the methodology applied for the development of the ELITe framework (see section Methodological considerations). Outlined in this section are the challenges and the implicit requirements for STEM teachers' CPD -as staring points of the developmental process, as well as the steps followed for the development, implementation and evaluation of the ELITe approach.

Then, provided is an overview of the framework's dimensions and components, followed by a detailed account of the framework components in each dimension, namely the contextual, the methodological, the thematic and the outcome dimensions.

Finally, concluding remarks are outlined, focusing on project's forthcoming activities, to be implemented under the scope of negotiating with educational stakeholders the validity of the project's understandings on STEM teachers' competence enhancement through the IBL methodology.

Methodological considerations

Starting points

The starting point for the development of the ELITe project framework was the identification of current challenges and implicit requirements on STEM teachers' professional learning (PL) for competence development, summarized in Figure 1.

From a contextual perspective, wide variety prevails across European countries, in the current approaches to teachers' competences (EC, Education and Training, 2013). General guidelines about the competences required for teaching are usually embedded in the national curricula and autonomy is then left to university or college providers to develop and apply detailed competence requirements in teacher education programs accordingly. Therefore ***the ELITe approach advocates that efforts to stimulate teachers' competence development through professional learning opportunities need to be place-based,*** taking into consideration the various interpretations and understandings not only among the different EU educational systems, but also among different stakeholders in each country.

From a methodological perspective, current prevailing approaches in initial and continuous training programs focus on subject knowledge, pedagogy and "practice"(classroom-based training) (EC, Education and Training, 2015). Such approaches, fail to recognize that ***teachers' dispositions towards learning and teaching - and as a consequence their practice - are highly influenced by the way teachers have received training themselves.***

Perspectives	*Challenges*	*Implicit requirements*
Contextual	Teacher competence requirements among and within EU countries	Place-based approach, consistent with national policy requirements and practice needs
Methodo-logical	Teachers' practice depends on the way it is developed by trainings	Modernization of teacher training methodology
Content related	Thematic addressing STEM broader aims	Relevance of the thematic to STEM broader educational aims
Outcome related	Evidence of the impact of competence based frameworks on teachers pro-fessional learning	Need for definition of indicators for STEM teachers competence development

Figure 1: Challenges and implicit requirements for STEM teachers' professional learning that have informed the development of the ELITe framework

Knowledge and skills on/about teaching is developed by teachers themselves, as they use theory and research to reflect upon their practices in professional learning communities (Hagger &McIntyre, 2006). In addition, formal and traditional forms of in-service training such as courses, workshops and conferences currently prevail in most educational systems. However, many teachers either do not find suitable professional development or cannot attend due to conflicting work schedules (OECD, 2009). ELITe argues that ***there is a need for providing flexible professional development opportunities in which the training methodology has a prevailing role, embedded on the concept of "change as professional learning perspective", which sees teachers as reflective practitioners, responsible for their own learning.***

From a content perspective, STEM education is currently defined as 'creative education to foster the future needs of society (Sutcliffe, 2011). STEM educators – under the Responsible Research and Innovation (RRI) policy agenda- are expected to equip students as future citizens to understand socio-scientific issues, applying science knowledge, ethical values and inquiry skills to form evidence based opinions (EC, 2015). In addition there are expected to aspire science related careers to students and support students develop positive attitudes towards science. Therefore, ***the thematic of the professional learning activities for STEM in-service teachers need to reflect current policy orientations under the RRI agenda on the role of STEM education and help teachers to model key competences required*** (knowledge, skills and attitudes) in order to help students to acquire them.

From an outcome oriented perspective, studies on the impact of the teacher standards approach in different countries show wide variations in standards implementation and use, according to the contexts and the responsibilities for judgement (Caenna, 2011). ***The need to create instruments to determine the impact of learning under a competency orientation is sustained*** (Munoz and Araya, 2017).

Process of development

The developmental process for structuring the ELITe framework took place in four stages:

Stage 1: Identification of the space of intervention in four national EU contexts (namely Greece, the Netherlands, Bulgaria and Spain) for supporting STEM teachers' professional learning for competence development

Stage 2: Definition of outcome indicators and sub-indicators for evaluating the impact of professional learning activities targeting competence development

Stage 3: Development of the ELITe project "learning –in – teaching via e-inquiries approach"

Stage 4: Evaluation of the approach through pilot implementation of 26 scenarios for STEM professional learning that address 9 thematic areas in the 4 national contexts with more than 200 STEM teachers.

Specifically, each stage of the developmental process followed the following methodological steps:

Stage 1: Identification of the space of intervention in four national EU contexts (namely Greece, the Netherlands, Bulgaria and Spain) for supporting STEM teachers' professional learning for competence development

Layers of analysis in identifying contents and forms of teachers' professional development have been adapted by J.Scheerens (2010) and include: characteristics of the national education systems; teachers as members of the professional learning; teaching effectiveness and teacher effectiveness (see Figure 2).

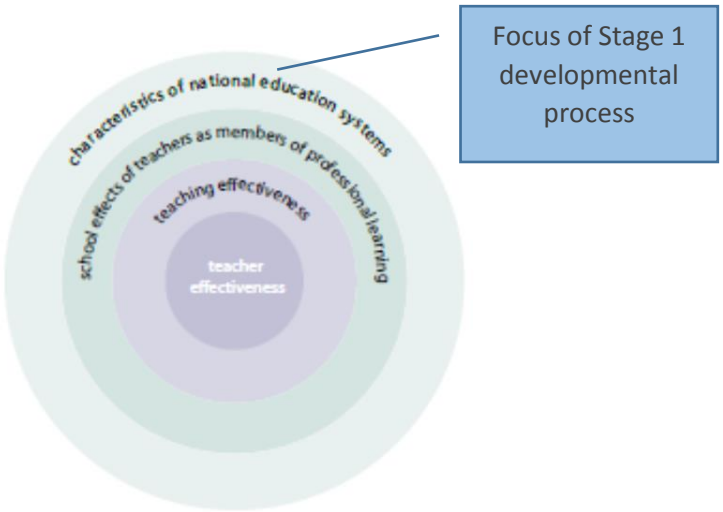


Figure 2: Layers of analysis in identifying contents and forms of teachers' professional development (J.Scheerens, 2010)-focus in Stage 1

Stage 1 of the developmental process was considered with the layer "characteristics of education systems" of the onion ring model for teachers' professional development. At this stage the aim was to enhance understandings on policy envisions and requirements for STEM teachers' competence development in the four piloting national contexts.

The framework of the analysis of the national contexts in terms of STEM teachers' competence requirements - presented in Figure 3 - consisted of the following elements: a) it examined 3 areas/dimensions of teachers' competences -namely knowledge & understanding, skills and dispositions & attitudes;

b) it considered aspects/features in the dimensions of knowledge & understandings , skills, dispositions & attitudes as identified in EC (2013);

c) it considered three levels of systematic analysis: 1. the macro-level regarding wider policy envisions and requirements, 2. the meso-level – relating to the way teacher training institutions and initiatives mediate the implementation of policies and 3. the micro-level – regarding classroom implementation requirements;

d) it defined as objects of the analysis official policy documents referring to (STEM) teachers competence development & initial and CPD curricula from STEM teachers training providers (allowing the identification on whether aspects of the competence are evident) & also STEM curricula for students (allowing the identification of competences which are implicitly evident/required.

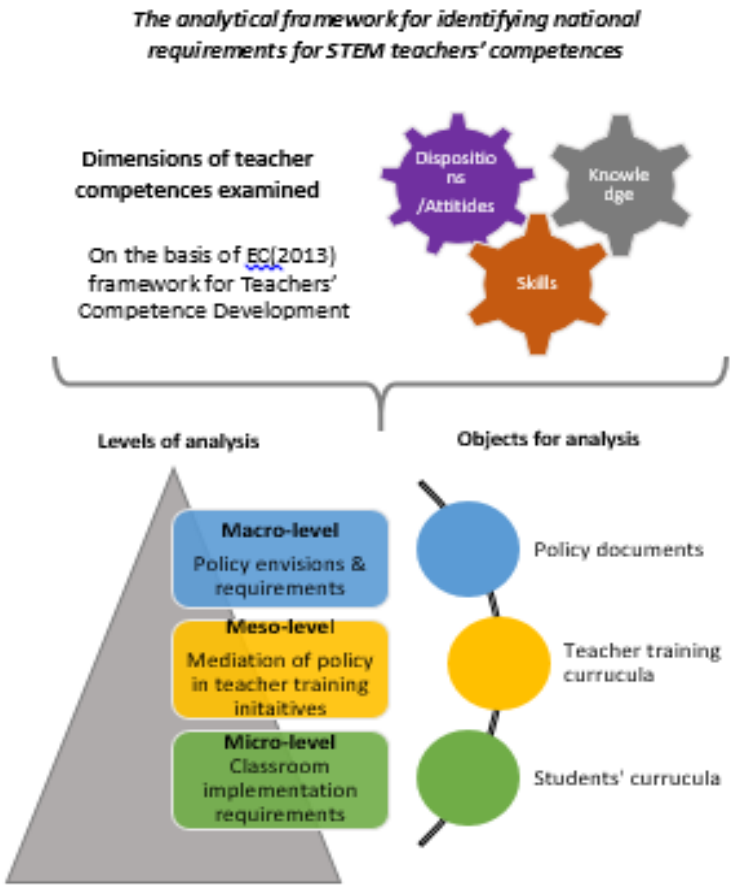


Figure 3: The analytical framework for investigating national contexts

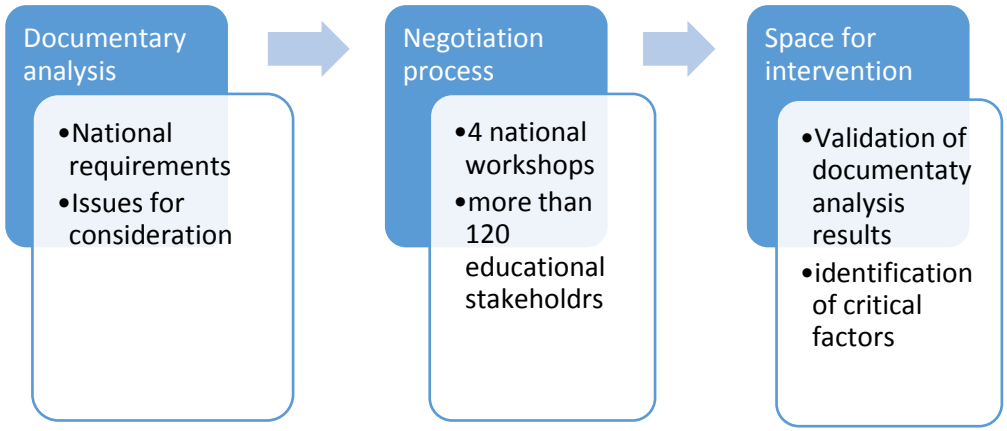


Figure 4: Outline of the Stage 1 developmental processes

The review of the national contexts provided on the one hand insights on the competences (knowledge & understanding, skills, dispositions and attitudes) that are explicitly and implicitly evident at policy, policy mediation and teaching practice levels and on the other allowed the identification of prominent issues for consideration in each country.

