Teacher Professional Development

for Implementing

Open Schooling in Science Education

Teacher/Practitioner Handbook

Deliverable Documentation Sheet

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Author(s)	Daphne Goldman
Contact email	dafnag@beitberl.ac.il
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Teacher professional development handbook for open schooling in science education

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Author: Daphne Goldman

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Introduction – preface

> "*This project proved to be a success in many aspects. On the one hand, it contributed to the pedagogical development of the teacher community and increased students' engagement in meaningful learning. Parallel to this, it strengthened the school-community connections and led to a broader understanding concerning the importance of citizenship involvement*" (I2C2)
>
> "*The project has supported not only professional growth for teachers but also empowered students to take an active role in their learning and in their communities [...] the project has effectively promoted a culture of collaboration, innovation, and sustainability within our schools [...] The project was quite successful in creating a more open and engaged school community*." (P2B2)
>
> "*The professional development as a result of being involved in the COSMOS project goes beyond the skills developed for the implementation of the project*" (n.d.)

This handbook is intended for educational practitioners - principals, teachers and teacher educators, as well as non-formal educators in science education, who seek to engage in a change process in the pedagogy guiding their school and teaching science, by opening their school to its surrounding community and involving diverse stakeholders from the community in science education around relevant socio-scientific issues (SSI) that impact the lives and well-being of the community.

We call this educational approach **C**reating **O**rganizational **S**tructures for **M**eaningful Science education through **O**pen **S**chooling for all, or 'COSMOS'. It aims to transform the school's organizational culture such that open schooling (**OS**) in science education (**SE**) becomes a prevalent way of conducting science classes/education, thus creating open schools with partnerships in their communities that foster meaningful science education for all citizens. In practice, OS in SE is about establishing Communities of Practice (**CoP**) that jointly develop learning units for science classes implementing a pedagogy called Socio-Scientific Inquiry-Based Learning (**SSIBL**)[1] around socio-scientific issues that are relevant to the community.

COSMOS provides a response to promoting scientific literacy and responsible citizenship by opening schools to their communities and facilitating meaningful science education by connecting science to the learners' real world.

COSMOS responds to the key challenge of young peoples' low interest in science and the need to develop their global competences as responsible and engaged citizens. It's about promoting quality education (Sustainable Development Goal 4).

[1] SSIBL – SSIBL pedagogy was developed in the PARRISE (Promoting Attainment of Responsible Research and Innovation in Science Education) project funded by the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 612438.

Key to this endeavour is teacher professional development (TPD) – empowering teachers as *change agents* in realizing educational reform in terms of open schooling and its application in the context of science education. Accordingly, capacity building of teachers in COSMOS targets developing the teachers' competencies for implementing socio-scientific inquiry-based learning within communities of practice, honing their capacities as reflective practitioners and cultivating their professional identity regarding OS and learning in/as communities. This entails developing a deep understanding of **learning in and as a community** and **employing SSIBL** (Socio-Scientific Inquiry Based Learning) as the pedagogical framework for developing, in Communities of Practice, learning units for science classes around relevant socio-scientific issues. Together, these comprise the COSMOS open schooling approach. **The aim of this handbook is to provide guidelines for this capacity building of teachers and other practitioners who choose to promote the COSMOS approach in their educational settings.**

This TPD handbook was developed through an iterative process. A first version of the TPD process was conducted with 18 teaching teams in 16 primary and secondary schools in six different countries (Belgium, Israel, Netherlands, Portugal, Sweden, UK). Consequent to this first implementation, an intensive series of TPD workshops were conducted during in an international COSMOS TPD conference (Prague), with the teachers who participated in the implementation and the consortium partners leading the project. The aim was to critically reflect on how the TPD played out and obtain insights, from the perspective of the TPD implementers and recipients, for refining the professional development guidelines. The refined TPD process was implemented during a consecutive school year with 19 new and continuing primary and secondary schools, after which analyses of the experience and insights from the consortium partners and the teachers led to the final version of the TPD handbook.

Section 1 of this handbook provides a brief overview of the major concepts and theoretical framework[2] of school openness underlying the COSMOS approach and presents the COSMOS TPD model that was constructed based on these conceptual groundings.

Section 2 provides a [suggested] framework of practical guidelines and activities for developing teachers' capacities to implement the COSMOS approach to OS in SE. This section includes four subsections: (a) a general overview of the COSMOS TPD process; (b) learning in/as a community; (c) selecting a SSI and developing around it a SSIBL learning unit within a CoP; and (d) honing reflective capacities. Each of these subsections presents the objectives, a learning process with suggested activities, and a list of references for further reading. Each sub-section is also supplemented with selected practical teaching resources that were developed during the project and implemented with teaching teams in participating schools.

Section 3 centers on the how to **adapt** professional development around OS in SE **for different contexts**. COSMOS is not a 'one size fits all' process of organizational change. Accordingly, teacher professional development for realizing such educational reform needs to be context-sensitive to the attributes and needs of the school, specifically the professional attributes of the teachers, the school culture and the characteristics of the national and school curriculum. Based

[2] Sarid, A., Boeve-de Pauw, J., Christodoulou, A., Doms, M., Gericke, N., Goldman, D., Reis, P., Veldkamp, A., Walan, S. & Knippels, M.C.P.J. (2024). Reconceptualizing open schooling: towards a multidimensional model of school openness. Journal of Curriculum Studies. https://doi.org/10.1080/00220272.2024.2392592

on the insights obtained from implementing TPD in the different countries and school contexts, this section offers evidence-based practical considerations for designing and implementing an effective process of TPD for applying OS in SE within specific educational settings/circumstances.

Section 4 – This final section looks at **key success factors** for COSMOS TPD and points out **opportunities** COSMOS TPD creates for the teachers and the school. This section opens a window to "the **teachers' voice**" with a selection of quotes provided by teachers who participated in the COSMOS project, communicating their personal reflections about how their experience in COSMOS, via its professional development, has influenced their teaching in science education, and perspectives of open schooling in science education and as a broader educational approach.

