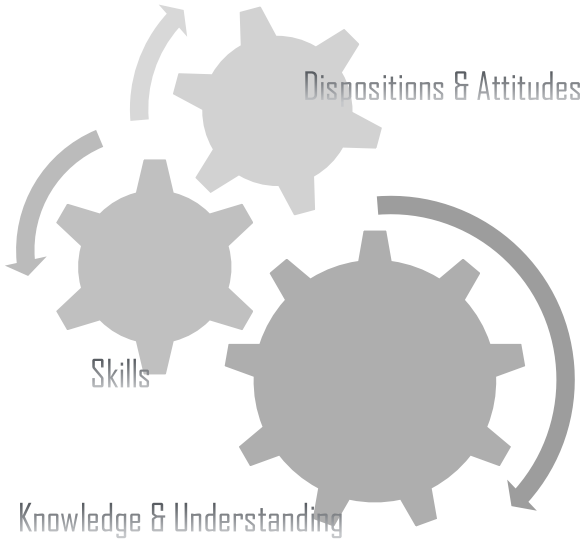
SUPPORTING STEM TEACHERS INQUIRY AND REFLECTIVE PRACTICE

The ELITe project's recommendations towards a new model for STEM professional learning

Extended Document



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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, on the one hand, to 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)

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Preface

In recent years the European policy agenda has prioritized the need to promote of Science, Technology, Engineering and Mathematics (STEM) teachers' competence development through Continuous Professional Development (CPD) provisions. The underlying concern is to effectively support STEM teachers facilitate students to acquire knowledge, skills and attitudes they need for living and working in the 21st century.

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.

This publication is a response to the need for reconsidering STEM professional learning provisions, so as to effectively facilitate STEM teachers respond to their challenging roles as learners, facilitators of students learning and members of educational communities. The document aims to inform curriculum design in STEM teacher education by providing recommendations for policy and policy making towards a new model for STEM professional learning that can respond to current challenges –contextual, thematic, methodological and outcome related - in STEM teachers CPD.

The content of this publication is informed by activities conducted in the frame of ELITe project - which aims to highlight the links between inquiry skills practicing and STEM teachers' competence development. In the course of the project, one-day events were conducted in May and June 2019 in the national contexts of Greece, the Netherlands, Bulgaria and Spain, under the scope of negotiating with educational stakeholders the validity of the project's understandings on STEM teachers' competences enhancement through inquiry based learning (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 are embedded in this document - in which suggested are proposals for enhancing STEM teachers' curricula towards ensuring teachers' inquiry and reflective practice.

It is hoped that this document provides the basis for the establishment of dialogic process between research, policy and practice towards effective STEM CPD provisions. On such a basis, educational stakeholders may reflect on their own policy context and consider how strategic policy priorities are not only achieved but also negotiated for further educational improvements.

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Introduction: The need for reconsidering STEM professional learning provisions

The recent and current discourse on educational policy across Europe increasingly acknowledges the ***need to promote the development of teachers' competences through Continuous Professional Development (CDP) provisions*** as a prerequisite for enhancing students' learning outcomes and achievement. For example, one of the core issues addressed by current work of the ET2020 Working Group on Schools (July 2018 till June 2020) is the one of supporting the quality and the professionalism in the teaching professions, with a particular focus on enhancing professional development (PD) provisions and on enhancing teachers' competency frameworks [1].

Science, Technology, Engineering and Mathematics ***(STEM) teachers' PD 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. 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*".

Supporting measures for teachers' developing and improving their professional practice so as to respond to their challenging roles ***are available in most EU countries.*** According to the 2018 Eurydice report "Teaching careers in Europe: Access, Profession and Support" [3] CPD is strongly encouraged in European countries: it is considered a professional duty in the large majority of educational systems; countries have developed different incentive to encourage CPD participation; schools tend to be involved to varying degrees in the definition of CPD needs and priorities; additional supporting measures involve specialist support within schools; while thirty-two education systems have developed a teacher competence framework to varying degrees.

The above indicate that there is currently consensus among policy and policy mediation that a key lever for facilitating teachers respond to their challenging roles is the provision of effective PD**.** The question that arises though is: ***Which are the characteristics of impactful forms of CPD?*** Results from TALIS 2013 [4] and TALIS 2018 [5] – consistent with research literature on effective forms of CPD - indicate that impactful forms of CPD include:

- *Type of CPD:* Effective teacher professional development that has an impact on teachers' instructional practices are ***activities that take place in schools*** – rather than non-school embedded activities- and allow teachers to work over time, in collaborative groups, on problems of practice. Like school embedded PD,

participation in professional networks has also been identified as an innovative and effective form of PD.

- *School conditions*: The above mentioned types of activities are most likely to occur in ***schools that are characterised by co-operation amongst teachers and strong instructional leadership***.
- *Characteristics of CPD*: ***Content focus*** (Built on teachers' prior knowledge; adapted to personal needs; coherent structure); ***Active learning and participation*** (opportunities of active/collaborative learning, focused on innovation); ***Sustained length*** (follow-up activities, extended period of time); ***school embedded*** (takes place at school, involves most colleagues from school, participation in professional networks)
- *Teachers' individual characteristics*: Teacher beliefs (such as ***feelings of preparedness, self-efficacy, constructivist pedagogical beliefs, and satisfaction with performance***) is associated with the impact of professional development. Teachers with moderate levels of these beliefs are the most likely to implement new knowledge and skills acquired through PD.

How do current provisions correspond to impactful forms of CPD? According to TALIS 2013 teachers reported ***lower participation rates in the kinds of professional development that has shown to be effective.*** Teachers participate most often in non-school embedded professional development activities, such as workshops and qualification courses and they participate less often in school embedded professional development that involves teacher collaboration on activities within their schools [4]. This is also the case, according to TALIS 2018 results: while participation in some kind of CPD has been reported by more than 90% of the survey participants, only 44% reported participation in training based on peer-learning and networking [5]. In relation to the content focus, according to TALIS 2018, more than 80% of the teachers reported attending training focusing on building knowledge (both subject-based and pedagogical), while there is no particular need for this kind of training; instead teachers report high training needs on ICT, teaching methods for multicultural skills and teaching methods for students with special needs[5].