The results of the exploration of the nation context through the documentary analysis were communicated and negotiated with 30 educational stakeholders (policy makers, responsible for STEM teachers' training and STEM teachers). Main outcomes of the negotiation process was the validation of the results of the documentary analysis, and the provision of insights from policy, policy mediation representatives and practitioners on how to support more effectively STEM teachers' professional learning for competence development.

Stage 2: Definition of outcome indicators and sub-indicators for evaluating the impact of professional learning activities targeting competence development

Outcome (or output) indicators reflect the quantity of outcomes produced, including immediate measurable results, and direct consequences of activities implemented to produce such results (Burke, 1998). The methodological steps followed for the development of outcome indicators for evaluating the impact of professional learning activities targeting STEM teachers; competence development were the following:

• First, ***defined were the expected outcomes of STEM PL activities***, ***on the basis of Deakin & Crick (2008) definition of competences as requirements for teaching and learning,*** according to which a competence is best described as '*a complex combination of knowledge, skills, understanding, values, attitudes and desire which lead to effective, embodied human action in the world, in a particular domain'*. The dimensions of teachers' competences (knowledge & understanding, skills, dispositions & attitudes) served as the basis for the definition of the expected outcomes of STEM teachers' participation in initiatives for competence development.

		Expected Outcomes
Dimensions of teachers' competences	Knowledge & Understanding	Develop knowledge & understanding on learning and teaching *"I have knowledge and understanding on this"*
	Skills	Develop skills for learning and teaching *"I can do this"*
	Dispositions & Attitudes	Come to value learning and teaching – develop positive dispositions and attitudes *"This is important to me"*

• Then, ***identified were outcomes indicators, by clustering the aspects of competences defined in EC (2013) framework for competence development*** and translating the formulated clusters into indicators for evaluating the expected outcomes. Clusters were informed the layers of analysis in identifying contents and forms of teachers' professional development (J.Scheerens, 2010). Of relevance here are the layers: teachers as members of the professional learning; teaching effectiveness and teacher effectiveness.

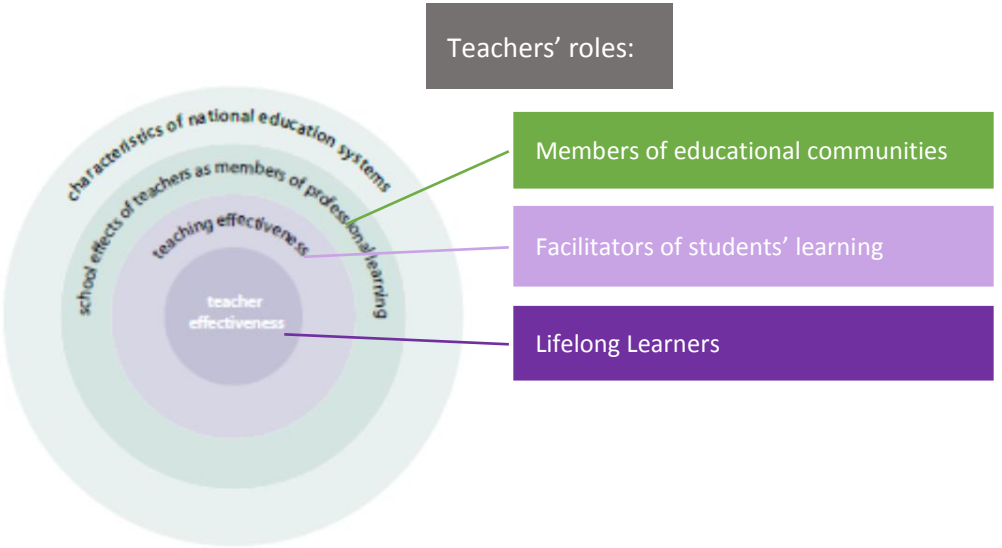


Figure 4: Layers of the onion ring model for teachers' professional development that informed clustering of competences of the EC (2013) framework for defining outcomes indicators

For the dimension of "*Knowledge & Understanding*" three groups of aspects were formed, namely:

- aspects relating to *knowledge and understanding of the teaching and learning content* (Subject matter knowledge; Pedagogical content knowledge; Curricular knowledge; Developmental psychology; Inclusion and diversity) → teachers as lifelong learners
- aspects relating to *knowledge and understanding on methodologies and methods on STEM learning and teaching* (Pedagogical knowledge ; Group processes and dynamics learning theories, motivational issues; Evaluation and assessment; Effective use of technologies in learning; Knowledge on innovative STEM methodologies) → teachers as facilitators of students' learning
- aspects relating to *knowledge and understanding on contextual aspects of teaching and learning* (Educational science foundations; Contextual institutional and organisational aspects of educational policies)→ teachers as members of educational communities

Aspects of skills of the EC (2013) framework were clustered in three groups, namely:

- *learning skills* - relating to teachers' own learning) (Using, developing and creating research knowledge to inform practices ; Reflective, metacognitive and interpersonal skills for learning individually and in professional communities) → teachers as lifelong learners
- *teaching skills* - relating to the promotion of students' leaning (Planning, managing and coordinating teaching; Using teaching materials and technologies; Managing students and groups; Monitoring, adapting and assessing teaching/learning objectives and processes; Collecting, analysing, interpreting evidence and data for professional decisions) →teachers as facilitators of students' learning
- *professional skills* - relating to teachers' role as part of educational communities (Collaborating with colleagues, parents, and social services; Negotiation skills (social and political interactions with multiple stakeholders, actors and contexts; Adapting to educational contexts) → teachers as members of educational communities

Aspects of dispositions and attitudes of the EC (2013) framework were clustered in three groups, namely:

- *dispositions and attitudes towards teachers' own learning* (Epistemological awareness; Dispositions to change, flexibility, ongoing learning and professional improvement, including study and research; Critical attitudes to one's own teaching) → teachers as lifelong learners
- dispositions and attitudes relating to the promotion of students learning (Teaching skills through content; Transferable skills; Commitment to promoting the learning of all students; Disposition to promote students' democratic attitudes and practices as European citizens, including appreciation of diversity and multiculturality) → teachers as facilitators of students' learning
- dispositions and attitudes relating to teachers' role as part of educational communities (Dispositions to team working, collaboration and networking; Sense of self-efficacy))→ teachers as members of educational communities

An example of how the formulated clusters were translated into indicators for the dimension of skills is provided here below.

			Outcome indicators
Clustering of aspects of teachers' competences of EC(2013) framework Skills dimension	Learning skills (relating to teachers' own learning)	=>	Enhanced learning skills, relating to the promotion of teachers' own learning
	Teaching skills (relating to the promotion of students' STEM learning)	=>	Enhanced teaching skills, relating to the promotion of students' learning
	Professional skills (relating to teachers' role as part of educational communities)	=>	Enhanced professional skills, relating to teachers' role as part of educational communities

• Finally, ***the aspects of competences in each cluster were translated into sub-indicators***. Using information from the review of the national contexts identified were the national contexts (for Greece, the Netherlands, Bulgaria & Spain) in which each sub-indicator is most relevant to. An example of how the aspects of competences were translated into sub-indicators is provided here below.

Cluster of skills	Aspect of skills		Outcome sub-indicator
Teaching skills	Managing students and groups	=>	Demonstration of mastery in managing students and groups

Stage 3: Development of the ELITe project "Learning –in – teaching via e-inquiries approach"

The aim of Stage 3 developmental process was to develop the ***ELITe's Learning in teaching approach via e-inquires*** approach, an adaptation of inquiry methodology for teachers' competence development, taking into consideration results and insights obtained during the previous stages.

The key processes of the development of ELITe ***Learning in teaching approach via e-inquiries*** STEM teachers competence development scenarios were structured and implemented around the questions:

1. **In what context?**
2. **What for?**
3. **Which content areas?**
4. **How to structure and implement?**
5. **How to ensure evidence on the value?**

For each key process, in Figure 7 outlined are: the objectives, the methodology followed to achieve the objectives and the results of previous work conducted in the frame of ELITe project (as well as the weSPOT project) that served as input for building our PL approach.

Figure 5: Outline of the key methodological processes that led to the development of the ELITe's learning in teaching approach via e-inquires

KEY PROCESS 1 – IN WHAT CONTEXT?		
Objectives	**Methodology**	**Input for building the PL approach**
To identify: • national policy priorities and actual practice • systemic opportunities and challenges on/for STEM teachers competence development in the national contexts of Greece, the Netherlands, Bulgaria and Spain	• Documentary analysis of national policy documents, STEM teachers training curricula, STEM students curricula under the EC (2013) framework for teachers' competence development • Negotiation with educational stakeholders in national workshops under the EASW methodology	• Requirements for STEM teachers' competences (knowledge & understanding, skills, dispositions & attitudes) as evident explicitly in policy documents and teacher training curricula and implicitly in students STEM curricula in Greece, the Netherlands, Bulgaria and Spain (documented in IO1) • Systemic opportunities and challenges for implemented PL activities for STEM teachers competence development in Greece, the Netherlands, Bulgaria and Spain (documented in IO3)

KEY PROCESS 2 – WHAT FOR?		
Objectives	**Methodology**	**Input for building our PL approach**
• To define the expected outcomes of the PL approach • To define indicators for evaluating the expected outcomes	Clustering aspects of teachers' competences (knowledge, skills and attitudes) of the EC (2013) framework for teachers' competence development into groups of expected outcomes Translating aspects of competences of the EC (2013) framework for teachers' competence development into indicators and sub indicators for evaluating the expected outcomes	Definition of: • expected outcomes • indicators and sub-indicators relevant to the national contexts of Greece, the Netherlands, Bulgaria & Spain for evaluating the ELITe's learning in teaching activities (documented in IO2)

KEY PROCESS 3 – WHICH CONTENT AREAS?		
Objectives	**Methodology**	**Input for building our PL approach**
To identify content areas for the PL activities most relevant for each national context	• Review of recent large scale surveys ((OECD), Teaching and Learning International Survey TALIS 2013, Conceptual Framework, 2013), ((OECD), Teaching and Learning International Survey TALIS 2018, Brochure, 2018)) which offers an interesting insights into secondary teachers' self-perception of needs and participation in continuous professional development (CPD) • Negotiation with educational stakeholders in national workshops under the EASW methodology on content areas most relevant to each national context	Content areas for the PL activities most relevant for each national context (documented in IO3)

KEY PROCESS 4 – HOW TO STRUCTURE & IMPLEMENT?		
Objectives	**Methodology**	**Input for building our PL approach**
• To define the methodological steps of the PL activities • To identify the recourses needed • To produce an implementation plan	• Adaptation of the weSPOT IBL model for teachers' professional learning activities • To review available OER (Open education Resources) • Detailed implememation plan	• The weSPOT IBL model (documented in the weSPOT project's deliverable D2.4) • OER available on the web

KEY PROCESS 5 – HOW TO ENSURE EVIDENCE ON THE VALUE?		
Objectives	**Methodology**	**Input for building our PL approach**
• To clarify what we want to learn by implementing and evaluating the PL activities • To align the development of the approach with the requirements of future project work	Orientation towards facilitating data gathering for subsequent project work relating to the added value	• Requirements of the evaluation framework- research questions to be (documented in IO2) • Requirements for developing IO4 • Requirements for developing IO8

The processes applied led to the development of 26 sample scenarios for professional learning activities under the IBL methodology (6 for each national context and two common scenarios) relating to current challenges for STEM professional teaching and learning and addressing the thematic areas of:

- Dealing with inclusion and diversity
- Teaching STEM for skill development
- Incorporating RRI in STEM education
- Innovative STEM methodologies (IBL & project work, self-directed learning, computational thinking)
- Opening up school science
- Assessment challenges in STEM
- ICT enhanced STEM learning and teaching
- Confronting challenges of new curricula
- Enhancing teachers-parents collaboration

Stage 4: Evaluation of the ELITe project "Learning –in – teaching via e-inquiries approach"

The evaluation of the ELITe's approach focused on the following research questions:

- Which inquiry skills/competences have been practiced by teachers and by which Inquiry Based Learning activities?
- What are the outcomes of the ELITe professional learning activities in teachers' competence development (knowledge and understanding; skills; dispositions and attitudes on/for learning and teaching)?
- Is practicing inquiry skills enhances teachers competences?
- How relevant and useful is the ELITe approach for STEM teachers' needs for professional developments?