Acknowledgements

We thank all those teachers and students who took part in this project. The motivation, dedication and professional experience of the teachers was crucial in realizing the goals of this project including the ongoing development and refining of teacher professional development in open schooling in science education. These teachers serve as an inspiration for all educators who aspire and have the courage to enter pedagogical change processes, such as open schooling, that contribute to improving our schools and schooling, strengthening the quality of education our students experience and improving community well-being.

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Glossary

CoP	Community of Practice
CORPOS	Core Organisational Structure for Promoting Open Schooling
COSMOS	Creating Organizational Structures for Meaningful science education through Open Schooling for all
OS	Open schooling
PD	Professional development
PLC	Professional Learning Community
PI	Professional Identity
SE	Science Education
SSI	Socio-Scientific Issue
SSIBL	Socio-Scientific Inquiry-Based Learning
TPD	Teacher Professional Development
TPI	Teacher Professional Identity

Section 1 – The COSMOS approach

1.1 COSMOS concepts underlying the TPD model

Open schooling and school openness – 'Open schooling' has emerged in recent years as a burgeoning theme in the discourse on how to rethink education for the 21st century and transform schools into better, more relevant and adaptable organizations (EC, 2015, 2024; OECD, 2020). This rearticulation of 'Open schooling' has been spearheaded by recent reports by the OECD (2006, 2020), such as the OECD Scenarios for the Future of Schooling and the European Commission's (EC, 2015) Science Education for Responsible Citizenship, which call for transforming schools into 'hubs of learning' by bringing down school walls, fostering collaborations with the community, and engaging in innovative research. The European Commission applies the following definition: *"[Educational] Institutions that promote partnerships with families and the local community with a view to engaging them in the teaching and learning processes but also to promote education as part of local community development."* (EC, 2015, p. 69). Based on this definition, the COSMOS project offers the following succinct catch phrase for depicting the essence of open schooling:

Open schooling is education *with*, *as* and *for* the community

A multidimensional ecological model of school openness dimensions was developed within the COSMOS project and serves as an underlying theoretical framework of OS for building the teachers' capacities to open the school up to the community (Sarid et al., 2024, Figure 1). According to this model, school openness is expressed in eight interrelated dimensions organized in three categories that account for organizational, pedagogical and communal aspects of school openness. For educational practice, this theoretical understanding of what school openness means and entails is employed at the start of the TPD process as a self-assessment tool for the school teams to examine and identify the openness of their school, consider which dimensions are relevant and meaningful for the school and its community, and prioritize dimensions of openness they see seek to change (see unit 1 section 2.1.2 – the school openness assessment tool), as well as at later stages to monitor and reflect on development. A meaningful TPD process will employ this framework for discourse creating awareness of the benefits school openness offers the school for improving its education, and thus, for moving outward (to more openness) on its dimensions.

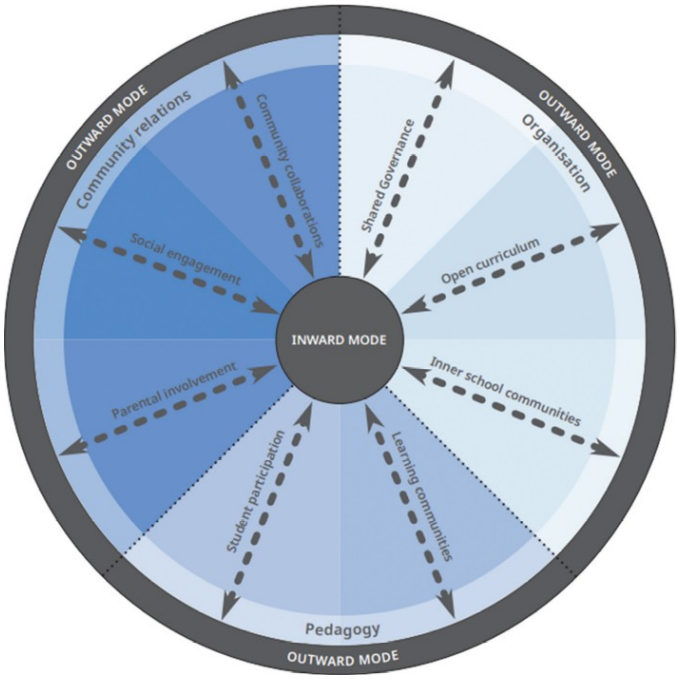

Figure 1. Ecological model of school openness (Sarid et al., 2024)

Communities of practice (CoP) – Represents a distinctive element of the COSMOS approach as it promotes mutual engagement among community stakeholders (e.g., students, teachers, families, scientists, companies, NGOs, science centres). CoPs are defined by three constituting elements, each facilitating OS for SE: CoP members share a common concern or a passion (*Joint enterprise*) and learn how to improve together their knowledge and behaviour (*shared repertoire*) as they interact collaboratively (*mutual engagement*) (Wenger-Trayner & Wenger-Trayner, 2015).

More detail on CoP may be found in section 4 of the 'COSMOS Framework'.

Socio-Scientific Inquiry-Based Learning (SSIBL) – Socio-Scientific Inquiry-Based Learning (SSIBL) serves as a *pedagogy* that fosters OS in SE. SSIBL was developed in pre- and in-service TPD programmes for primary-, lower- and upper-secondary science education, in the FP7 PARRISE project (Levinson et al., 2017). Through SSIBL, students can see and experience the links between science *in*, *for* and *with* society. This is achieved through the interrelations among three key pillars of the SSIBL framework: socio-scientific issues (**SSI**), inquiry-based learning (**IBL**), and citizenship education (**CE**), under the umbrella of **RRI** (Responsible Research and Innovation). SSIBL is organized in three stages (Levinson et al., 2017):

(1) ASK- Students and science teachers *raise specific investigative questions connected to real-life* socio-scientific issues, which require the involvement of multiple stakeholders identified.