In summary:

- ***The provision of effective CPD for STEM teachers' is prioritized by policy and policy mediation across EU countries,*** under the concern to support STEM teachers ensure that students acquire the competences they need for living and working in the 21st century
- ***Research literature and recent TALIS surveys provide insights on characteristics of impactful forms of CPD***, among others being: school based activities, participation in professional networks, active learning and cooperation based on innovation, content adapted to practice needs, sustained length and follow-up activities.
- ***Recent TALIS surveys report low participation rates of teachers in the kinds of professional development that has shown to be effective,*** and a mismatch between STEM teachers' needs for training and the actual content and learning modes of activities that are provided – results that call for a need to conceptualize and reconsider STEM professional learning provisions.

The ELITe project approach for 21st century STEM teachers' professional development

The ELITe project underlying concern is to facilitate 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. Towards this end, the project developed a framework for STEM teachers' inquiry and reflective practice, implemented and evaluated in 4 EU national contexts, namely in Greece, the Netherlands, Bulgaria and Spain (see figure 1 for a schematic illustration of the ELITe framework). A four stage development process was followed for the development of the ELITe approach/framework:

Stage 1: Identification of the space of intervention in four national EU contexts 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"- identification of thematic areas and structuring of professional learning scenarios

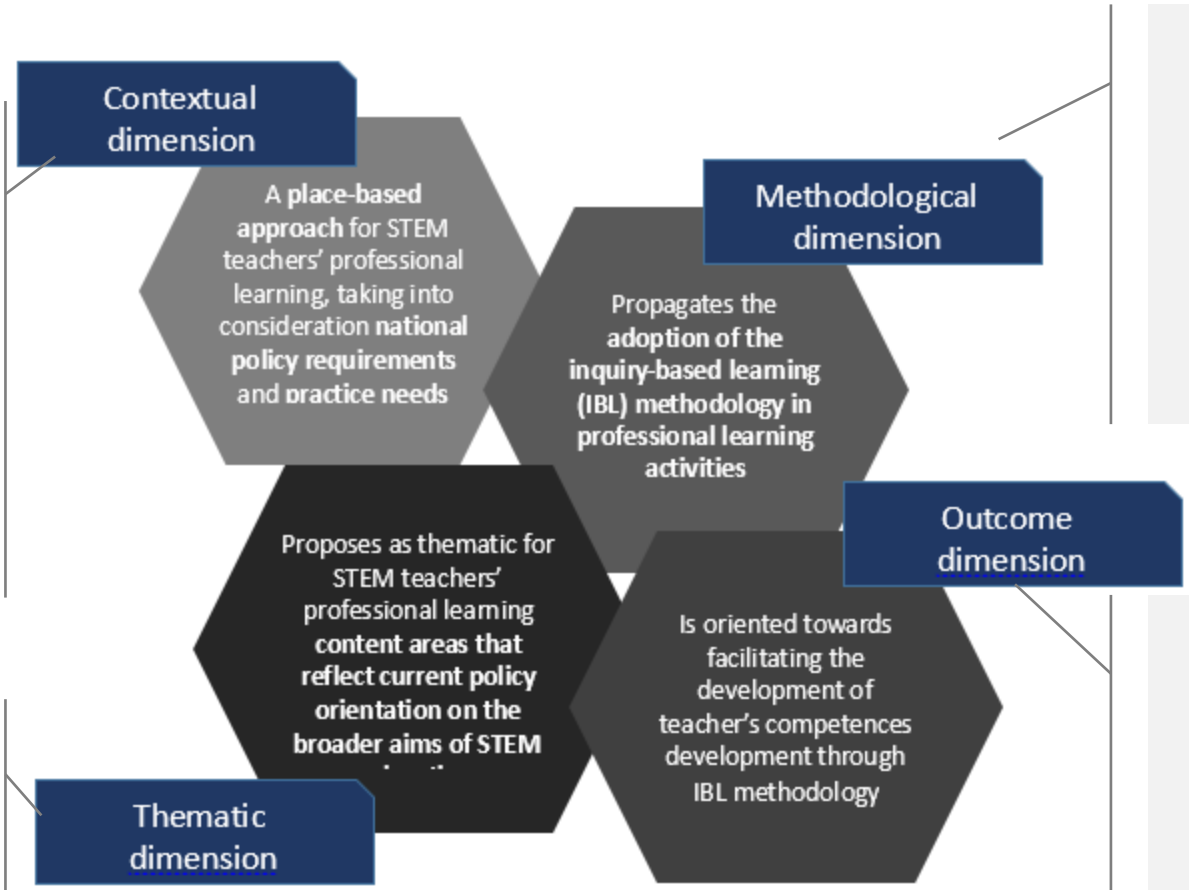
Stage 4: Evaluation of the approach through pilot implementation of 26 scenarios for STEM professional learning that address 9 thematic areas in the 4 national contexts with more than 280 STEM teachers

In short, the ELITe framework for STEM professional development calls for ***a reconsideration of professional learning provisions under the perspectives*** of:

- ***Adopting place-based approaches***, taking into consideration national policy requirements and practice needs;
- ***Modernizing the thematic of STEM teachers learning provisions***, taking into consideration content areas that reflect current policy orientations on the broader aims of STEM education and teachers' practice needs;
- ***Targeting towards the development and the assessment of STEM teachers' competences***, needed for their challenging roles as learners, teachers and menders of educational communities;
- ***Utilizing the potential of the Inquiry Based Learning (IBL) methodology,*** as a means for inquiry and reflective skills practicing and teachers' competence development.

In the following sections of this document provided are for each of the above dimensions ***lessons learnt from the implementation and the evaluation of our approach.*** Provided are also ***critical issues and recommendation for adopting the approach***, as emerged from a negotiation process of our approach with more than 120 educational stakeholders in the above mentioned counties (for more on the methodological approach of the negotiation process and country specific processes and outcomes refer to APPENDIX 1). The underlying concern is to provide ground for reflection towards new modes for PD targeting STEM teachers' competence development.