In the course of the project, developed and implemented were teachers' professional development activities through an IBL approach in GR, NL, BG, ES. Developed and implemented with STEM teachers were eight teacher training scenarios under the weSPOT IBL model in each national context, relating to current challenges in STEM learning and teaching. The professional learning activities ran during the period December 2017-January 2019 with the full participation of 287 teachers (44 from Greece; 55 from the Netherlands, 128 from Bulgaria and 55 from Spain). The vast majority of the participants (78,8%) were female; as for the age distribution, approx. 55% aged between 30 and 50 years old, 31% were below 30 and 14% aged above 50 years old. Participants were mainly experienced teachers: 28% had more than 16 years of teaching experience; approx.15-16% had experience of 11-15, 6-10, 3-5 or 1-2 years, while only approx.. 8% had no teaching experience at all. More than 75% of the participants were STEM teachers in secondary (general and vocational) education, while an approx. 15% were primary education teachers. Data gathered through pre- and post-self-evaluation questionnaires.

Dimensions and components of the ELITe framework for STEM teachers' competence development

The ELITe project framework for supporting STEM teachers' competence development bears the following elements:

- Adopts a ***place-based approach*** for STEM teachers' professional learning, taking into consideration national policy requirements and practice needs
- Propagates the ***adoption of the inquiry-based learning (IBL) methodology in professional learning activities***, highlighting the links between inquiry skills practicing and STEM teachers' competence development
- Considers ***content areas that reflect current policy orientation on the broader aims of STEM education***, proposing exemplar digital learning scenarios that address them
- Is oriented towards ***facilitating the assessment of STEM teacher's competence development***, proposing outcome indicators for evaluating the impact of professional learning activities on STEM teachers practice.

Accordingly, the framework is structured in ***four dimensions (contextual, methodological, and thematic and outcome oriented),*** each of which consists of the following components:

Contextual dimension components:

- ✓ National requirements for STEM teachers' competence development in 4 EU countries
- ✓ Critical factors that affect STEM teachers' professional learning for competence development
- ✓ Recommendations for improving national policies for STEM teachers' competence development

Methodological dimension components:

- ✓ Professional learning methodology under an inquiry approach
- ✓ Process indicators for inquiry skills development
- ✓ Links between inquiry skills development and STEM teachers competence development

Thematic dimension components:

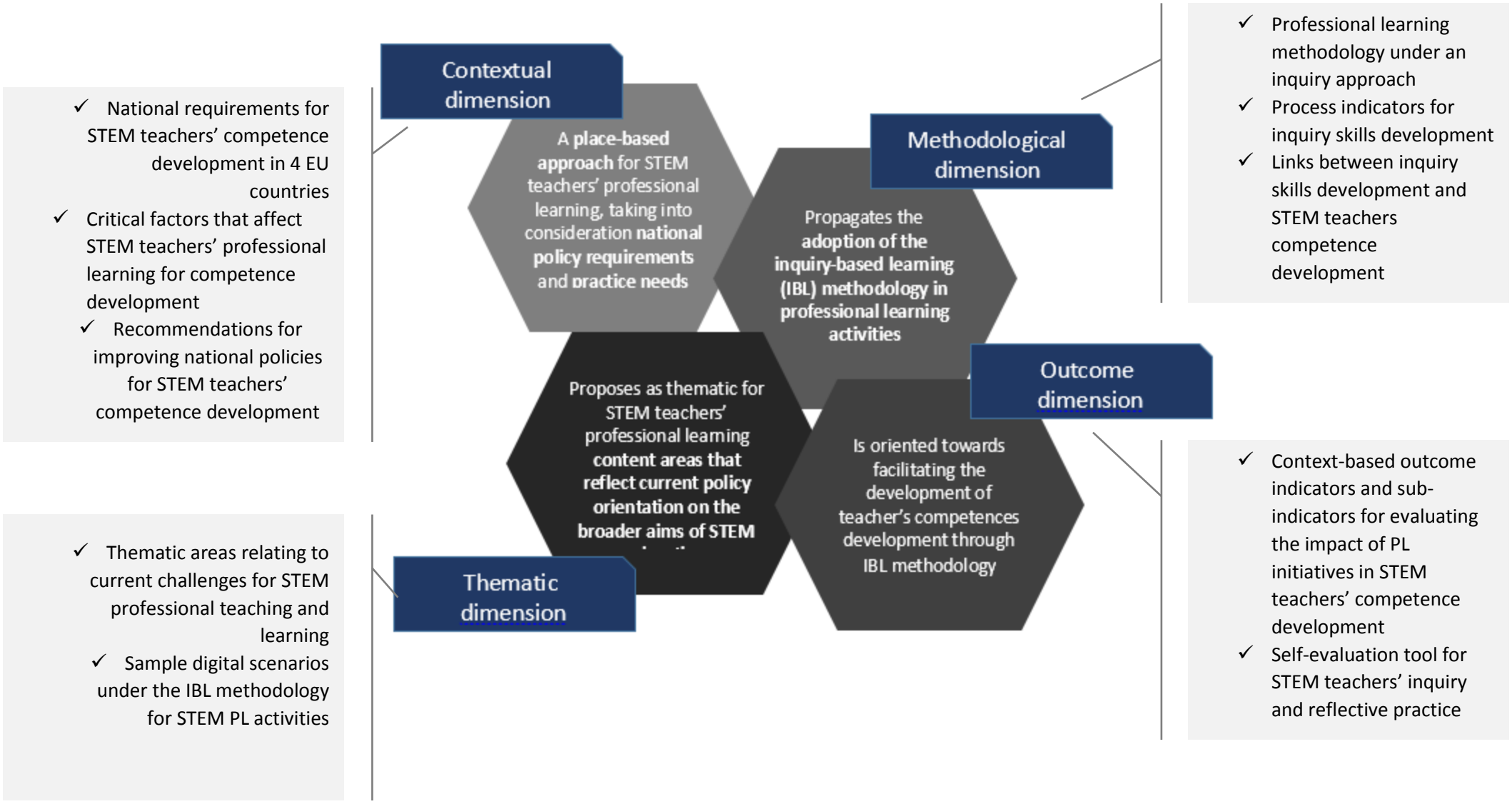
- ✓ Thematic areas relating to current challenges for STEM professional teaching and learning
- ✓ Sample digital scenarios under the IBL methodology for STEM PL activities

Outcome dimension components:

- ✓ Context-based outcome indicators and sub-indicators for evaluating the impact of PL initiatives in STEM teachers' competence development
- ✓ Self-evaluation tool for STEM teachers' inquiry and reflective practice

Figure 6 below outlines the structure of the ELITe framework

Figure 6: Structure of the ELITe framework for STEM teachers' competence development under an inquiry approach: dimensions & components



Contextual dimension

- ✓ **National requirements** for STEM teachers' competence development in 4 EU countries: GR, NL, BG, ES
- ✓ **Critical factors** that affect STEM teachers' professional learning for competence development

  & Recommendations for improving national policies for STEM teachers' competence development

National requirements for STEM teachers' competence development in 4 EU countries: GR, NL, BG, ES

Provided here-below is a comparative overview of STEM teachers' competences that are required in the national contexts of Greece, the Netherlands, Bulgaria and Spain, under their roles as lifelong- learners themselves, as facilitators of students' learning and as members of educational communities. The overview is the outcome of a documentary analysis of policy documents, STEM teacher training curricula and students STEM curricula in each national context.

Considered are three dimensions of competences (knowledge & understanding, skills, dispositions & attitudes), while aspects in each dimension explicitly evident refer to evidence as demonstrated in the national policy documents and the curricula for STEM teachers' training; aspects implicitly evident refer to evidence as demonstrated in students' STEM curricula.

Figure 7: Comparative overview of STEM teachers' competence requirements in GR, NL, BG and ES

STEM teachers **as lifelong learners** are required by national policies to develop, practice, demonstrate:		**Knowledge & Understanding on STEM related teaching and learning content**					**Learning skills, relating to the promotion of teachers own learning**			**Dispositions & Attitudes relating to teachers own learning**		
		STEM knowledge	Pedagogical Content knowledge	Curricular Knowledge	Developmental psychology	Issues on Inclusion and diversity	Use, develop, create research knowledge	Reflective, metacognitive skills	Interpersonal skills	Epistemological awareness	Flexibility, ongoing learning	Critical attitudes on own learning
GR	*Explicitly*			☑	☑	☑	☑	☑	☑	☑	☑	☑
	Implicitly	☑	☑		☑	☑						
NL	*Explicitly*	☑	☑	☑	☑	☑	☑					☑
	Implicitly					☑	☑	☑	☑		☑	☑
BG	*Explicitly*	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
	Implicitly									☑		
ES	*Explicitly*	☑		☑	☑	☑	☑	☑	☑		☑	
	Implicitly		☑		☑	☑	☑					

STEM teachers **as facilitators of students' learning** are required by national policies to develop, practice, demonstrate:		**Knowledge & Understanding on methodologies relating to STEM learning and teaching**				**Teaching skills, related to the promotion of students' learning**						**Dispositions & Attitudes, related to the promotion of students learning**		
		Pedagogical knowledge	Innovative STEM methodologies	Evaluation and assessment	New technologies	Plan, manage, coordinate teaching	Use teaching materials & technologies	Manage students & groups	Monitor, adapt & assess teaching objectives	Collect, analyze, interpret evidence	Teaching skills through content	Transferable skills	Promote learning of all students	Promote democratic attitudes & practices
GR	*Explicitly*	☑			☑	☑	☑		☑				☑	☑
	Implicitly	☑		☑	☑	☑	☑	☑		☑	☑		☑	☑
NL	*Explicitly*	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑		☑	☑
	Implicitly	☑	☑		☑	☑	☑	☑	☑	☑		☑		☑
BG	*Explicitly*	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
	Implicitly				☑	☑	☑	☑						
ES	*Explicitly*	☑		☑	☑	☑	☑	☑	☑		☑		☑	
	Implicitly				☑					☑				☑

STEM teachers **as members of educational communities** are required by national policies to develop, practice, demonstrate:		**Knowledge & Understanding on contextual aspects of learning and teaching**		**Professional skills, relating to STEM teachers' role as part of educational communities**				**Dispositions & Attitudes relating to STEM teachers' role as part of educational communities**	
		Educational Science foundations	Contextual, institutional and organizational aspects of educational policies	Collaboration skills	Negotiation skills	Ability to adapt to educational contexts	Life and career skills	Dispositions to team-working, collaboration and networking	Sense of self-efficacy
GR	*Explicitly*	☑	☑					☑	
NL	*Explicitly*	☑	☑	☑				☑	
	Implicitly					☑		☑	
BG	*Explicitly*	☑	☑	☑		☑		☑	
	Implicitly						☑		
ES	*Explicitly*	☑	☑						
	Implicitly					☑		☑	

Critical factors that affect STEM teachers' professional learning for competence development in 4 EU contexts & Recommendations for improving national policies

Insights from documentary analysis

The review of the national contexts through documentary analysis allowed the identification of prominent issues for consideration in terms of STEM teachers' competence development in each country, presented here below.