(2) FIND OUT- All stakeholders involved collaboratively support students in *conducting personally relevant* [scientific-, social-, personal] *inquiries*.

(3) ACT- Students, and stakeholders (e.g. families, scientists, companies, science centres), substantiate their science knowledge and learn how it can be applied within their communities for the benefit of the community. In this process they develop *decision-making skills and formulate modes of action* (e.g., campaigning for climate action, writing to their local authorities, conducting actions that promote the quality of their local environment) that empower them to contribute responsibly in/to their communities.

While inquiry-based learning is prevalent in teaching science subjects, SSIBL presents a more socially responsible approach that, via these three stages, integrates the inquiry-based science learning around SSIs and citizenship education. Applying this pedagogy deviates from science teachers' routine experience in mainstream inquiry-based teaching as it involves diverse types of inquiry – scientific, social and personal, places learning in a socio-scientific context and includes taking action as part of the learning outcomes.

More detail on SSIBL may be found in section 5 of the 'COSMOS Framework'.

Teachers as 'reflective practitioners' – A key to being an effective teacher is the ability to critically reflect – to examine and learn from one's experience or an educational situation and use this knowledge to reframe one's thinking and improve one's teaching. A reflective teacher is one who is aware of the considerations behind the decisions he/she makes and the implications of those decisions; it is about the teacher thinking about what he/or she does, questioning one's own practice or underlying consideration, and making changes when necessary. Critical reflection is about questioning not only one's practice, but also the broader issues, values and ethics around education, challenging the existing practices and considering alternatives. In other words, it's about **reframing one's thinking**. This is especially crucial when considering the role of education as a means for change, and for teachers as change agents, as is the case of COSMOS. A critically reflective practitioner (e.g. Schön, 2017) is aware of and understands the changing circumstances in which he/she functions and is able to change his/her ideas and assumptions (i.e., frames-of-reference) concerning what is a best practice in the evolving circumstances (Mezirow, 1997).

NOTE: More information on the theoretical underpinnings and core concepts of the COSMOS approach may be found in the 'COSMOS Framework '

1.2 The COSMOS TPD model

In COSMOS, OS in SE is about establishing Communities of Practice (CoP) that jointly develop learning units for science classes implementing Socio-Scientific Inquiry-Based Learning (SSIBL) around socio-scientific issues that are relevant to the community.

The process of TPD in COSMOS is organized around three conceptual components (i.e., 'conceptual stages') of the COSMOS approach, as depicted in the model of TPD for OS in SE (Figure 2):

(a) **COSMOS approach** – Creating an understanding, developing a mindset, and cultivating in the teachers and the school a professional identity concerning learning *in* and *as* a community.

(b) **SSIBL pedagogy** – Capacity building for developing, within a CoP, inquiry-based learning units on a locally relevant SSI. This entails understanding the SSIBL pedagogical model and employing it within the COSMOS approach - in co-designing and implementing, within a CoP, an inquiry-based learning unit (or units) on a selected socio-scientific issue.

(c) **Reflection** – Cultivating the teachers as 'reflective practitioners'; conducting meaningful reflection of the process in which the teachers share and critically assess their experiences in implementing CoP-based SSIBL and identify areas for improving the process, strengthening the capacities of school teams, and sustaining COSMOS in the school (the latter is also tied to the role of the CORPOS [school openness team] within the school organization).

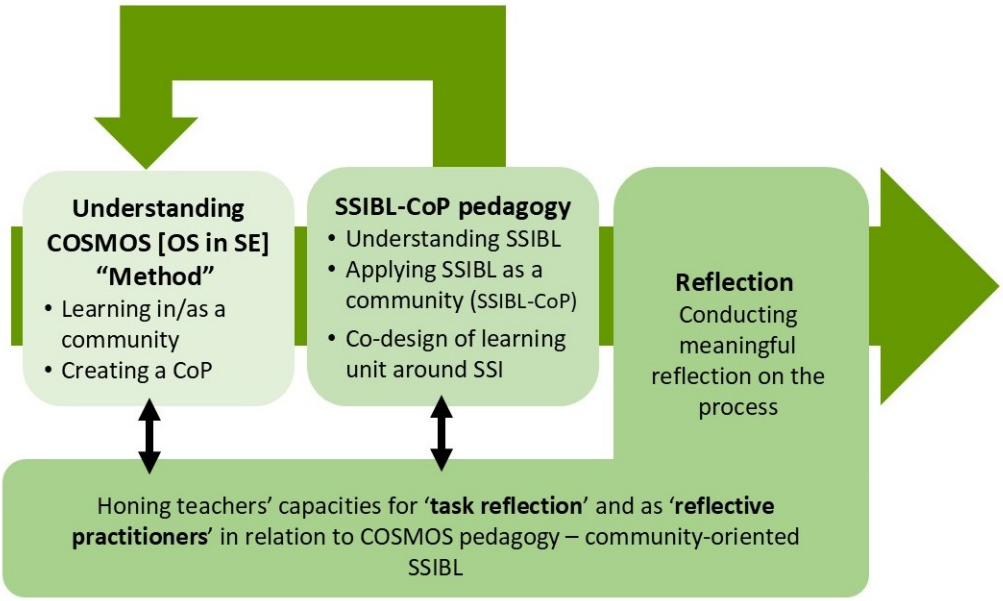

Figure 2. TPD model of conceptual components for open schooling in science education

While this model reflects a **progressive process**, its starting point can differ (as depicted in Figure 2): TPD can follow the proposed sequence, starting with focus on the underlying theoretical approach of learning within a community (including thinking about practical issues of

learning in and as a community) and then proceeding to familiarizing with SSIBL pedagogy. Alternatively, the point of departure for TPD can be the practical pedagogical component of identifying a SSI, and through working on developing a SSIBL educational intervention, considering what the implications are [how to do] when doing this in a community approach as a CoP. **Where to start TPD is a crucial consideration for adapting the TPD process to the teacher team that will be involved in the process**.