Figure 1: the ELITe framework for STEM teachers' competence development under an inquiry approach: dimensions & 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

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

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

- ✓ 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

1. Towards place-based approaches in STEM professional learning

Wide variety prevails across European countries in the current approaches to teachers' competences. Accordin1.g to the Eurydice 2108 report "Teaching careers in Europe: Access, progression and Support" [1], sixteen educational systems in Europe have introduced competency frameworks in CPD, some of which defining areas of competences, while others provide details on related knowledge, skills and attitudes. The use of the teacher competence framework also varies. General guidelines about the competences required for teaching are 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. In addition, according to TALIS 2018 survey [2], contextual conditions such as school environment and individual characteristics of the teachers are factors that affect the impact of CPD initiatives.

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***. Place-based approaches to CPD are premised on the involvement of educational stakeholders from policy, policy mediation and practice on the conceptualization, definition and implementation of professional learning provisions in order to achieve coherence in expected outcomes among different systemic levels and teachers' policy ownership for capacity building.

Lessons learnt from the ELITe implementation

In the course of the ELITe project reviewed were the national contexts of Greece, the Netherlands, Bulgaria and Spain in terms of STEM teachers' competence requirements as evident at policy, policy mediation and practice levels, under the scope of identifying the space for intervention for STEM professional learning provisions. The review resulted in a comparative overview of national requirements for STEM teachers' competence development (presented in the project's IO1 [3]).

Outcomes of the review indicated that although major competences as defined in the EC (2013) teachers' competence framework are evident in all national contexts, there are disparities at policy mediation level: ***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.***

In the course of the project's first round of negotiation process with more than 120 educational stakeholders (policy makers, teacher trainers and STEM teachers) identified were critical factors that affect STEM teachers' PD for competence development in each country. These are presented in the project's IO3 [4] and are summarized in Figure 2 here below:

Figure 2: Critical factors that affect STEM teachers' competence development in GR, NL, BG and ES

Critical factors that affect STEM teachers' competence development: Results from the ELITe project 1st round of negotiation process with educational stakeholders			
Relevant to Greece	**Relevant to the Netherlands**	**Relevant to Bulgaria**	**Relevant to Spain**
Lack of effective communication of policy priorities to policy mediators and practitioners Fragmentation of training provisions & lack of coordination between policy mediation actors 'Top-down' approach for teachers' professional development rather than a 'partnership approach' Continuous professional development for STEM teachers is in practice optional and there is a lack of culture for lifelong professional learning Current teacher training provisions are not aligned with practitioners learning needs in respect to practice requirements – both from content & appropriate training methodologies perspectives	There is a need for: Facilities for professional learning Informal learning support Interaction and exchanges with colleagues Peer feedback and consultation Collaboration, Joint work on learning environment Access to knowledge & Doing Research Organizational changes, making school an organization for professional learning 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	There is a need for: STEM subject matter – new science achievements as well as changes in the students' curricula Interdisciplinary – practical trainings combining different STEM subject matter and relationships Innovative, interactive teaching methods Work with special students' groups, tailored to the specifics of the subject and the educational need Work with parents Dealing with administrative issues Evaluation in education Face-to-face or blended learning professional learning approaches Balance between learning at work place (school) and out the door courses Online courses – as a current support, and as an archive for long term use.	Teachers lack training on STEM-related methodologies, and examples of good practice. Need of application of active teaching and learning methods in the classroom. Inclusive education is still a challenge in front of Spanish teachers. Work with parents and with other actors is essential There a need for development of communities of practice between STEM teachers Need for innovative training methodologies. Need to adopt project work as the assessment methodology.

Critical issues for the adoption of the ELITe approach: contextual dimension

In the course of the project's second round of negotiation process with more than 120 educational stakeholders (policy makers, teacher trainers and STEM teachers), discussed were the relevancy of the ELITE approach to teachers' educators practice and the feasibility for adoption/adaption in each national context. Outcomes of the negotiation process are presented in Annex X of this document in the form of national reports. A summary of the critical issues identified for the adoption of the approach for each national context as documented in the national reports is presented here below:

Relevant to the national context of Greece

- Inquiry approaches in STEM teachers' professional development were characterized as "innovative" given that theoretical and teacher-centered approaches currently prevail in CPD provisions and "highly relevant to teachers' professional development needs". Important was considered though that inquiry approaches need to be incorporated in teacher training not only in CPD, but also at pre-degree university level and teachers' induction phase, under a common framework for teachers' competency development.
- The outlined "Critical factors affecting STEM teachers' professional learning" in the country were considered as valid, influencing the professional training STEM teachers in Greece. The pointed out that "*there is fragmentation of teachers' training provisions, these are practically optional, and there is a lack of life-long learning culture and a lack of culture for developing and accessing teachers' competences*".

Relevant to National context of Netherlands

- The ELITe project approach is considered as "*relevant for different domains and educational sectors in the Netherlands, and is tried out/implemented in a variety of ways*". Among the opportunities for adoption it has been mentioned that "*STEM education has become a part of upper primary school curricula and is included with the use of Inquiry Based Learning (IBL) elements in teacher training curricula.*"
- Attention though should be paid to the fact that "*while the proposed scenarios correspond to the interests and needs of STEM teachers, an integration in PD structures at schools is lacking. Without such integration, participation remains voluntary and knowledge consumption prevails*".

Relevant to the national context of Bulgaria

- The document "Comparative insights on national requirements for STEM teachers' competence development" has been commented by educational policy makers as "*directly applicable in their practice", as a) a confirmation that the national policies are developed in sync, and in some cases being ahead of part of the other countries*".
- According to STEM teachers, the outlined "Critical factors affecting STEM teachers' professional learning" influence the professional training STEM teachers in Bulgaria. The pointed out that " *there is a need for more effective training, blended with on-the spot and online sessions (paying particular attention to on-line*

feedback and reflection) applying innovative methods that teachers themselves need to apply".

- Attention though should be paid two issues: one has to do with the poor equipment in part of schools which "*prevents the IBL implementation at schools" and might lead to "a demotivation of teachers to develop competences for implementing the IBL approach in student education*"; the other draws caution to the fact that "*teacher educators need to provide timely and systematic feedback to learners*" in IBL approaches applied within a distance or blended mode of learning.