- ***At macro level (policy),*** major aspect of teacher competences (knowledge & understanding, skills, dispositions & attitudes) as defined in EC (2013) framework are emphasised in all national contexts of GR, NL, BG and ES.
- ***At meso level (mediating mechanisms),*** disparities are evident among the countries: In the Netherlands, the regulatory framework has been long been in place and has been adopted and implemented by teacher education institutes; in Spain, there is a lack of consensus on the acceptance of the new policies among regions, local authorities and educational councils and as such implementation is being challenged; in Greece and Bulgaria, on the other hand, currently there is uncertainty on how providers of teacher education and training will respond to and implement the new regulatory framework.
- ***At micro-level (teaching practice),*** in all national contexts, a high level of coherence is evident between teacher competences required/envisions by policy and the skills that students are aimed to develop via STEM studies.

The above indicate that ***in the national contexts of Greece, Bulgaria and Spain the main challenge identified in respect of STEM teachers' competence development lays on the grounds of policy mediation***, i.e. on how teacher education institutions and providers implement policy envisions and requirements.

In ***the Dutch context***, on the other hand, given that the regulatory framework for teachers' competence development has long been established and implemented by mediating mechanisms, ***the main issue identified for further exploration and discussion is on the impact of teacher learning for competence development on the school practice.***

Insights from negotiation process

The results of the exploration of the nation context through the documentary analysis were communicated and negotiated with more than 30 educational stakeholders in each country (policy makers, responsible for STEM teachers' training and STEM teachers), in the course of the ELITe's project multiplier events. Outcomes of the negotiation process allowed the identification of critical factors that affect STEM teachers' PD for competence development in each country.

GREECE

Critical factors relevant to the Greek national context

- **Lack of effective communication of policy priorities to policy mediators and practitioners*:*** Teachers' capacity building is seen as an essential component of recent and current reforms for improving quality in education, while efforts for the establishment of a regulatory framework for teachers' competence development are evident in the country. A need for better coordination between educational policies and actors responsible for teacher training is needed. In addition, measures and incentives for boosting practitioners' motivation to participate in continuous professional learning activities are required.

- **Fragmentation of training provisions & lack of coordination between policy mediation actors (providers of STEM teachers' professional development):** Initiatives to support STEM teachers' professional development are in place in the country, for example programmes organized by University Departments, ASPAITE, regional Peripheral Educational Centers, and School Science advisors. The initiatives though are fragmented, and there is a lack of partnerships that could foster networking, practice-sharing and programmes co-development towards the common goal of teachers' capacity building.

- **'Top-down' approach for teachers' professional development rather than a 'partnership approach':** Good practice in teachers' professional learning increasingly propagates the adoption of 'learning communities' paradigm. In this model, teachers along with families, informal science providers and community stakeholders are engaged in ongoing work and dialogue together to share knowledge and expertise. Initiatives for such learning communities' partnerships are rare, while more bureaucratic top-down approaches to teachers' professional learning are in place.

- **Continuous professional development for STEM teachers is in practice optional and there is a lack of culture for lifelong professional learning:** Although the complexities of the teaching profession require a lifelong learning perspective to adapt to fast changes and evolving constrains and needs, in-service training is not mandatory. As emerged from the negotiation process in the ELITe workshop, access and financial resources are limited and there is lack of culture for lifelong learning from practitioners.

- **Current teacher training provisions are not aligned with practitioners learning needs in respect to practice requirements – both from content & appropriate training methodologies perspectives:** As an outcome of the negotiation process in the ELITe workshop, concerns were raised by STEM teachers on current teacher training activities in terms of: the content focus, the content delivery methodology, the duration of training, and the opportunities for active learning and co-learning between teachers from various disciplines. The need for modernization of teacher education provisions so as them to enable informing teaching practice was emphasized.

Recommendations relevant to the Greek national context

- ✓ **Enhancement of communication** of policy priorities, towards facilitating policy implementation and policy ownership from teacher trainers and practitioners
- ✓ **Promotion of partnerships** among STEM teachers' education providers that can foster networking, practice-sharing and programmes co-development for supporting teachers' capacity building
- ✓ **Develop a 'partnership approach'** under the 'learning communities' paradigm for professional learning within schools in which parents, informal science providers and community stakeholders become real partners in school life
- ✓ **Ensuring that continuous professional development and learning becomes a requirement** and a right for all teachers throughout their teaching career
- ✓ **Modernizing STEM teacher training provisions** from content and methodology perspectives

THE NETHERLANDS

Critical factors relevant to the Dutch national context

Prominent are the ***need in facilities at the workplace*** and ***collaboration***, being able to ***communicate and collaborate with colleagues at the workplace and outside***. In professional learning activities teachers need:

- **Facilities for professional learning:** Support and time for learning (taking courses), more time to develop lessons; trust and independence in designing and implementing lessons
- **Informal learning support:** Use of daily practice as a source of professional learning; more opportunities to learn from each other; Coaching at workplace on effective teaching
- **Interaction and exchanges with colleagues:** Exchange of experiences, talking to colleagues, meeting colleagues, brainstorm about tasks with others
- **Peer feedback and consultation:** Asking feedback/getting feedback from colleagues; more supervision by colleagues; visiting each other lessons; open door policy
- **Collaboration:** Joint work on learning environment; collaboration and exchange of ideas with colleagues from other schools; sustainable models of knowledge sharing
- **Access to knowledge:** Lecture, courses, training and experience in new pedagogies, socio-emotional development, new teaching methods, and behavioral disorders of school children
- **Doing Research:** Together colleagues setting up experiments and study what works; more inquiry based reflection on the teaching process

- **Organizational changes:** Changing school organization; making school an organization for professional learning, less control, more autonomy and trust, less administrative workload
- **Self-directness and self-regulation**: Being able to reflect one's actions, reflecting on one's skills; motivations and ambitions; learning to make mistakes and learn from them
- **Teacher skill:** Learn to motivate students; develop better digital skills; time management skills

An offer of professional learning trajectories that caters to these needs is both a challenge and an opportunity to contribute to teacher professional development in an effective way.

Recommendations **relevant to the Dutch national context**

✓ ***Alignment with the national framework is both relevant and necessary***

-All learning activities need to be part of the national professional learning requirements (lerarenregister) to realize this alignment

✓ ***School management should be responsible for facilitating learning, allocating time for it and creating pre-requisites***

-School boards are partner in the organization of learning activities and are responsible for facilitation learning at the workplace

✓ ***Practice level: Introduction of new technologies and approaches should be part of both learning and teaching practice. Support is needed in both.***

-Learning events should be linked to teaching practice or be easily transferrable to it

-Teachers are owners of their designs that they can develop in the learning situation and try out in their own practice.

-Exchanges with other teacher on their hands-on experiences is a valuable part of learning for teaching.

BULGARIA

Critical factors **relevant to the Bulgarian national context**

In relation to ***the content of the teacher training courses***:

- **STEM subject matter – new science achievements as well as changes in the students' curricula.** Special attention is dedicated to the use of ICT's in STEM disciplines education in terms of simulations of phenomena and dependencies, giving possibilities for students to experiment and generate hypothesis, reasoning, and conclusions. The use of professionally developed interactive digital learning resources and applications is much more important for schools where there is not labs for real experimental work.
- **Interdisciplinary** – practical trainings combining different STEM subject matter and relationships, in collaboration with other STEM subject teachers; learning design, implementation and evaluation of students' achievements.
- **Innovative teaching methods** – interactive methods of teaching / learning, design and implementation of student's inquiry, group

work management, use of innovative ICTs in education, etc., focused to STEM education

- **Work with special students' groups, tailored to the specifics of the subject and the educational need** – involving students with special educational needs, work with talented students, and work with students with learning disabilities.
- **Work with parents** – effective communication and collaboration with parents, involving parents in school live, 'school for parents'.
- **Dealing with administrative issues** - familiarizing with administrative framework and approaches for more effectively carrying out administrative work
- **Evaluation in education** – approaches and technics for evaluation of educational process, how to implement classroom pedagogical experiment, evaluation of students'' textbooks and additional learning resources, formative and summative students assessments.

In relation to ***the forms of teachers' training courses***:

- **Face-to-face or blended learning** - Distance courses in a form of webinars are not efficient enough; face to face communication among trainees and between trainees and trainers is very important.
- **Balance between learning at work place (school) and out the door courses**- regional, national workshops as environment for sharing ideas and experience. Active practical learning process is preferred by practitioners instead of lectures and formal exams. Also, demonstration and participation in innovative teaching methods implementation is very important for the successful transfer of given teaching methodology to the classroom.
- **Online courses** – as a current support, and as an archive for long term use. Training courses content online for future use is useful, as well as to have an online tool for support of the established professional community during the course.

Recommendations relevant to the Bulgarian national context

- ✓ ***Building teacher competences by the teacher trainings***: STEM learning content should be provided to spread widely the approach

-Policymakers at national, regional and local level need to organize work together of traditional training providers (holding the methodology knowledge) and new one (holding concrete practical skills)

-Policymakers and all levels need to create conditions IBL approach to be embraces by new teacher trainings providers (business, publishing houses, etc.) and teaching materials to be relevant to them

-Content providers need to respond to the new requirements of schools and teachers with new curricula and updated learning content interweaving the approach into it, and to be flexible for permanently changing requirements.

- ✓ ***Focus on schools management strategy, curricula and teaching approaches:*** Building stable relationships between different disciplines teachers and environment for common work, design

and delivery of interdisciplinary projects, and effective application of ICTs in STEM education.

-School authorities need to manage autonomy and freedom for decisions, and respectively – more responsibilities, so to use it to develop environment and space for application of the IBL

-School managers need to support relationships with different institutions – museums scientific labs, observatories, high-tech centers, etc.

-School managers need to support relationships between STEM teachers and interweaving of different disciplines during STEM education.

- ✓ ***Teacher competence are needed to design IBL activities in the class implementing inclusive education for students with special educational needs.*** Teachers need support for IBL day-to-day application.

-Teachers need to build competences to design the education in IBL manner, to develop IBL scenarios and introduce them into day-to-day practice.

-Teachers needs support to design IBL activities.

Teachers need to be supported to deliver, manage and assess students' achievements during the IBL approach implementation.