Reflection is a core component of COSMOS TPD and is incorporated throughout the process. Conducting reflection in all stages makes TPD a **developmental** process, in which the teachers' discourse is guided to move from basic familiarization with the key concepts and components and a basic level of task reflection (e.g., how to incorporate the community within the three stages of SSIBL) to a more advanced and critical reflection on one's practice and on the community aspects of learning (e.g., what are the assumptions and values that support the use of SSI in teaching science, how the school can foster meaningful and stronger connections with the local community via learning around a SSI). Reflection throughout the TPD process guides the teachers to critically analyse their experiences in developing and implementing SSIBL within CoPs (e.g., what worked well, what were challenges and how were these addressed, areas for improvement). Reflection reinforces the teachers' capacities as facilitators of community-oriented inquiry-based science education and deepens their comprehension of open schooling as an approach to education and its benefits for science education. Through these, reflection guides the teachers to see themselves as **facilitators of community-based learning**, thus nurturing their **professional identity as community educators**. Reflection in COSMOS TPD is, therefore, a significant tool for empowering the teachers a **'agents of change**'.

Conducting TPD with different scopes of participants

TPD can be conducted in different scales in terms of the scope of participants. Teacher professional development commonly focuses on development of the teacher as an individual – developing the individual teacher's competences in the respective area. Consistent with the community approach, OS in SE aims for learning not only at the individual teacher level but also for **learning at the organizational level**. Therefore, corresponding with the school openness dimensions, TPD in the context of OS in SE looks at the school's organizational structure and targets development not only at the level of the individual teacher, but also **organizational change** – changing the culture of how the school approaches its teaching. In line with the learning in/as a community approach, OS in SE envisions TPD to be conducted within a **professional learning community** (PLC) (Huijboom et al., 2023). The process of collective-collaborative learning, which lies at the heart of PLC, is one aspect of changing the organizational structures and culture to promote open schooling in COSMOS.

Ideally, TPD is envisioned as being conducted in three scales in terms of the participants:

COSMOS School Community scale – This level entails encouraging (and supporting) creation of a community of schools that together comprise a **professional learning community**. Conducting part of the TPD in a community of schools is a desirable situation as it enables exposure and enrichment of diverse perspectives and ideas, fresh insights and reinforces motivation; it epitomizes the essence of COSMOS. Creating a 'COSMOS School Community' may

also occur at different levels - at a school district level (i.e., schools within the same school district), a regional level, a country level (in the case that there are several schools in the country) or even at an international (international COSMOS school community) in the case that there are school teams who aspire to be part of an international professional community of learning. It may also occur with individual teachers who are motivated to being part of such a group.

The international TPD conference conducted in Prague after the first implementation round provided such an opportunity at the international level. In the selection of following quotes, the participating teachers attest to the values of such international interactions:

"*Meeting teachers from other countries and seeing their perspective*" (n.d.)

"*To share experiences and ideas with colleagues*" (n.d.)

"*Very informative and stimulating to work with different parts of the project and see what other schools have been up to" (n.d.)*

"[...] opportunities to share ideas with other teachers, which gives us other valuable options" (n.d.)

"[...]to see other projects from different countries and schools. I got a better understanding about the way to implement a COSMOS approach" (n.d.).

School scale – The school team participating in the implementation round, including the principal, CORPOS members, participating teachers, and possibly members of the CoP established around the SSI.

Individual Teacher scale – Individual work with the teachers involved in the project to provide guidance and support in addressing ad-hoc questions, challenges and problems that arise during the different stages the teachers are at in the design and implementation of the learning unit/educational intervention.

The following comment of one of the teachers expresses the value of both individual and team work:

"*Those one-to-one meetings [with HEI partner], those were really effective. Because you can achieve a lot in those one-on-one sessions within an hour you really had a lot. But I still liked the fact that we got together every now and then to give feedback on each other's thing [lesson plans*].' [N2B2]

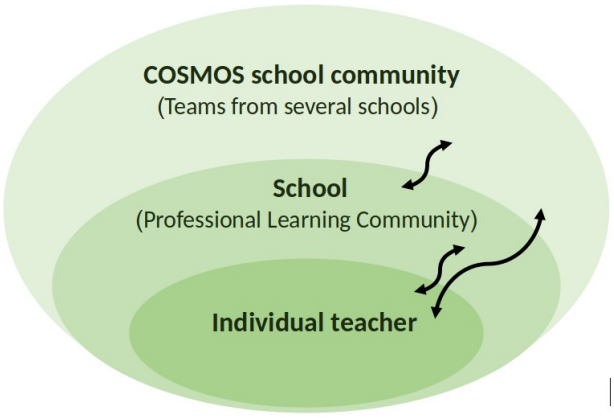

Figure 3. Scales of TPD participants in OS in SE

Scheduling Teacher Professional Development Actions

COSMOS TPD on OS in SE is a progressive and developmental process. Thoughtful planning concerning when to conduct the TPD components and activities will ensure a process that develops teachers' deep understanding of the fundamental principles of the COSMOS approach and cultivates their competencies for implementing these. Strategic timing will facilitate a process that is reflective (assumes an iterative learning approach), aligns with community engagement events and is also coordinated with the school year (annual curriculum and other programs and initiatives).

TPD will be most effective when introduced progressively, allowing teachers time to internalize the COSMOS principles and integrate them within their teaching, parallel to coordinating these with key moments of community engagement within the course of conducting OS in SE. Timing TPD actions with other community activities in the COSMOS process will ensure that the teachers are well prepared and competent to contribute to these engagements, benefit from them and maintain productive relationships with community members involved in the opens schooling process.

Figure 4 offers a broad timeline for scheduling TPD activities that addresses: (a) the various conceptual components, allowing teachers to gradually and progressively familiarize themselves with the foundational principles of community-oriented inquiry-based science education and effectively implement these within their teaching, (b) benefits of the timing of the different TPD components.