Relevant to the national context of Spain

- The new educational policies (such as the organic law for the improvement of educational quality) focuses on the development of teachers competences. Also, the curriculum is now organized according to a competency approach, in which knowledge, skills and attitudes have been identified in all subjects and at all levels, and the STEM teacher education programs at Universities are now organized according to competences. Another opportunity is the possibility of being able to establish a common regulatory framework that allows the certification of professional competence and the certification of activities that demonstrate effective professional development for teachers and trainers.
- However, there is some tiredness from teachers facing the continuous legal changes and also dealing with short budgets in education. In addition, there is a lack of examples of good practice in IBL applied to STEM CPD programmes, while there is a lack of structure for initial and in-service teacher training around a new competence model of 21st century education professionals.

Considerations for policy

- Educational policy should consider place-based approaches to STEM Continuous Professional Development for addressing country-specific critical issues that impede upon effective policy implementation. ***The exchange of good practices among other EU educational contexts enhances the knowledge base and strengthens capacity building for effective policy implementation.***

- ***In the national contexts of Greece, Bulgaria and Spain*** – given that the main challenge identified in respect of STEM teachers' competence development lays on the grounds of policy mediation - ***educational policy should prioritize efforts for enhancing the communication of policy priorities, towards facilitating policy implementation and policy ownership from teacher trainers and practitioners***.

- ***In the Dutch context*** – given that the regulatory framework for teachers' competence development has long been established and implemented by mediating mechanisms – efforts should focus on ***promoting initiatives that provide evidence on the impact of teachers' learning for competence development on the school practice.***

2. Modernizing the thematic of STEM professional learning

Results from TALIS 2013 and 2018 surveys provide evidence that currently ***there is a discrepancy between science and mathematics teachers 'needs and topics covered currently in CPD***. In specific, data for the national contexts of the Netherlands, Bulgaria, Spain and Greece indicate that:

In the Netherlands, CPD activities for science teachers mainly cover topics: knowledge & understanding of subject fields, pedagogical competences in teaching subject, and knowledge of the curriculum for which science teachers express less needs. Science teachers express more needs approaches to individualized learning, teaching cross curricula skills and new technologies in the workplace, for which CPD provisions seem not to cover needs expressed.

In ***Bulgaria.*** Topics mainly covered in CPD refer to knowledge & understanding of subject fields, pedagogical competences in teaching subject, and knowledge of the curriculum for which science teachers express less needs. Topics relating to teaching students with special needs, new technologies in the workplace and teaching in multilingual settings are among which provisions do not seem to cater for teachers expressed needs.

In Spain, topics referring to knowledge & understanding of subject fields, pedagogical competences in teaching subject, and knowledge of the curriculum are prominent in CPD despite science teachers expressing for these topics moderate or low level needs. However, topics relating to student career guidance and counseling, teaching in multicultural settings and approaches to individualized learning are less evident in CPD, despite high level needs from teachers.

In Greece, noted should be that according to EC/EACEA/Eurydice (2015) report, at EU level 'knowledge and understanding of my subject field(s)' and 'pedagogical competencies in teaching my subject field(s)' stand out as the two topics most covered in professional development activities. Among the five topics in which training was felt to be most needed 'ICT skills for teaching' was also covered, with over 50 % of teachers including it in their professional development work. While 'approaches to individualized learning' and 'new technologies in the workplace' are the sixth and seventh most covered topics, under 40 % of teachers were involved in activity related to either. Somewhat troublingly, 'teaching cross curricular skills' and 'teaching students with special needs' come ninth and tenth in coverage, with just over one third of teachers involved in professional development activities covering these two topics.

Overall, the above data in respect to the topics covered in CPD activities indicate a mismatch between the needs expressed by STEM teachers and the actual content of those activities, and call for a reconsideration of the content of PD activities.

Lessons leant from the ELITe implementation

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 3: 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 professional learning scenarios addressing the above thematic have been developed in the course of the project and are presented in the project's IO4 [1]

Critical issues for the adoption of the ELITe approach: thematic dimension

In the course of the project's second round of negotiation process with more than 120 educational stakeholders (policy makers, teacher trainers and STEM teachers), discussed were the relevancy of the ELITE approach to teachers' educators practice and the feasibility for adoption/adaption in each national context. Outcomes of the negotiation process are presented in the Annex of this document in the form of national reports. A summary of the critical issues identified for the adoption of the approach for each national context as documented in the national reports is presented here below:

Relevant to the national context of Greece

- The modernization of the thematic of STEM professional learning provisions was considered as an imperative among the ELITe project participant in the Greek negotiation event. Participants made reference that currently professional learning provisions are too theoretical, and hardly address their practice needs.
- The ELITe thematic areas were evaluated as of high relevance to STEM teachers' needs for CPD. Most popular topics were: Dealing with socio-scientific RRI issues; ICT enhanced STEM learning and teaching; Teaching STEM for skill development; confronting challenges of new curricula and enhancing teachers-parents collaboration.

Relevant to the national context of the Netherlands

- The thematic areas proposed by ELITe were all found relevant and all courses delivered under the developed scenarios enjoyed interest with resulting high enrolments
- The attitude, however, of the learners on the implemented scenarios was that of "knowledge consumers" and the scenarios were hardly followed in a systematic inquiry fashion

Relevant to the national context of Bulgaria

- Strengths of the ELITe approach in relation to the thematic dimension include: Relevancy of the thematic areas to the school needs of STEM professional competence development; Direct applicability of the sample digital scenarios in others institutions teachers' training practice; The proposed scenarios are directly achievable both in the local training of STEM teachers in one school and in international ERASMUS+ projects
- Among the opportunities for the adoption of the ELITe approach mentioned have been: sharing good practices rather than purely theoretical approach to the development of teacher training designs; creation of a national database with a description of best practices open to teacher trainers and teachers; development of shared platforms between academic institutions to describe innovative methods and good practices in the training of the teacher trainers.

Relevant to the national context of Spain

- The thematic areas were considered by participants as relevant to teachers 'needs.
- However some teachers were skeptical on the appropriation of innovative methodologies that address the proposed themes for the development of teacher training, unless there is evidence that the proposed methodology succeeds in the classroom.