-Teachers need to be supported to include students with special educational needs in fully valuable STEM learning process.

SPAIN

Critical factors relevant to the Spanish national context

The following critical factors that affect STEM teachers' professional learning for competence development in the country are identified, related to ***the content, the methodology, the form and the assessment of professional learning provisions***:

- **Teachers lack training on STEM-related methodologies, and examples of good practice.** For STEM teachers to improve their teaching methodologies, there is a need of the use of open science resources, or the inclusion of topics related to the socio-scientific issues that attract students' attention. Practical courses related to the use of STEM digital resources, and interdisciplinary courses are needed so that teachers can collaborate with other colleagues in developing a more integrated view of STEM, and as a consequence, on developing STEM competencies of their students.
- **Need of application of active teaching and learning methods in the classroom.** Special attention is dedicated to the inquiry-based and project based learning methods, which are emerging in the Spanish schools, and are required to develop STEM competences in an integrated way.
- **Inclusive education is still a challenge in front of Spanish teachers.** Aspect related to the STEM and the fighting gender stereotypes in STEM, were discussed and an agreement upon including this area for teacher training was reached.
- **Work with parents and with other actors.** The role of parents associations in the school is very important. They organize extracurricular activities, many of them related to STEM areas, as

e.g. robotics, science days, etc. Furthermore the role of parents is also key in order to break stereotypes about science among their sons, and more importantly among girls. They also are sensible to introducing learning innovations and projects (many times with science centers) since this means prestige for the school and better outcomes.

- **There a need for development of communities of practice between STEM teachers,** something that can be done both face-to-face and online, especially given the limitations of teachers in terms of schedule and geographical distribution.
- **Need for innovative training methodologies.** Teachers' training should be based on the same innovative learning methods which are expected teachers to apply in the classroom, as opposite to the popular lecture-based teaching, which is less and less popular in Spain.
- With respect to the assessment system, there is a need to adopt **project work as the assessment methodology**.

Recommendations relevant to the Spanish national context

- ✓ Promotion of active teacher strategies in STEM teachers' training offers: inquiry based learning & problem based learning
- ✓ Inclusive education / dealing with diversity in education as a priority for teachers training provisions
- ✓ Focus on topics related to socio scientific issues for STEM learning
- ✓ Enhancement of teachers' capacities to work with digital resources
- ✓ Consider the school as a learning community and open-up STEM school learning
- ✓ Modernization of training methodology and assessment approaches in professional learning provisions

At policy level

-The administration should work together with other institutions for providing realistic STEM teachers training paths, including online delivery.

-Researchers in the area of STEM should participate in the institutional plans, providing advice on contents and methodology, as well as on impact evaluation of the STEM programmes.

-As with respect to plans for introducing STEM innovation the educational policymakers, need to coordinate with all key players, as e.g. universities (as providers of both pre-service and inservice), science centres, publishing houses, other local training institutions, practitioners, etc.

At policy mediation level

-The teachers' timetable should be organized taking account the time and the space necessary in order for those of different disciplines (but with the same students) being able to work together in organising IBL activities.

-It would be very important that school managers support the introduction of the IBL methodology in the study program, adjusting and/or adapting the learning objectives to the stages needed to implement STEM this way (considering the flexibility of the local curricula).

-School authorities should promote the communication between teachers and parents on the potential and the benefits of the IBL methodologies for STEM education.

-Teachers need more opportunities for in-service training. Give the timetable limitations, online teacher training (or a combination of online and face-to-face) is a good approach in many cases.

At practice level

-Teacher's need more support to design and implement IBL activities in the class.

Teachers need to master IBL methodology, so they can feel confident to implement IBL activities in their class.

-For beginner teachers, a database of best resources and learning units can facilitate the STEM take up, and the design and the implementation of IBL activities. These resource should be innovative, combining traditional content and STEM current themes been able to raise the interest of students.

-Teachers require seeing STEM in a more integrated way, then going beyond the traditional subjects and combining contents through project-based learning. This requires many time the understanding of parents, reducing their anxiety in front of innovation learning results

READ MORE

- Policy envisions and requirements for STEM teachers' competence development: State of affairs in 4 EU countries http://learning-in-teaching.eu/index.php/en/intellectual-outputs/io1
- Systemic opportunities and challenges for STEM teachers' competence development in Greece, the Netherlands, Bulgaria and Spain http://learning-in-teaching.eu/index.php/en/intellectual-outputs/io3
- Supporting STEM teachers' professional learning for competence development: Insights on the space for intervention – the cases of Greece, the Netherlands, Bulgaria and Spain http://learning-in-teaching.eu/index.php/en/briefing-docs/policy

Methodological dimension

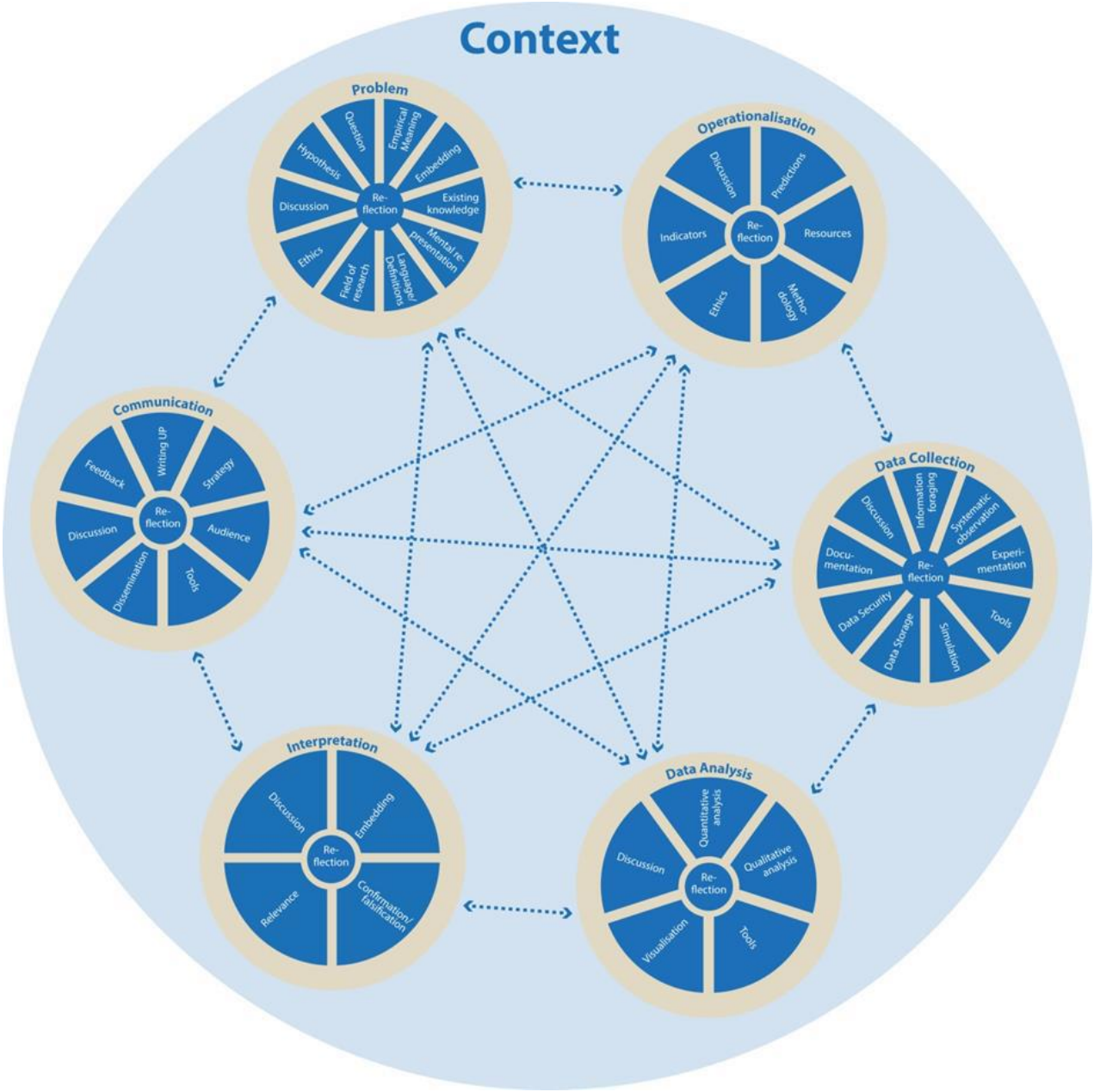
- ✓ **Professional learning methodology under an inquiry approach**
- ✓ **Process indicators for inquiry skills development**
- ✓ **Links between inquiry skills development and STEM teachers competence development**

Professional learning methodology under an inquiry approach

The ELITe ***Learning in Teaching via e-inquiries*** teacher competence development approach builds on the weSPOT IBL cyclic model, designed especially for successful inquiry-based learning supported by free ICT tools.

The weSPOT model consists of six phases, placed within the context, that mirror the phases that researchers need to go through in order to conduct their research, since inquiry is an integral feature of science. Each phase also consists of a number of activities, ranging from six to eleven. Activities in each phase are outlined below:

Figure 8: The weSPOT IBL model on which the ELITe professional learning activities are based on



- **Problem/Topic**: Embedding; Existing knowledge; Mental representation; Language/definitions; Field of research; Ethics; Empirical meaning; Discussion/Argumentation; Question; Hypothesis; Reflection
- **Operationalisation** (realisation of idea with the aim of measuring): Indicators; Predictions; Resources; Methodology (of data collection and processing); Ethics (Ethical issues); Discussion/Argumentation; Reflection
- **Data collection:** Information foraging; Systematic observation; Experimentation; Tools; Simulation; Data storage; Data security; Documentation; Discussion/Argumentation; Reflection
- **Data Analysis (processing):** Quantitative analysis (Statistical methods/analysis); Qualitative analysis; Tools; Visualisation; Discussion/Argumentation; Reflection
- **Interpretation**: Embedding (into existing theories/results/domain knowledge (classification)); Confirmation/falsification (of the initial question/hypothesis); Relevance (of results); Discussion/Argumentation; Reflection
- **Communication**: Strategy; Audience; Tools; Dissemination (Events/Presentation/Publication); Discussion/Argumentation; Feedback (Receiving and reacting); Writing up; Reflection

The model creates an environment for practicing inquiry skills & competences. **Skill** is seen as a goal-oriented and well-organised behaviour developed through practice, which gradually becomes automatic. Skill is a much narrower term than competence and focuses on the ability to use knowledge to accomplish a task. **Competence,** on the other hand, is defined as a set of observable performance dimensions, including individual knowledge, skills, attitudes, and behaviours, as well as collective team, process, and organizational capabilities, that are linked to high performance.

Skills, related to IBL, developed by the weSPOT model:

- Analytical skills to research a topic, develop a project plan and timeline, and draw conclusions from research results.
- Science skills to break down a complex scientific system into smaller parts, recognize cause and effect relationships, and defend opinions using facts.
- Comprehension, read and understand scientific and technical materials.
- Experimentation skills to know different methodologies and processes required.
- Mathematic skills for calculations and measurements.
- Attention to detail to follow a standard blueprint, record data accurately, or write instructions.
- Technical skills to troubleshoot the source of a problem, repair a machine or debug an operating system, and ICT skills to stay up-to-date on appropriate software and equipment.