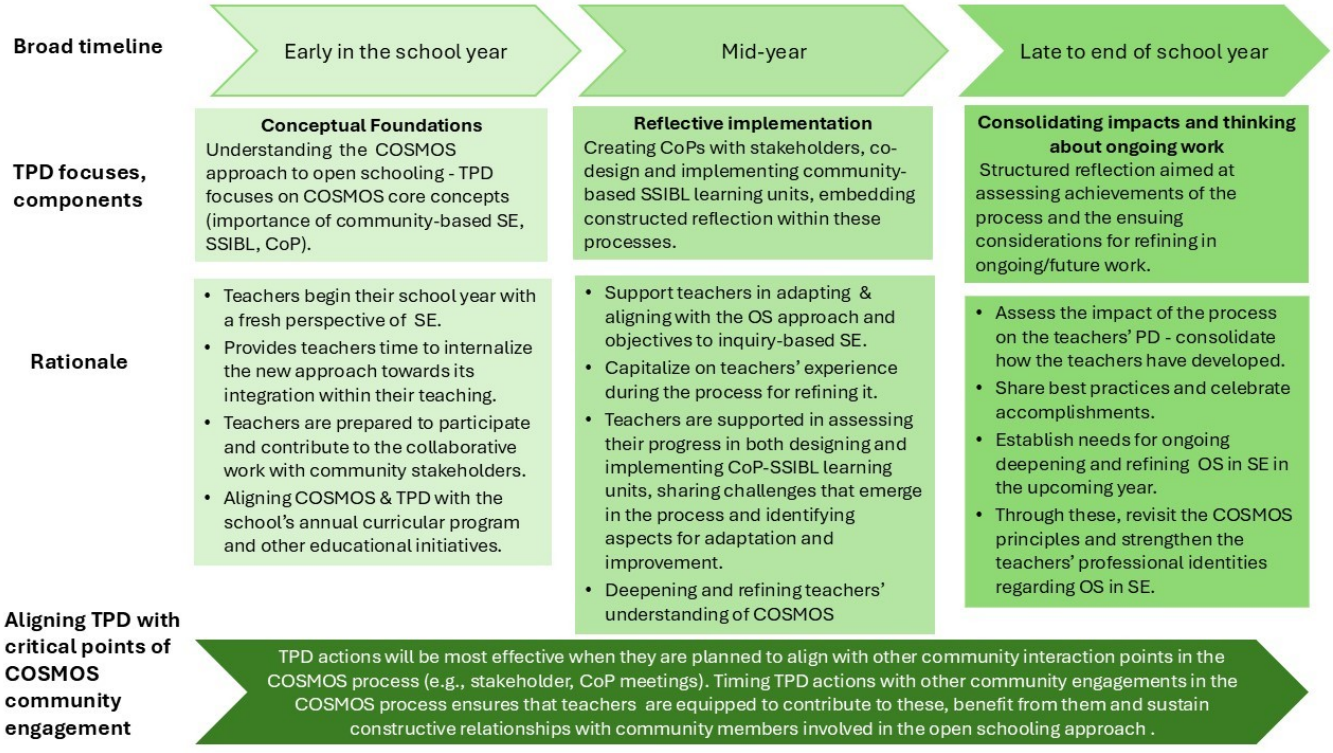

Figure 4. Broad timeline for scheduling TPD activities throughout the school year

1.3 General principles for enhancing effective TPD on OS in SE

Following are some principles to consider for enhancing the effectiveness of the TPD process. These principles have been consolidated from conducting COSMOS TPD for two years with primary and secondary school teams from 24 new and continuing schools in six countries.

- *School level* – The TPD guidelines and activities are generic and can be adapted for teachers in primary and secondary (junior high school) school levels.
- *Flexibility and adaptability* – Applying COSMOS TPD is not a "one size fits all" but should be context-sensitive – to the specific attributes and needs of the teachers, the school as well as the national and school curriculum. Thus, while this handbook offers a structured process of TPD, employing a flexible and adaptive approach will enhance the effectiveness of this process. Flexibility and adaptivity is expressed in several interrelated aspects:
    - Flexibility in the TPD structure – The TPD process can start with different components (concepts) of the TPD model. For example, if the professional learning community prefers to enter its PD from the aspect of praxis, with emphasis is on the practical aspect of understanding SSIBL and its implementation in learning science, TPD can commence with this component, and address learning in/as a community (i.e., incorporate the aspect of learning as a community) as this emerges/ surfaces/ becomes exposed around SSIBL.
    - School openness attributes – Tailoring TPD to the **openness attributes** of the school. This is built into the TPD process as one of its first activities in which the school team (professional learning community) characterizes the school through the lens of the openness dimensions, identifies where it is situated on these dimensions (on the inward – outward continuum) and prioritizes those dimensions to be addressed.
    - Teaching team's needs – Flexibility in adapting the TPD activities to the **teachers' needs** and their incoming competences (e.g., their familiarity and experience in community-based education, with SSIBL, etc.) in each participating school. These incoming foundations of the teachers are a significant factor in determining how TPD should play out, and where emphases should be placed.
    - Flexibility in TPD structure also concerns adapting the intensity and duration of TPD initiatives to school schedules and time constraints.
- *Emergence* – Enable the TPD process to include an **emergent aspect** by enabling the stakeholders (in the CoP and open schooling team/CORPOS) and the teachers to be actively involved in co-constructing the TPD process and contributing PD content and activities based on their experience.
- *Making concepts explicit* – Think about content focus and **how to make the concepts and ideas concrete**. Provide the participating teachers with concrete examples of practice and teaching materials.
- *Sharing and peer feedback* – TPD in COSMOS is framed as a professional learning community. Enabling collegial discussions among the participating teachers in which they share ideas and provide reflective feedback is an important factor towards effective TPD.