Considerations for policy

- There is currently ample evidence according to large scale international and European studies that there is discrepancy between STEM teachers' needs for professional development and the thematic currently addressed in professional learning provisions. ***Educational policy should prioritize the need that teacher education organizations modernize the thematic of STEM CPD, so to address current challenges and needs in STEM teaching practice.***
- In relation to content of CPD provisions, the following ***thematic areas are of current interest and relevance for STEM teachers' practice and it is proposed to be promoted by educational policy and to be incorporated in training provis***ions: Dealing with inclusion and diversity; Teaching STEM for skill development; Incorporating RRI in STEM education; Innovative STEM methodologies; Opening up school science; Assessment challenges in STEM; ICT enhanced STEM learning and teaching; Confronting challenges of new curricula; Enhancing teachers-parents collaboration.
- ***The modernization of the thematic of STEM CPD requires knowledge negotiation among policy and policy mediation and capacity building of the educators of STEM teachers***. Educational

policy should initiate negotiation processes with teacher training providers on the issue and support educators of teachers to develop and implement professional learning activities under the new thematic.

3. Targeting towards the development and assessment of STEM teachers' competences

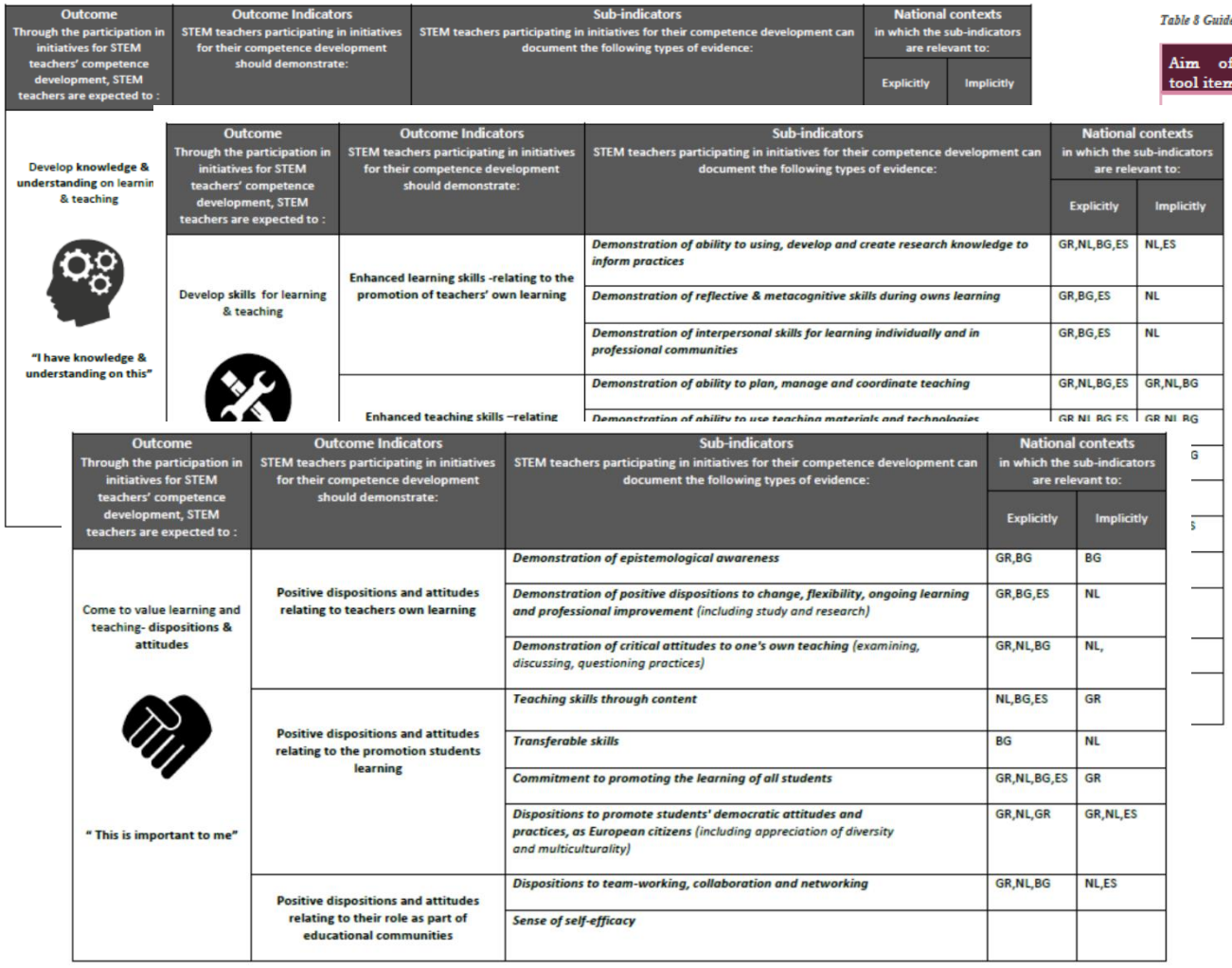
> "*Describing, defining and assessing teachers' professional knowledge and competence at any career stage is not simple or straightforward, neutral or universal, fixed or certain, but historically and culturally bound, subject to change. Competence statements, so as to recognise the complex, multifaceted nature of teaching, acknowledging the role of values, ought to be clear and not over-elaborate. […] Teacher competences should be high-level, broadly defined statements of the characteristics of teachers at different career stages, and therefore be built on a concept of teaching as praxis interweaving theory, practice and the ability to reflect critically on one's own and others' practice."* [1, p.12]

Currently, according to the 2018 Eurydice report "Teaching careers in Europe: Access, Profession and Support" [2] : Thirty-two education systems have developed a teacher competence framework to varying degrees. Some only define areas of competences, others provide details on related skills, knowledge and attitudes. Only four education systems have defined teacher competences at different stages of their career, while the use of the teacher competence framework also varies. For many countries it is mainly an instrument to define which competences teachers should master at the end of initial teacher education, while for others it is used at different stages of the teaching career. Thirteen of the education systems with teacher competence frameworks use them both for initial teacher education and continuing professional development, thus denoting a trend to use them throughout the teaching career.