- Presentation skills
- Cooperation skills to listen to others needs or interact with project partners.
- Creative skills/abilities to solve problems and develop new ideas.
- Leadership skills to be able to lead a team.
- Organisation skills to keep track of lots of different information.
- Metacognitive skills

Competences, related to IBL, developed by the weSPOT model:

- **Research competence:** To have research competence, one should be able to apply a variety of analytical skills, mathematical and technical skills, experimentation skills and knowledge, to sometimes apply creative skills to obtain a solution, presentation skills, collaboration and communication skills, especially if working within a team, and so on.
- **Problem solving**: Problem solving is a competence that requires several skills, knowledge and behaviours to be performed well. For example, to solve problems effectively one must have the skill to define the problem, have knowledge of all possible solutions, and exhibit behaviour that enables them to make a decision. Problem solving competences can be applied to technical as well to non-technical tasks/areas.
- **Communication:** Communication as a competence relies on a combination of certain skills, behaviour and knowledge. To communicate effectively, for example, a person may need to understand cultural diversity, have advanced language skills, behave with patience, have technical skills regarding different presentation media, etc.
- **Critical thinking**: Critical thinking includes a wide range of cognitive skills and intellectual dispositions necessary to interpret, analyse, and evaluate arguments, problems and systems, and then to synthesise, evaluate and explain an appropriate response. This response may be innovative and go beyond standard conventions.

Additionally, the weSPOT model builds on reflective practice – each phase contains sub-stages for discussion, reflection and feedback that makes it a really effective model for inquiry & reflective teacher competence development practice.

Process indicators for inquiry skills development

Process indicators for inquiry skills practicing refer to means for facilitating and assessing the inquiry process in professional learning activities. They aim to serve as a formative assessment tool that indicates whether an inquiry skill has been practiced by learners when performing IBL activities. They could be an invaluable source of information on teaching and learning quality because they investigate the core of the inquiry learning experience (e.g. quality of teaching, curriculum, assessment, services and facilities). Also, they can provide information and context to facilitate the interpretation of outcomes.

In the course of the ELITe project evaluation phase, and with an aim to explore the links between teacher training activities and teachers practicing of inquiry skills, we investigated on the one hand the contribution of teachers in each activity of the IBL cycle, namely: questioning, planning the method, review and analyze data, hands-on-activity, communication; on the other hand, we got insights from self-evaluation tool implementation on the believed practiced inquiry skills during the PD activity (i.e. Critical thinking; Information literacy; Analytical skills; Communication skills; Digital skills; Metacognitive and reflection skills; Other research skills). The question under investigation was whether the activities applied in PD affect the IBL skills practiced.

Results of the regression analysis provide insights on the cause and effect relationship between Inquiry Based Learning activities and inquiry skills practicing, presented in Figure 9.

Figure 9: Cause and effect relationship between IBL activities and inquiry skills practicing

Believed practices skills in the course	Contributed activities in the course: questioning	planning the method	review and analyze data	hand-on activity	communication
critical thinking	✓	×	×	✓	✓
information literacy	×	×	×	✓	×
analytical skills	×	×	✓	×	✓
communication skills	×	×	×	✓	✓
digital skills	×	×	✓	✓	×
metacognitive and reflection skills	×	×	✓	×	✓
other research skills	×	✓	✓	×	✓

In order to identify indicators that facilitate the learning process and the formative assessment in STEM PD, the starting point was previous research work conducted in the frame of the development of the weSPOT IBL model. First the activities of the weSPOT model performed by learners were clustered in groups, on the basis of the inquiry skills to which they relate (under the regression analysis results). Activities in each model phase were then translated into process indicators that enable to identify whether an activity has been performed and as such the skill aligned to it has been practiced. Outcomes of this process are presented in Figure 10.

Figure 10: Process indicators for inquiry skills practicing

Inquiry skill/competence	IBL phase	Process indicators (Indicating whether an IB skill /competence has been practiced by learners when performing IB activities)
Critical thinking (argumentation skills, comprehension skills, evaluation skills and inferring)	Questioning	➢ Providing a wonder moment ➢ Developing a concept map ➢ Concept defining ➢ Describing what we still need to know ➢ Understanding different kinds of scientific questions and examining and evaluating this aspect of the learning experience thinking (evaluation)
	Hands-on-activity	➢ Interpreting findings in light of previous knowledge ➢ Judging evidence and counterevidence ➢ Checking the interpretation (process) and coming up with alternatives, and examining and evaluating this aspect of the learning experience
	Communication	➢ Discussing the findings in a critical manner (implications, limitations, lessons learned) ➢ Checking the method of communication and coming up with alternative approaches, and examining and evaluating this aspect of the learning experience
Information literacy (existing knowledge and learning)	Hands-on-activity	➢ Interpreting findings in light of previous knowledge ➢ Judging evidence and counterevidence ➢ Checking the interpretation (process) and coming up with alternatives, and examining and evaluating this aspect of the learning experience
	Communication	➢ Discussing the findings in a critical manner (implications, limitations, lessons learned) ➢ Checking the method of communication and coming up with alternative approaches, and examining and evaluating this aspect of the learning experience
Analytical skills (classification, quantitative & qualitative analysis and statistical skills)	Review and analyze data	➢ Make sure that data are relevant to the problem ➢ Clustering data ➢ Checking the analyses and coming up with alternatives, and examining and evaluating this aspect of the learning experience
	Communication	➢ Discussing the findings in a critical manner (implications, limitations, lessons learned) ➢ Checking the method of communication and coming up with alternative approaches, and examining and evaluating this aspect of the learning experience
Communication skills (presentation, language, writing skills)	Hands-on-activity	➢ Interpreting findings in light of previous knowledge ➢ Judging evidence and counterevidence ➢ Checking the interpretation (process) and coming up with alternatives, and examining and evaluating this aspect of the learning experience
	Communication	➢ Discussing the findings in a critical manner (implications, limitations, lessons learned) ➢ Checking the method of communication and coming up with alternative approaches, and examining and evaluating this aspect of the learning experience

Digital skills	Review and analyze data Hands-on-activity	➢ Make sure that data are relevant to the problem ➢ Clustering data ➢ Checking the analyses and coming up with alternatives, and examining and evaluating this aspect of the learning experience ➢ Interpreting findings in light of previous knowledge ➢ Judging evidence and counterevidence ➢ Checking the interpretation (process) and coming up with alternatives, and examining and evaluating this aspect of the learning experience
Metacognitive and Reflection skills	Review and analyze data Communication	➢ Make sure that data are relevant to the problem ➢ Clustering data ➢ Checking the analyses and coming up with alternatives, and examining and evaluating this aspect of the learning experience ➢ Discussing the findings in a critical manner (implications, limitations, lessons learned) ➢ Checking the method of communication and coming up with alternative approaches, and examining and evaluating this aspect of the learning experience
Other research skill (experimentation, observation, organisation and planning skills)	Planning the method Review and analyze data Communication	➢ Coming up with resources and ways how to measure/ instruments (qualitative and quantitative) ➢ Coming up with indicators for concepts that can be measured to develop or test ideas [and relationships among them] ➢ Formulating hypotheses and coming up with alternative hypotheses ➢ Setting up experiments to test hypotheses or set up other inquiry procedure ➢ Showing ethical concern within research setup ➢ Discussing the phase in a critical manner (e.g. implications, limitations of approach, lessons for future studies) by providing arguments ➢ Make sure that data are relevant to the problem ➢ Clustering data ➢ Checking the analyses and coming up with alternatives, and examining and evaluating this aspect of the learning experience ➢ Discussing the findings in a critical manner (implications, limitations, lessons learned) ➢ Checking the method of communication and coming up with alternative approaches, and examining and evaluating this aspect of the learning experience

Links between inquiry skills development and STEM teachers competence development

In the course of the ELITe project, developed and implemented were teachers' professional development activities through an IBL approach in four EU national contexts, namely Greece, Netherlands, Bulgaria and Spain. The design of the ELITe professional learning activities was based on the following elements:

- ✓ learning through inquiry based learning method; self-regulated learning; learning with peers;
- ✓ hands-on learning;
- ✓ focus on reflection and metacognition.

The activities were developed under an adaptation of the weSPOT IBL cyclic model, designed especially for effective inquiry learning supported by digital means.

Developed and implemented with STEM teachers were eight teacher training scenarios under the weSPOT IBL model in each national context, relating to current challenges in STEM learning and teaching (see Figure 3, for the thematic areas addressed). The professional learning activities ran during the period December 2017- January 2019 with the full participation of 287 teachers (44 from Greece; 55 from the Netherlands, 128 from Bulgaria and 55 from Spain).

The vast majority of the participants (78,8%) were female; as for the age distribution, approx. 55% aged between 30 and 50 years old, 31% were below 30 and 14% aged above 50 years old. Participants were mainly experienced teachers: 28% had more than 16 years of teaching experience; approx.15-16% had experience of 11-15, 6-10, 3-5 or 1-2 years, while only approx.. 8% had no teaching experience at all. More than 75% of the participants were STEM teachers in secondary (general and vocational) education, while an approx. 15% were primary education teachers.

From an evaluation perspective, the aim of the implemented activities was to provide insights on the links between inquiry skills development and STEM teachers' competence development.

The research questions investigated are the following:

- RQ1: What are the outcomes of the ELITe's learning in teaching activities ***on enhancing STEM teachers' knowledge and understanding on teaching and learning***?
- RQ2: What are the outcomes of the ELITe's learning in teaching activities ***on STEM teachers' development of skills for learning and teaching***?
- RQ3: What are the outcomes of the ELITe's learning in teaching activities ***on STEM teachers' depositions and attitudes on learning and teaching***?

Results from the evaluation in respect to the effects of the ELITe IBL methodology on STEM teachers' competence development are summarized in Figure 11. Considered are teachers' competences (knowledge and understanding, skills, dispositions and attitudes) for teachers' roles as: lifelong learners, facilitators of students'' learning and members of educational communities

Figure 11: Effects of IBL methodology on STEM teachers' competence development

STEM teachers roles	Teachers' competences developed: Knowledge & Understanding	Skills	Dispositions & Attitudes
Lifelong learners	-Pedagogical content knowledge -Curricular knowledge	-Use, Develop and create research knowledge to inform practices -Reflective and metacognitive skills	-Flexibility ongoing learning -Critical attitudes on own learning
Facilitators of students learning	-Pedagogical knowledge -Innovative STEM methodologies -Evaluation and assessment -New technologies	-Plan, manage coordinate teaching -Use teaching materials and technologies -Manage students and groups -Monitor, adapt and assess teaching objectives -Collect analyze and interpret data	-Teaching skills through content -Transferable skills
Members of educational communities	-Contextual, institutional & organizational aspects of educational policies	-Collaboration skills -Negotiation skills	-Positive dispositions to team working collaboration and networking

READ MORE

- Context-based indicators for evaluation STEM teachers' competence development http://learning-in-teaching.eu/index.php/en/intellectual-outputs/io2
- Evaluation and validation report of the ELITe's learning in teaching approach via e-inquiries http://learning-in-teaching.eu/index.php/en/intellectual-outputs/io8

Thematic dimension

- ✓ ***Thematic areas*** relating to current challenges for STEM professional teaching and learning
- ✓ ***Sample digital scenarios under the IBL methodology*** for STEM PL activities

Thematic areas relating to current challenges for STEM professional teaching and learning

The ELITe approach for professional learning advocates that the thematic of the professional learning activities for STEM teachers need a re-orientation, from content focusing on subject and pedagogical knowledge that currently prevails towards thematic that addressed teachers practice needs. In addition, the content of STEM CPD needs to take into consideration current policy orientations under the Responsible Research and Innovation (RRI) agenda on the role of STEM education and help teachers to model key competences required (knowledge, skills and attitudes) in order to help students to acquire them. STEM educators – under the RRI policy agenda- are expected to equip students as future citizens to understand socio-scientific issues, applying science knowledge, ethical values and inquiry skills to form evidence based opinions (EC, 2015). They are also expected to aspire science related careers to students and support students develop positive attitudes towards science.