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Section 2 – TPD Guidelines and Materials

The following section includes: (a) *A [suggested] framework* of a TPD process; (b) *practical material* – suggested learning activities for each stage of the TPD accompanied by selected practical teaching resources that were developed during the project and implemented with teaching teams in the participating schools and (c) *theoretical material* – suggested reading for establishing and deepening the knowledge foundation regarding the conceptual focuses of TPD (learning in / as a community, SSIBL).

Some clarifications:

- While the suggested activities reflect a **sequential progression**, within each conceptual stage of PD, the activities are modular; that is, the activities can be conducted as a stand-alone component of the PD process, and the order and specific application can be changed according to contextual (i.e., school teams) characteristics and needs.
- The activities are suggestions we view as a starting point and it is expected that they will be modified (1) to suit specific contexts, (2) upon teachers' engagement in the co-design learning process.
- COSMOS adopts the community approach by which it is beneficial to conduct the PD activities as a professional learning community. Accordingly, the activities can be conducted at the school level (with the individual school team) or at the COSMOS school community level (with groups of schools that work jointly).
- While TPD concerns working with the science and other teachers who will be involved in COSMOS, corresponding with the COSMOS community approach we envision the creation of an inner-school open schooling team (CORPOS) and the participation of its members in the PD process. Thus, to our understanding these guidelines can apply also to working with an open schooling team (CORPOS) that serves as a professional learning community for open schooling.

Overview of the TPD

Each unit is elaborated further on with suggested activities, comments for implementation and suggested reading.

Table 1. Overview of TPD units with aims and suggested PD aspects to address

TPD unit – conceptual focus	Aims	Suggested PD components of the unit
1 The COSMOS approach – learning in and as a community.	• Initiate the process of creating a mindset and professional identity (as a teacher, and a school) regarding the notion of 'open schooling' via communities of practice • Understand the educational benefits of learning in and as a community • Concretize how these play out in practice in the social and physical context of the school	1. "**Recruiting" the school - Engaging the school with COSMOS** (whether with individual schools or in school groups) –- Familiarizing with COSMOS and creating motivation and a sense of identification with the idea of 'open schooling' in the context of science education. 2. Initial **Focus group assessing the school openness attributes -** Conducting a reflective discussion on the school's current reality in relation to the openness dimensions (see Figure 1), prioritize the dimensions - which of the dimensions will be addressed earlier, which later... **3. Learning in/as a community Workshop** – Concretizing, in the context of COSMOS, basic elements that define a learning community: joint enterprise, mutual engagement, shared repertoire.
2. Community-oriented SSIBL pedagogy, developing a SSI learning unit	• Understand the rationale and three stages of SSIBL and how these play out when conducted as a community of practice. • Link the selecting of a SSI and establishing a community of practice around it.	1. Principles of SSIBL (based on the PARRISE project) toward inquiry-based learning in COSMOS 2. **Selecting a SSI** and **creating a CoP** around it – this TPD component reflects adapting the 'ASK' stage of SSIBL to COSMOS: it connects the process of identifying and

within a CoP	• Provide support for the teachers during the process of (a) developing, within the CoP that has been established, a learning unit(s) on the selected SSI for implementation in science classes, (b) implementing the learning unit	selecting a SSI with starting to create a CoP [*]. [*] At the TPD stage, the CoP may begin to form, and it will continue to grow during the process of developing the learning units, as relevant and interested stakeholders are identified.
3. Reflection on the process	Improve the learning process: • Selecting a SSI and designing an appropriate learning process for inquiring and addressing the SSI within a community [joint enterprise] • Identifying and selecting relevant partners for the CoP [joint enterprise, mutual engagement] • Engaging in a learning process that is based on participation and shared authority [mutual engagement] • Mediating different points of view within the CoP • Creating new knowledge as an outcome of the participation of diverse community members [shared repertoire] • Critically reflecting on instances that contributed or hindered the process of opening the school through SSIBL.	1. Reflection is included in the activities of most of the different units. 2. Reflection processes are linked to assessment components (WP7), at the onset and end of the implementation and employ these as part of the reflective process (such as reflecting on the school's openness attributes). 3. Suggested generic framework supporting the educational teams' reflection skills

Unit 1 – The COSMOS approach – learning *in* and *as* a community

The first component (i.e., conceptual stage) of teachers' PD focuses on developing an understanding of and identification with the COSMOS approach/method – developing a COSMOS mindset in the aim of facilitating the school team's (and CORPOS's) motivation to implement this in the school and adopt this as part of the school's organizational culture.

Objectives

- Initiate the process of creating a mindset and professional identity (as a teacher, and a school) regarding the idea of 'open schooling' via communities of practice.
- Understand the educational benefits of learning in and as a community.
- Concretize how these play out in practice in the social and physical context of the school.

Suggested PD components

This unit is comprised of three optional PD components. As stated above, a modular approach is adopted, thus, the PD activities are suggestions that can be adapted to the local or school-team context; and the choice of activities is left to the discretion of the school depending on various factors, such as, the needs of the teachers, the time available for TPD sessions, how the teams are progressing. COSMOS adopts the community approach by which it is beneficial to conduct the PD activities as a PLC (school level or group or individual school team).

2.1.1 "Recruiting" the school – Engaging the school with OS in SE

The use of the term "recruitment" refers to the recruiting of a mental process. Accordingly, the TPD activities involve a process of familiarizing and engaging with the COSMOS method and understanding the educational contribution of entering the COSMOS change process.

The following table also includes a 'school recruitment call'. This is relevant in cases in which entering the OS in SE process is not an internal initiative of the school (principal, teacher) but an external initiative such as that of a superintendent of a school district, higher-level official or decision maker aiming to initiate the process with a group of schools. In this case a recruitment call may be distributed to schools. In such situations, capacity building commences at “recruitment”; “recruiting” a school inherently involves initial elements of PD (such as familiarizing with OS in SE and its relevance and benefits for the school, initiating thinking in terms of COSMOS concepts, creating motivation or a sense of identification with the notion of 'open schooling') and can, thus, be utilized towards PD.