Outcomes/ lessons leant from the ELITe implementation

In the course of the ELITe project, we built on the EC (2013) framework [2] in order to define outcome indicators for evaluating the impact of professional learning activities that target STEM teachers' competence development. Processes followed and results achieved are reported in the project's Intellectual Output O2 [3]. In the course of the project developed also has been a self-evaluation tool which has a double role: On the one hand, it aims to facilitate teacher educators evaluate the impact of professional learning activities on teachers' competence development; and evaluate the course in the dimensions of: relevance (of the content, methodology, objectives of modules to participants' needs); usefulness of the course to participants; accomplishment of the expected learning outcomes. On the other hand, it aims to facilitate STEM teachers to reflect on their expectations, on the learning experience and on what they have gained from it. The tool is reported in project's Intellectual Output O6 [4].

Figure 4: The ELITe project indicators and sub indicators for evaluating STEM teachers' competency development & self-evaluation tool



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 learnin & teaching "I have knowledge & understanding on this"	Develop skills for learning & teaching	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	*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
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		

Table 8 Guidelines for structuring evaluation tool

Aim of the tool item	Dimensions	Example of tool item
...vide for ...ag ...ions	- Relevance of the thematic to participants' needs - Relevance of learning through IBL methodology - Relevance of expected learning outcomes	How relevant are the following to my professional learning needs (1: not at all – 5: to a great extent) 1 2 3 4 5 Thematic of the module Learning through inquiry methodology Expected learning outcomes as in the module outline
...vide on ...nts' and ...ions		What is your motivation for participating in this course? What do you expect to gain from taking part in it? {open question}
...ng ...ict: ...vide data ...ers' ...nce ...nent	Knowledge & understanding	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) 1 2 3 4 5 Before the course was ... After the course is ...
	Skills	Note: Refer to outcome indicators and sub-indicators from table 6 → *dimension Skills*

Access the ELITe self-evaluation tool for STEM teachers' competence development in http://learning-in-teaching.eu/index.php/en/intellectual-

Access the briefing document: "Outcome indicators for evaluating the impact of initiatives on STEM teachers competence development" in http://learning-in-teaching.eu/index.php/en/briefing-docs/research

Critical issues for the adoption of the ELITe approach: outcome dimension

In the course of the project's second round of negotiation process with more than 120 educational stakeholders (policy makers, teacher trainers and STEM teachers), discussed were the relevancy of the ELITE approach to teachers' educators practice and the feasibility for adoption/adaption in each national context. Outcomes of the negotiation process are presented in the Annex of this document in the form of national reports. A summary of the critical issues identified for the adoption of the approach in relation to the outcome dimension for each national context as documented in the national reports is presented here below:

Relevant to the national context of Greece

- The self-evaluation tool was evaluated as very useful by the vast majority of the ELITe workshop participants (more than 80%); comments pointed out that it allows self-regulated learning and reflection on training goals.
- Participants though were skeptical on the use of such instrument for formal assessment purposes in relation to their career progression ; some of them pointed out their reluctance to be involved in any self-evaluation procedure, in the view that they are uncertain on how the results of the evaluation are to be used and how this can influence their career prospects.

Relevant to the national context of the Netherlands

- The self-evaluation tool was found useful by the ELITe workshop participants and usable by a broad range of potential users-teacher practitioners. The tool has the potential to stimulate self-directed and self-regulated learning as it supports setting and evaluating realistic goals and reflecting on the goals in the context of learning.
- The development of an online application of the self-evaluation tool is feasible, and it can be used in a variety of domains for professional learning of teachers.
- However, for learners who are used to have external assessment and validation frameworks and credits the tool might be considered as novel and conceptually not easy to be accepted; it requires effort, as it needs to be contextualized for use.
- It is vital to distinguish between the contexts of use: using the instrument in contexts that require formal assessment and accreditation might negatively influence the credibility of certificates based on such self-evaluation of learning outcomes.

Relevant to the national context of Bulgaria

- Both the outcome indicators document and the self-evaluation tool was found very convenient for the design of training activities by the participants of the Bulgarian workshop. The indicators and the tool is considered as directly applicable and the participants plan to use them both on schools (NHSMS and MG Varna) and in the Regional Methodological councils.
- However, the tool lack indicators about competence development for special-oriented learning and the impact of the methodology applied on learners' self-effectiveness.

Relevant to the national context of Spain

- Teachers seek to remain informed about the possibility of professional training that provides them with the necessary tools to meet the current requirements of the students
- However, some teachers might not be willing to provide arguments or be decisive in the use of innovative teaching models

Considerations for policy

- The description, definition and assessment of teachers' professional competences is not simple, fixed or universal, but context dependent and subject to change. ***National education policy should develop and promote competence frameworks, which take into consideration contextual aspects and are flexible enough to incorporate changes, as a response to new challenges emerging.***

- Educational policy should consider the ***promotion of the use of context-based outcome indicators for teachers' competence, as they are highly useful for the development of instruments for assessing the impact of STEM professional learning activities.***

- Teachers' attitudes towards the assessment of their practice and the level of acceptance of assessment may vary among different educational contexts: in some EU contexts (for example in the Netherland) teachers are used to have external assessment and validation frameworks and credits , while in others (for example in Greece) the culture of self-assessing professional practice is lacking. ***Policy efforts to promote assessment of teachers competence development should ensure that there are common understandings on the purpose of assessment efforts and take measure for effective use of competency assessment instruments.***

4. Utilising the potential of the Inquiry Based Learning Methodology as a means to STEM teachers' competence development

Inquiry is a core term in the rhetoric of STEM educational reforms internationally, as reflected in educational frameworks (PISA 2015 Science framework (OECD, 2016) [1], 21st century skills (NRC, 2013) [2]), national standards (Next Generation Science Standards (NGSS Lead States, 2013 [3]), and EU national curricula [4]. Arguments for the adoption of inquiry approaches in STEM learning and teaching are currently rooted on considerations about: a) what students need to learn for the 21st century under an RRI perspective (European Commision, 2015– *Science Education for Responsible Citizenship [5])*; and b) how students learn more effectively under constructivist, learner centered approaches to learning. Such arguments are supported by almost thirty years of empirical studies investigating the impact of IBL approaches, leading to a comprehensive body of both empirical research and meta-analysis studies that provide evidence on the effectiveness of inquiry pedagogies in the development of science learning and the improvement of students' inquiry skills.