On the basis of the results recent large scale surveys and the outcomes of negotiation processes with educational stakeholders 4 EU contexts ELITe proposes 9 thematic areas for STEM CPD. Figure 3, provides an overview of the identified thematic areas and outlines the national contexts for which each area is most relevant to.

Figure 12: Thematic areas proposed by ELITe for STEM CPD and relevancy to the national contexts of GR, NL, BG and ES

Thematic areas for STEM CPD	Relevancy to the national contexts			
	GR	NL	BG	ES
Dealing with inclusion and diversity	O		O	O
Teaching STEM for skill development	O	O		O
Incorporating RRI in STEM education	O			O
Innovative STEM methodologies	O	O	O	O
Opening up school science	O	O	O	O
Assessment challenges in STEM	O	O	O	
ICT enhanced STEM learning and teaching	O	O	O	O
Confronting challenges of new curricula			O	
Enhancing teachers-parents collaboration	O	O	O	O

Sample digital scenarios under the IBL methodology for STEM PL activities

In correspondence with main thematic areas outlined, each country has outlined the topics of 8 national specific scenarios. Three of them are on general teaching learning thematic, three – of STEM related issues, and last two – on the teachers/parents related issues.

SCENARIOS in the THEMATIC AREAS of:

Dealing with inclusion and diversity

- Reflective practice for tackling inclusion and diversity issues in STEM classrooms (GR)
- Neither sees nor hears, but succeeds /researchers with SEN in school/ Creating a learning design for successful learning through Inquiry based learning approach of pupils with SEN (BG)
- Dealing with diversity in education: gender differences, learning styles, personalisation,etc. (ES)

Teaching STEM for skills development

- Promoting students' achievement in STEM: Changing perspectives from knowledge acquisition to skills development (GR)
- Learning to design Inquiry-based learning with DojoIBL: an exploration (NL)
- Design of good IBL activities based on DojoIBL for teaching and learning (ES)

RRI in STEM education

- Dealing with controversial socio-scientific issues in contemporary science (GR)
- Strategies for introducing socio-scientific issues in the classroom: dilemmas, controversies, conversations (ES)

Innovative STEM methodologies

- Design and delivery of an interdisciplinary STEM project (GR)
- Self-directed learning for professionals in Education (NL)
- Computational thinking in STEM classrooms and beyond (NL)
- Detectives in the classroom IBL approach in STEM discipline -how to design, deliver, conduct and evaluate IBL education in STEM (BG)
- Overcoming key difficulties of Inquiry Based Learning for STEM teachers (ES)

Opening up the STEM classroom

- Opening-up science education: Taking advantage of the potential of informal science education (GR)
- Learning and teaching in a seamless way (combining classroom learning with learning in the outside world: an introduction (part 1) and designing seamless learning experiences (part 2) (NL)
- Open air lessons – myth or not… Design of the open air field IBL education in STEM (BG)
- Approaching STEM in collaboration with scientific centres, and science museums and other local institutions (ES)

Assessment challenges in STEM

- Confronting challenges on IBL from implementation and assessment perspectives (GR)
- Assessment of 21 century skills with technology: how do you do that in practice? Viewbrics, a tool for assessment of 21st century skills (NL)
- Measure three times, cut once: Assessment for success (methods, techniques and tools for assessment IBL project work and team work) (BG)

ICT enhanced STEM learning and teaching

- Challenges of Inquiry based learning and how to tackle them using DojoIBL. A design-oriented course for teachers of secondary vocational education (in STEM related domains) (NL)
- Dream or Reality: Combining "dreams" (online tools, virtual reality, augmented reality and others) and "reality" (real places for educational visits (BG)
- Emerging ICT technologies in STEM education: computational thinking, robotics, and game-based learning (ES)
- Open Science resources: use , adaptation and design of digital resources for the STEM classroom (ES)

Confronting challenges of new curricula

- The challenges in the new ICT curriculum for 8- th grade The scenario is dedicated to familiarize trainees with new challenges there and to prepare them for teaching under its framework (BG)

Enhancing teachers-parents collaboration

- Overcoming personal bad experiences of parents for STEM success of their children (GR, NL, BG, ES)
- Supporting gender-neutral approaches to STEM at home (GR, NL, BG, ES)

READ MORE

- All digital scenarios in the national languages for Greece (GR), the Netherlands (NL), Bulgaria (BG) and Spain (ES) can be accessed here below:

Scenarios GR: http://www.learning-in-teaching.eu/index.php/en/intellectual-outputs/io4/scenarios-gr

Scenarios NL: http://www.learning-in-teaching.eu/index.php/en/intellectual-outputs/io4/scenarios-nl

Scenarios BG: http://www.learning-in-teaching.eu/index.php/en/intellectual-outputs/io4/scenarios-bg

Scenarios ES: http://www.learning-in-teaching.eu/index.php/en/intellectual-outputs/io4/scenarios-es

- Scenarios descriptions and outline structure are available in English in:

Sample digital scenarios for STEM teachers' competence development via inquiry methodology http://learning-in-teaching.eu/index.php/en/intellectual-outputs/io4

AN EXAMPLE OF SCENARIO IMPLEMENTATION

Scenario title: Neither sees nor hears, but succeeds

Country: Bulgaria

Period of implementation: March – May 2018

Implemented by: Sofia University

Target group(s): In-service teachers and teachers' educators in the STEM

(Science, technology, engineering and mathematics) domain

Brief summary: The scenario "Neither seen nor heard, but succeed /researchers with special educational needs (SEN) in school/" concerns inclusion of students with SEN in the learning process by applying IBL methodology. The main goal of this scenario is to meet teachers' needs of knowledge and skills on how to work with SEN students, and also to find the best ways to include students with SEN when applying IBL.

Goals: The aim of this scenario is to brings IBL approach, STEM

domain and SEN students together and develop specific teachers' competences to apply IBL in STEM and to involve SEN students in an appropriate way in this process. The main goals of the scenario are to develop:

- ✓ knowledge about the limitations and needs of different types of SEN;
- ✓ knowledge about different methods and tools for inclusion of SEN students in the educational process;
- ✓ skills to include SEN students when applying IBL approach in STEM area;
- ✓ skills to create a learning design, in a STEM area based on IBL approach adapted to involve SEN learners.

Structure/Contents: The "Neither seen nor heard, but succeed" scenario is structured in several phases. The first phase of the scenario is related to focusing on the problematic subject. For this purpose is used a role playing game in which the participants are divided into groups and takes different roles of learners with SE. One participant from the group plays the role of a teacher who leads the group and assists other participants in solving a predefined simple task. At different stages, participants change their roles. Each participant in a group has to go through each of the roles. The game ends with a reflection in which each participant shares how he felt when entering the different roles, what difficulties he faced as a SEN learner and as a teacher. The reflection continues with discussion and research about existing knowledge in SEN area. In the next phase participants study and collect information from different sources addressed to the SEN learners. The in the final phase, based on collected data, divided into groups according to STEM disciplines, participants develop a learning design that applies the IBL method and allows successfully to include learners with SEN.

The training that is be based to the presented scenario is aimed to provide both knowledge and skills to apply the IBL approach in STEM domain, and basic knowledge related to the specific needs of students with different types of SEN – different approaches applied in their training, the legal framework governing the education of these students, and how to involve them in the lessons when applying IBL approach. This makes the scenario complex, because it combines three different elements:

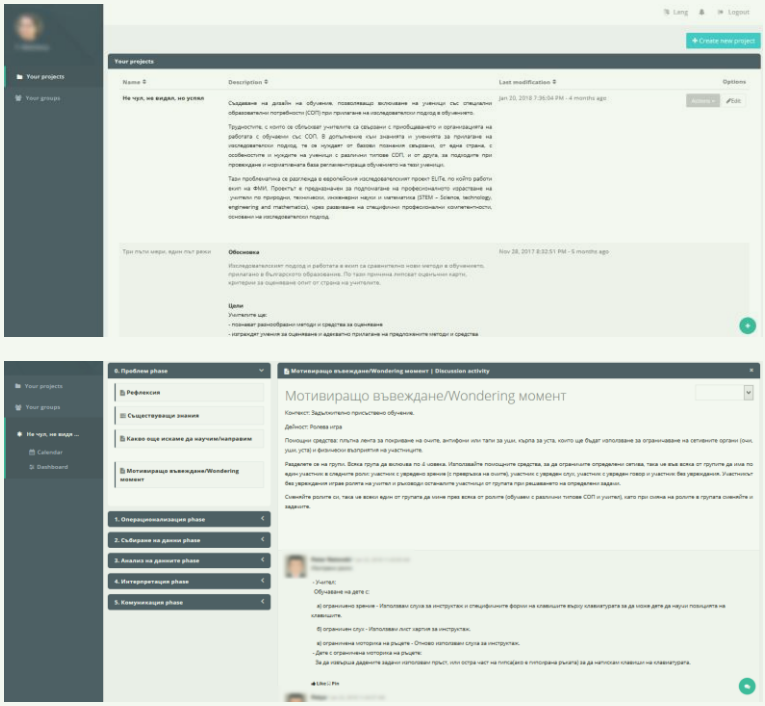
• IBL – a learning approach which implementation requires knowledge and experience in its application as well a good organization, and clear ideas about how the lesson will be structured;

• STEM – a group of several academic disciplines that require a specific tools in knowledge discovering, such as exploration, observation, experimentation and research;

• SEN students – a specific target group that needs of specific teaching approach.

Lessons learnt: The inclusion of learners with SEN when applying the IBL approach is an additional challenge for teachers. Difficulties faced by teachers are related to both problems: how to apply the IBL in their lessons and how to include, and organize the work with SEN learners. The role playing game has special importance for the success of the training. Entering into the role of different SEN learners is very important for understanding and realising the problems of these learners. During the reflection, many participants sharethat they have managed to realize the

real problems of these learners, thanks to the entry into a role and their placement in a particular situation, which greatly helps to build own knowledge and skills to work with SEN learners.