The activities can be conducted with an individual school team or with a group of schools.

Table 2. Outline of PD activities and resources around 'Engaging the schools in COSMOS'

	Content / Activity	Suggested duration	Material/ Resources
1.1 School recruitment call [This is relevant in cases when entering the OS in SE process is not the initiative of the school (principle, teacher) but that of the superintendent of a school district, higher-level official or decision maker aiming to initiate a process with a group of schools]	The call for COSMOS contains some information on COSMOS Prior to Introductory meeting, request from the school a written statement: *Why is it important for your school to participate in this project?*	The call for COSMOS is optional, depending on the process of approaching schools; the request for a written statement is relevant for any school prior to the first meeting.	School recruitment call
1.2 Introductory meeting with schools as a group [f-t-f or long distance]	Presentation of COSMOS. After the meeting: Request for written statement: *Share information about the school that is relevant to the project*	1 hour: 30'- minute presentation, 30' Q's & A's about the project	Presentation 'Introducing COSMOS'
1.3 Workshop [F-t-F] - with the school team or with a group of schools	**Objective**: Schools begin to think how COSMOS is relevant to science subject (science education) in their school. **Identify:** In your school team identify a socio-scientific issue that exists in your area that you see relevant and suitable as an issue for study in your school. Discuss with your team the following	~2 hours: 1. Identify – ~30' [school team & group discussion] 2. Crucial components in	Identify table Suggested learning unit table 'Canvas' for mapping

	points: why did you select this issue? House does it relate to the science curriculum in your school? How does the community fit into this issue (creating/solving it)? If the workshop is conducted with a group of schools, include group sharing. **Crucial components of SE**: Prepare a list of important components and attributes of learning science. Try and categorize these. Then choose which component/s (or attribute/s) is/are impossible to remove [which component/s learning science cannot do without]. Conduct a discussion around this. **Generic learning unit** - Create a preliminary generic sketch of a learning unit that can be learned in your school and reflects COSMOS principals as you currently understand them (unit aims, suggested content, suggested CoP members- teachers and from community) **Partnerships** - Canvas for mapping partnerships	learning science – ~15' [as a group] 3. Preliminary unit - ~30' [school team] 4. Thinking about partnerships – 30~ [as a group]	community partners

Materials for 'Engaging school/s with COSMOS' workshop

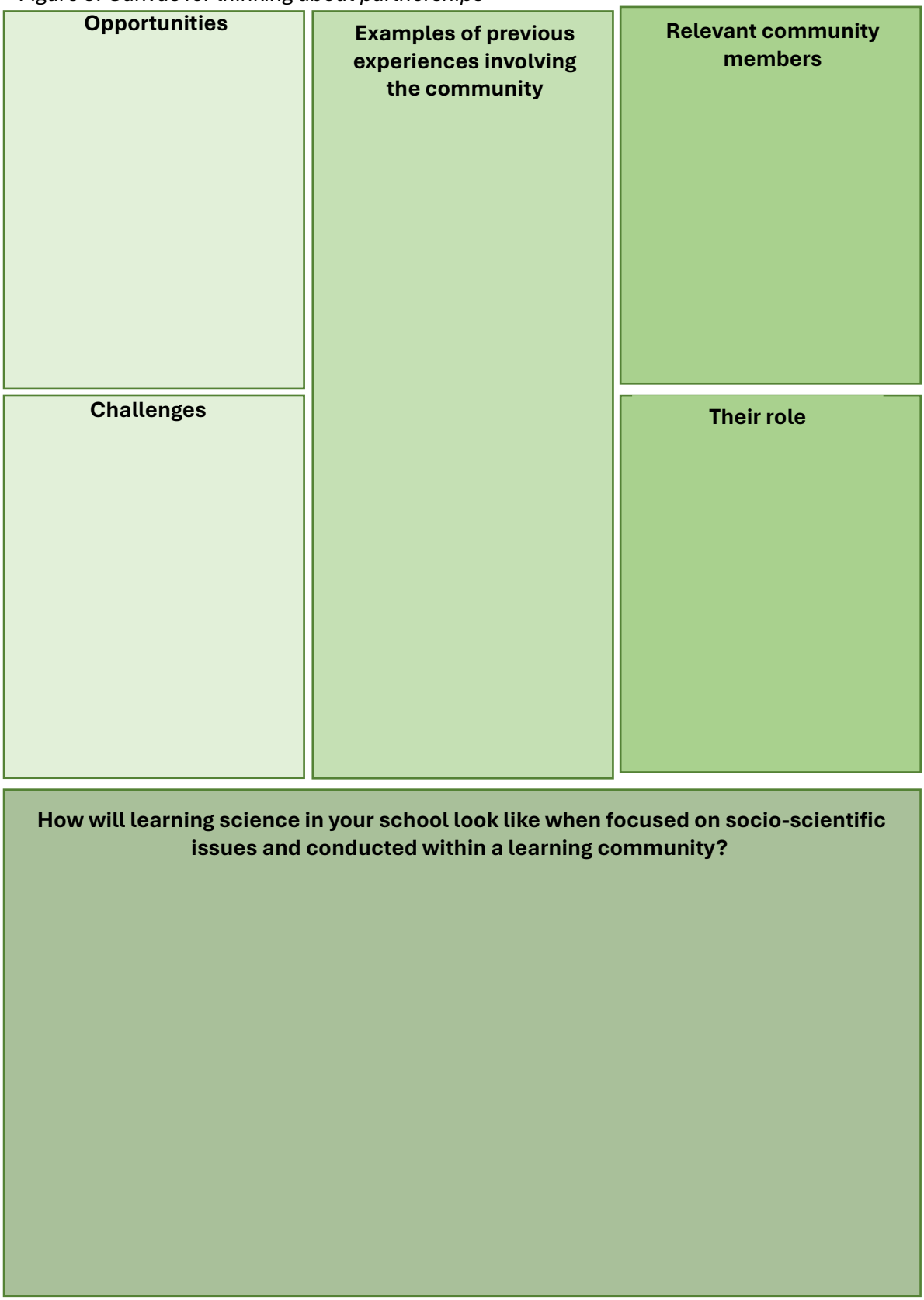
Table 3. Identify socio-scientific issue