In recognizing the qualities of IBL as a means to promote learning and skills development to students, we also need to consider the potential of its effectiveness in STEM teachers' professional learning. During the last decade there has been an increasing interest on IBL as an instructional approach in STEM PD. IBL in CPD contexts has been mainly investigated as a means to facilitate teachers' adoption of IBL approaches in their classrooms. In ELITe it is argued that the potential of inquiry approaches in STEM PD lies beyond facilitating IBL adoption in STEM teachers; rather it should be seen as a means for facilitating teachers to develop skills, needed in their professional life under their roles as learners themselves, as facilitators of students' learning and as members of educational communities. Under this perspective, ELITe focused on the investigation of the inquiry skills being practiced by teachers in the course of STEM professional learning through inquiry and sought to provide insights on the links between teachers' professional learning through IBL and teachers' competence development.

Outcomes/lessons learnt from the ELITe implementation

In the course of the 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 [6].

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. Outcomes of the evaluation of the PL activities are presented in the project's Intellectual Output O8 [7] and are summarized in the figures here below.

Figure 5: Cause and effect relationship between IBL activities and inquiry skills practicing

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

Figure 6: Effects of IBL methodology on STEM teachers' competence development

	Teachers' competences developed		
STEM teachers roles	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

Critical issues for the adoption of the ELITe approach: methodological dimension

In the course of the project's second round of negotiation process with more than 120 educational stakeholders (policy makers, teacher trainers and STEM teachers), discussed were the relevancy of the ELITE approach to teachers' educators practice and the feasibility for adoption/adaption in each national context. Outcomes of the negotiation process are presented in the Annex of this document in the form of national reports. A summary of the critical issues identified for the adoption of the approach in relation to the methodological dimension for each national context as documented in the national reports is presented here below

Relevant to the national context of Greece

- The IBL approach is still considered as a novelty in the Greek classroom reality and as such teachers are not familiarized with the methods. In addition, lecture-type teaching prevails teachers CPD provisions.
- However, IBL methodology was evaluated as of high relevance and attractive by teachers participated in the ELITe project activities

Relevant to the national context of the Netherlands

- Inquiry Based Learning is a well-known approach and widely accepted methodology in the Dutch education system to young learners; further research on teachers' professional development and the effects of inquiry approaches leads to the increase of the evidence base for evidence informed implementations
- However, there is a movement in the Netherlands propagating back to the basic education and the evidence-based character of direct instruction competed to weak evidence on the effectiveness of IBL. In addition, informal discussions with ELITe workshop participants indicated that the stringent model based inquiry approaches can be drawback and may lack feasibility. The above may influence the ELITe model implementation in the country

Relevant to the national context of Bulgaria

- The ELITe methodology and the applied tools offer an easy way to learn during teacher training, especially if it based on a ready-to-use scenario. Participants of the Bulgarian workshop were enthusiastic and full of ideas for its implementation in the environment they work.
- Teacher educators commented that the model is applicable to teachers' training but it is good to be clear that the model is flexible and every educator has the opportunity to adapt it to their own needs. Also, according to teachers' educators, it takes a longer time to persuade teachers to apply IBL approach to schools, but once they apply it teachers find the approach more effective in comparison to classical way of teaching.
- The ELITe methodology was commented as extremely strong and innovative because it give teacher educators a model on how to develop competence to their students. It is directed towards developing specific teachers' competences, unlike mass teachers' trainings that are primary focused on memorizing learning content.

- Highly measured characteristics of the ELITe methodology and its transferability to students education: learning through entertainment; learning through co-experience and co-design; getting to the shoes of the other; application of the scenarios in practice, motivation and interest,
- Substantial part of school principals hold more traditional view on teacher training, and there is a danger that they oppose to the introduction of innovative forms of teacher training at schools and subsequent transfer to the teaching processes.
- Innovative learning methods require more time in designing and implementation than the traditional ones. It is not clear how IBL methodology will have a place in teacher training curricula in which academic hours are reserved for lectures and exercises only.
- Lack of policies to promote inquiry and in general - innovative teachers' training, both in universities and in-place local school trainings. Short lectures in lecture style are supported.
- Breaking the stereotype of teaching / learning teachers - they are accustomed to the traditional style of listening to lectures and taking notes. They are afraid that they could become "foolish" if they engage in IBL activities, and they could be compromised in front of their students, show lack of specific skills, etc.

Relevant to the national context of Spain

- Current educational policies focus on competency development, yet there is a low adaptation of IBL methodology at all educational levels.
- Also there is a lack of examples of good practice in IBL applied to STEM CPD programme.
- Teacher educators have found that the scenarios under IBL methodology developed by ELITe is a good way to achieve active and constant teachers' participation

Considerations for policy

- Educational policy should ***promote curriculum redesign of STEM professional development provisions*** not only in terms of content, but ***mainly in terms of training methodology,*** considering that teachers are likely to reproduce to their classrooms the method they have themselves been trained ("teach as you preach" principle)
- The ELITe project evaluation results provide strong indications that the Inquiry Based Learning (IBL) methodology is not only effective for young learners but applicable and effective in supporting STEM teachers' competence development. ***Educational policy should consider the promotion of the IBL methodology in STEM teachers CPD contexts, and promote actions that assess its impact on teachers' competence development, so as to increase the knowledge base for evidence informed implementations.***
- In educational contexts in which a more traditional form of STEM teachers CPD prevails', it is considered important that the educators of teachers get familiarized and get training themselves in innovative methodologies. ***Educational policy should take measures and support lifelong learning of***

teachers 'educators and acknowledge and reward teachers educators innovative training initiatives.