Outcome dimension

- ✓ ***Context-based outcome indicators*** and sub-indicators for evaluating the impact of PL initiatives in STEM teachers' competence development
- ✓ ***Self-evaluation tool*** for STEM teachers' inquiry and reflective practice

Context-based outcome indicators and sub-indicators for evaluating the impact of PL initiatives in STEM teachers' competence development

Presented here below are proposed indicators (and sub-indicators) for evaluating the impact of initiatives on STEM teachers' competence development, relevant to the national contexts of Greece (GR), the Netherlands (NL), Bulgaria (BG) and Spain (ES). Identified indicators and sub-indicators are based on EC (2013) framework for teachers' competence development. The Output O1 "Policy envisions and requirements for STEM teachers' competence development: the case of Greece, Netherlands, Bulgaria and Spain" provided the information relating the national contexts in which each sub-indicator is relevant to (explicitly as evident in national policy documents and the curricula for STEM teachers' training, and implicitly as evident in students STEM curricula).

Figure 13: Outcome indicators and sub-indicators for evaluating the impact of STEM professional learning activities for competence development

Outcome Through the participation in initiatives for STEM teachers' competence development, STEM teachers are expected to :	Outcome Indicators STEM teachers participating in initiatives for their competence development should demonstrate:	Sub-indicators STEM teachers participating in initiatives for their competence development can document the following types of evidence:	National contexts in which the sub-indicators are relevant to:	
			Explicitly	Implicitly
Develop knowledge & understanding on learning & teaching  **"I have knowledge & understanding on this"**	**Enhanced knowledge and understanding on STEM related & teaching and learning content**	***Demonstration of enhanced STEM knowledge*** *(knowledge in specific content areas)*	NL,BG,ES	GR
		Demonstration of enhanced Pedagogical Content Knowledge (knowledge of tasks, learning contexts & objectives; knowledge of students' prior knowledge & subject specific learning difficulties; strategic knowledge of instructional methods & curricular materials)	NL,BG	GR, ES
		Demonstration of enhanced Curricular Knowledge *(knowledge of STEM curricula- e.g. the planned and guided learning of subject specific contents)*	GR,NL,BG,ES	
		Demonstration of knowledge on issues pertaining to developmental psychology	GR,NL,BG,ES	GR,ES
		Demonstration of knowledge on issues of inclusion and diversity	GR,NL,BG,ES	GR,NL,ES
	Enhanced knowledge and understanding on methodologies and methods relating to STEM learning and teaching	***Demonstration of enhanced Pedagogical knowledge*** *(knowledge of teaching and learning methodologies &* processes; group processes & dynamics; learning theories & motivational issues)	GR,NL,BG,ES	GR,NL
		Demonstration of knowledge on innovative STEM methodologies *(e.g. inquiry based learning and teaching)*	NL,BG	NL
		Demonstration of knowledge on evaluation and assessment *(processes and methods)*	NL,BG,ES	GR
		Demonstration of knowledge on new technologies *(and their affordances as a tool for more effective learning)*	GR,NL,BG,ES	GR,NL,BG,ES
	Enhanced knowledge and understanding on contextual aspects of learning and teaching	***Demonstration of knowledge on educational sciences foundations*** *(intercultural, historical, philosophical and sociological knowledge)*	GR, NL, BG, ES	
		Demonstration of knowledge on contextual, institutional & organizational aspects of educational policies	GR, NL, BG, ES	

Outcome Through the participation in initiatives for STEM teachers' competence development, STEM teachers are expected to :	Outcome Indicators STEM teachers participating in initiatives for their competence development should demonstrate:	Sub-indicators STEM teachers participating in initiatives for their competence development can document the following types of evidence:	National contexts in which the sub-indicators are relevant to:	
			Explicitly	Implicitly
Develop skills for learning & teaching  "I can do this"	Enhanced learning skills -relating to the promotion of teachers' own learning	***Demonstration of ability to using, develop and create research knowledge to inform practices***	GR,NL,BG,ES	NL,ES
		Demonstration of reflective & metacognitive skills during owns learning	GR,BG,ES	NL
		Demonstration of interpersonal skills for learning individually and in professional communities	GR,BG,ES	NL
	Enhanced teaching skills –relating to the promotion of students' learning	***Demonstration of ability to plan, manage and coordinate teaching***	GR,NL,BG,ES	GR,NL,BG
		Demonstration of ability to use teaching materials and technologies	GR,NL,BG,ES	GR,NL,BG
		Demonstration of mastery in managing students and groups	NL,BG,ES	GR,NL,BG
		Demonstration of ability to monitor, adapt and assess teaching/learning objectives and processes	GR,NL,BG,ES	NL
		Demonstration of collecting, analysing, interpreting evidence and data skills for professional decisions and teaching/learning improvement	NL,BG	GR,NL,ES
	Enhanced professional skills- relating to teachers' role as part of educational communities	***Demonstration of collaboration skills*** *(with colleagues, parents and social services)*	NL, BG	
		Demonstration of negotiation skills *(social and political interactions with multiple educational stakeholders, actors and contexts)*		
		Demonstration of ability to adapt to educational contexts	BG	NL,ES
		Demonstration of Life and Career skills *(Flexibility and adaptability; Initiative and self-direction; Productivity; Leadership and responsibility)*		BG

Outcome Through the participation in initiatives for STEM teachers' competence development, STEM teachers are expected to :	Outcome Indicators STEM teachers participating in initiatives for their competence development should demonstrate:	Sub-indicators STEM teachers participating in initiatives for their competence development can document the following types of evidence:	National contexts in which the sub-indicators are relevant to:	
			Explicitly	Implicitly
Come to value learning and teaching- **dispositions & attitudes**  **" This is important to me"**	**Positive dispositions and attitudes relating to teachers own learning**	***Demonstration of epistemological awareness***	GR,BG	BG
		Demonstration of positive dispositions to change, flexibility, ongoing learning and professional improvement *(including study and research)*	GR,BG,ES	NL
		Demonstration of critical attitudes to one's own teaching *(examining, discussing, questioning practices)*	GR,NL,BG	NL,
	Positive dispositions and attitudes relating to the promotion students learning	***Teaching skills through content***	NL,BG,ES	GR
		Transferable skills	BG	NL
		Commitment to promoting the learning of all students	GR,NL,BG,ES	GR
		Dispositions to promote students' democratic attitudes and practices, as European citizens *(including appreciation of diversity and multiculturality)*	GR,NL,GR	GR,NL,ES
	Positive dispositions and attitudes relating to their role as part of educational communities	***Dispositions to team-working, collaboration and networking***	GR,NL,BG	NL,ES
		Sense of self-efficacy		

Self-evaluation tool for STEM teachers' inquiry and reflective practice

Guidelines for facilitating teachers' educators are provided here to structure an evaluation tool for inquiry and reflective STEM teachers' professional learning activities.

<table>
<tr><th>Aim of the tool item</th><th>Dimensions</th><th>Example of tool item</th></tr>
<tr><td>To provide data for evaluating course assumptions</td><td>- Relevance of the thematic to participants' needs
- Relevance of learning through IBL methodology
- Relevance of expected learning outcomes</td><td>How relevant are the following to my professional learning needs
(1: not at all – 5: to a great extent)
<table><tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr><tr><td>Thematic of the module</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Learning through inquiry methodology</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Expected learning outcomes as in the module outline</td><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td>To provide insights on participants' needs and expectations</td><td></td><td>What is your motivation for participating in this course? What do you expect to gain from taking part in it?
{open question}</td></tr>
<tr><td rowspan="2">Evaluating the impact:
To provide us with data on teachers' competence development</td><td>Knowledge & understanding</td><td>Note: Refer to outcome indicators and sub-indicators from table 5 → dimension knowledge & understanding
Example:
My knowledge and understanding on {indicative: implementing and assessing inquiry-based learning}:
(1:very poor – 5: very good)
<table><tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr><tr><td>Before the course was …</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>After the course is …</td><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td>Skills</td><td>Note: Refer to outcome indicators and sub-indicators from table 6 → dimension Skills</td></tr>
</table>

<table>
<tr><td></td><td></td><td>Example:
My ability to {indicative: use and adopt existing research knowledge to inform my practices}:
(1:very poor – 5: very good)<table><tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr><tr><td>Before the course was …</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>After the course is …</td><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td></td><td>Dispositions & attitudes</td><td>Note: Refer to outcome indicators and sub-indicators from table 7 → dimension Dispositions & attitudes

Example:
How important it is for me
(1: not at all – 5 to a great extent):<table><tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr><tr><td>{Indicative :To have critical attitudes to my own learning and teaching practice }</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>{indicative: To work in teams, collaborate and network with colleagues}</td><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td>To provide data on the IBL skills developed in the course aligned to IBL activities</td><td></td><td>During the course, I believe that I used the following skills
(1: not at all – 5 to a great extent):<table><tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr><tr><td>Critical thinking</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Information literacy</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Analytical skills</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Communication skills</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Digital skills</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Metacognitive and reflection skills</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Other research skills</td><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td></td><td>Activities that the learner contributed to</td><td>During the course, I contributed to the following activities
(1: not at all – 5 to a great extent):<table><tr><th>{indicative}</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr><tr><td>Formulating the question</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Planning the method</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Review and analysis of data</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Hands-on activity</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Communication</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>….</td><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td>Evaluation of the course</td><td>Usefulness</td><td>How useful were the following course elements to me?
(1: not at all – 5 to a great extent):</td></tr>
</table>

	Learning outcomes	Overall, where do I believe I am in relation to my learning outcomes? Please tick

	1	2	3	4	5
Learning through inquiry					
Self-regulated learning					
Leaning with peers					
Hands-on learning					
Reflection & metacognition					

	This is new information/experience for me and I need some time to process it
	I have connected new information to my previous learning
	I understand now how this new information fits into the bigger picture
	I am ready to share my new learning with others
	I can explain new information to others and help them understand it

Concluding Remarks

This document presented the ELITe project's framework for teachers' competence development under an inquiry based learning approach, with an aim to inform curriculum design in STEM teacher education.

It is hoped that the work reported in this document will contribute to policy mediation efforts to address current challenges and enhance STEM professional learning provisions by providing:

- **Ground for reflection on contextual aspects that affect and/or impede upon effecting policy implementation, through the cases of the four European countries** (national requirements, critical issues identified and aligned to them recommendations);
- **Evidence on the effects of the Inquiry Based learning methodology on STEM teachers' competence development** (links between inquiry skills practicing and teachers' development of knowledge, skills and attitudes on STEM learning and teaching);
- **Insights towards modernizing the thematic of STEM professional learning provisions** (proposed thematic areas and exemplar digital scenarios for STEM CPD)
- **Tools for facilitating the assessment of STEM teachers' competence development** (inquiry process indicators, outcome-indicators, operationalization through self-evaluation tool)

In the ELITe project's forthcoming activities (Multiplier Events) the presented framework will be communicated to educational stakeholders in GR, NL, BG and ES, under the scope of negotiating the validity of project's understandings on STEM teachers' competence enhancement through IBL methodology. In the course of the events participants were presented key outcomes of the ELITe project relating to the implementation and evaluation of the project's approach and engaged on, reflected on and negotiated the strengths and limitations of the project's approach for STEM professional learning in their national contexts.

Results from the negotiation process will be embedded in the final Intellectual Output of the project "*The ELITe project's recommendations towards a new model for STEM professional learning*"- in which suggested will be proposals for enhancing STEM teachers' curricula towards ensuring teachers' competence enhancement.