- School principals and leaders are considered key to ensuring the introduction of innovative forms of teachers training, especially in cases of school-based teacher training. ***Educational policy should promote knowledge sharing and negotiation initiatives at school level, in order to ensure acceptance of planned reform.***

What is next? Recommendations for policy and indicative actions proposed

RECOMMENDATIONS FOR POLICY

1. Towards place based approaches in STEM professional learning	➢ Consider place-based approaches to STEM CPD for addressing country specific critical issues and the exchange of good practices among other EU educational contexts ➢ For GR, BG, ES: Prioritize efforts for enhancing the communication of policy priorities, towards facilitating policy implementation and policy ownership from teacher trainers and practitioners. ➢ For NL: Promote initiatives that provide evidence on the impact of teachers' learning for competence development on the school practice**.**
2. Modernizing the thematic of STEM professional learning	➢ Prioritize the need teacher education organizations modernize the thematic of STEM CPD, so to address current challenges and needs in STEM teaching practice. ➢ Promote the following thematic areas to be incorporated in STEM CPD: Dealing with inclusion and diversity; Teaching STEM for skill development; Incorporating RRI in STEM education; Innovative STEM methodologies; Opening up school science; Assessment challenges in STEM; ICT enhanced STEM learning and teaching; Confronting challenges of new curricula; Enhancing teachers-parents collaboration. ➢ Initiate negotiation processes with teacher training providers and education stakeholders on the issue and support educators of teachers to develop and implement professional learning activities under the new thematic.

3. Targeting towards continuous development and assessment of STEM teachers' competences	➢ Develop and promote competence frameworks, which take into consideration contextual aspects and are flexible enough to incorporate changes, as a response to new challenges emerging. ➢ Promote the use of context-based outcome indicators for teachers' competence, as they are highly useful for the development of instruments for assessing the impact of STEM professional learning activities**.** ➢ Ensure that there are common understandings among educational stakeholders on the purpose of assessment efforts and take measure for effective use of competency assessment instruments.
4. Utilizing the potential of IBL methodology for STEM teachers' competence development	➢ Promote curriculum redesign of STEM professional development provisions not only in terms of content but mainly in terms of training methodology ➢ Consider the promotion of the IBL methodology in STEM teachers CPD contexts, and promote actions that assess its impact on teachers' competence development, so as to increase the knowledge base for evidence informed implementations ➢ Take measures and support lifelong learning of teachers 'educators and acknowledge and reward teachers educators innovative training initiatives ➢ Promote knowledge sharing and negotiation initiatives at school level, in order to ensure acceptance of planned reform.

INDICATIVE ACTIONS PROPOSED TO EDUCATIONAL POLICY

- ✓ **Identify critical issues in the national level that impede upon effective policy implementation using existing data or if necessary collecting new with a view to improve evidence-informed, place based policy making on STEM professional training.**

- ✓ **When designing national STEM CPD programmes, consider factors that have been identified as Europe-wide development trends in the field for quality, inclusive education (reference SDG4), especially considerations around STEAM and the crucial impact of previous experiences and parental attitudes towards STEM domains.**

- ✓ **Build on the existing knowledge base from current research in terms of effective forms of teachers CPD and practitioners' needs, and initiate negotiation processes with actors responsible for teacher training provisions, with the view to make professional learning content more relevant to STEM teachers' needs.**

- ✓ **Take measures for effective use of teachers' competence frameworks and competency assessment tools by teacher training providers through awareness development actions that ensure common understandings.**

- ✓ **Promote curriculum reform in terms of STEM Continuous Professional Development (CPD) methodological approach towards incorporating Inquiry Based Learning approaches, by supporting teachers' educators' capacity building on introducing innovative methodologies in CPD and promote actions that assess their impact.**

- ✓ **Ensured that school leaders and teachers are involved in reform initiatives and feel ownership of the policy, by setting-up mechanisms for providing feedback on implementing policies, promoting distributed leadership and widening the participation of school level stakeholders in decision making**

References

Introduction: The need for reconsidering STEM professional learning provisions

[1] https://www.schooleducationgateway.eu/downloads/Governance/2018-wgs6-Full-Final-Output.pdf

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018H0604(01)&from=EN

[3] https://eacea.ec.europa.eu/national-policies/eurydice/content/teaching-careers-europe-access-progression-and-support_en

[4] https://www.oecd-ilibrary.org/docserver/5jlss4r0lrg5-en.pdf?expires=1564910757&id=id&accname=guest&checksum=DE602EB30516D5F1CF6AB958555C3D06

[5] https://read.oecd-ilibrary.org/education/talis-2018-results-volume-i_1d0bc92a-en#page154

[6] https://www.anefore.lu/wp-content/uploads/2015/09/EURYDICE-THE-TEACHING-PROFESSION.pdf

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Towards place-based approaches in STEM professional learning

[1] https://eacea.ec.europa.eu/national-policies/eurydice/content/teaching-careers-europe-access-progression-and-support_en

[2] https://read.oecd-ilibrary.org/education/talis-2018-results-volume-i_1d0bc92a-en#page154

[3] http://learning-in-teaching.eu/index.php/en/intellectual-outputs/io1

[4] http://learning-in-teaching.eu/index.php/en/intellectual-outputs/io3

Modernizing the thematic of STEM professional learning

[1] http://learning-in-teaching.eu/index.php/en/intellectual-outputs/io4

Targeting towards the development and assessment of STEM teachers' competences

[1] Caenna, F. (2011) Literature review Teachers' core competences: requirements and development, EC, Education and Training 2020 Thematic Working Group 'Professional Development of Teachers'

[2] https://eacea.ec.europa.eu/national-policies/eurydice/content/teaching-careers-europe-access-progression-and-support_en

[3] European Commission (2013) Supporting teacher competence development for better learning outcomes http://ec.europa.eu/dgs/education_culture/repository/education/policy/school/doc/teachercomp_en.pdf

[4] http://learning-in-teaching.eu/index.php/en/intellectual-outputs/io2

[5] http://learning-in-teaching.eu/index.php/en/intellectual-outputs/io6

Utilising the potential of the Inquiry Based Learning Methodology as a means to STEM teachers' competence development

[1] https://www.oecd.org/publications/pisa-2015-assessment-and-analytical-framework-9789264281820-en.htm

[2] https://www.nap.edu/resource/13398/dbasse_070895.pdf

[3]http://epsc.wustl.edu/seismology/book/presentations/2014_Promotion/NGSS_2013.pdf

[4] https://mascil-project.ph-freiburg.de/policy/national-policy-analyses

[5] http://ec.europa.eu/research/swafs/pdf/pub_science_education/KI-NA-26-893-EN-N.pdf

[6]http://www.jucs.org/jucs_19_14/wespot_a_personal_and/jucs_19_14_2093_2111_mikroyannidis.pdf

[7] http://learning-in-teaching.eu/index.php/en/intellectual-outputs/io8