Suggested socio-scientific issue	Reasons for selecting this issue	Connections to science content in school	Community member/s & their role regarding the issue

Table 4. Preliminary learning unit around selected socio-scientific issue

Topic of unit	Content Curriculum links	Suggested CoP members from school staff	Suggested CoP members from community

Figure 5. Canvas for thinking about partnerships



2.1.2 Identifying and characterizing the school's openness – Focus group discussion

The aim of this PD component is for the teacher team / school to assess the school openness according to the eight dimensions of school openness. The resource for conducting this component is the 'COSMOS openness assessment' manual (presentation). It is suggested to include the following component to the discussion.

Aim:

The aim of this additional component is to enhance the process of contextualizing COSMOS to the school, identify those dimensions the team sees most suitable and productive for addressing – i.e., prioritizing the attributes for practical purposes, and outlining an achievable **'horizon for change'** based on: (1) the present conditions - where we are now, (2) the future- where we aspire to get to, and (3) what needs to change. This is conducted as a discussion guided by the following points:

- Which of the eight dimensions of the school do you see feasible for changing (toward the outward mode) via your participation in COSMOS?
- Which of these dimensions correspond with the school's [formal] vision, with other projects the school is involved in or promoting, with specific challenges confronting the school community that are important to address?
- **What is our Horizon** - How do we envision the school, regarding these dimensions, at the end of the COSMOS process – where would we like to be regarding these dimensions?
- What needs to change (and can we change) in order to reach the new conditions?
- What important things/features should be kept?

2.1.3 Learning in and as a community Workshop

The purpose of this workshop is to deepen the development of a COSMOS "mindset". Participants will begin to understand what learning in and as a community is about, what are the educational benefits of learning in a CoP as well as the challenges. The workshop communicates (concretizes) the essence of a CoP as a learning community and the basic concepts of CoP to the teachers (and possible CORPOS members) participating in the project, without explicitly using these terms. This is achieved through the specific **objectives**:

- Clarify and discuss what it means to learn in and as a community
- Think about the educational importance and benefits of a community-based learning process
- Become familiar with and gain an understanding of central concepts of a Community-of-Practice: joint enterprise, shared repertoire, mutual engagement.

This workshop is based on Etienne Wenger's theory of social learning (Wenger, 2000) , which identifies **CoPs as the basic units of social learning systems**, and identifies **three basic concepts of CoPs**: *Joint enterprise*, *Mutuality/mutual engagement*, and *shared repertoire*, which, together, address how the members understand what brings them together as a community, how decisions are made, how the participants understand their roles and responsibilities in the learning community, and how they interact and negotiate their mission, roles, and responsibilities. These three elements define the **competence** of CoP.

Joint enterprise: The CoP's collective developed understanding of what their community is about; CoP members hold each other accountable to this sense of joint enterprise. **Competence** is the understanding of the enterprise well enough to be able to contribute to it.

Mutuality / mutual engagement – The norms and relationships established regarding the interactions among CoP members.

Shared Repertoire – The pool of resources that the members bring into the CoP – language, routines, sensibilities, artifacts, tools. Stories, styles, etc. To be competent is to have the access to this repertoire and to be able to use it appropriately.

The interplay of competence and experience via the member's mutual engagement is what forms the CoP. CoPs offer the opportunity to negotiate competence through the experience of direct participation. The competence of the specific CoP, which has emerged from the combination of these three elements, and defines the specific CoP, makes the CoP a social unit of learning even in the context of larger systems. Essentially, the large systems are collections of interrelated CoPs.

Suggested duration – ~ 120'.
Learning settings – Room with tables for working in small groups
Materials required: A3 or A4 paper; Different coloured paper circles; Black markers; Sticky notes.

Table 5. Outline of activities and resources for Learning in/as a community workshop (unit 2.1.3)

Part	Activities	Duration	Materials
Part One – *Joint enterprise* - What are the common goals that bring us together as a learning community	This part is two activities: Activity 1: Attributes of learning in/as a community Question: Think about what it means to learn in a community? or, what are the characteristics of learning in a community Individual engagement: Participants are given 4-6 paper squares of different colors, on which they write an attribute they perceive as an important aspect of learning in a community. They place the squares on a sheet of paper and connect them with arrows that clarify, to their understanding, relations among these attributes, components, or concepts (see Figure 6). Options: Participants explain the reasoning for their choices. Discuss similarities & differences among the different ways the participants perceive learning in a community, or they defined the attributes of learning in a community. Group sharing is not conducted now. At a later stage the participants will return to their product of this first activity. Activity 2: Common goals Questions: What brings us to work together? What do you identify as the major aims of COSMOS? Individual work: The participants write the goals on different colored sticky notes. * Collect sticky notes on a board or write the goals on the board. Group Discussion to extract and formulate common goals: Identify similar goals; Group the goals into	Activity 1: ~15-20 Activity 2: ~15-20	Different coloured sticky note; A3 papers

	categories; Provide a title for each category. Is something important missing? Have we identified a of set goals that are common to us as a professional learning community [around COSMOS]?		
Part Two – Mutual engagement- What are my motivations? What do I learn/want to learn in this community?	Questions: Why are you in the COSMOS project? What are your goals or motivations for taking part in the project? What do you aspire to gain from participating? 1 Individual work 2 Group – Share (Create a "bank" of motivations/ individual goals). Discuss individual motivations; Are there similar / different motivations? Categorize the pool of motivations into groups (for example, conceptual, instrumental, ethical, etc.)? How do these motivations relate to each other? How do they relate to the set of common goals from the previous activity?	~20- 30'	A3, A2 paper; paper circles
Part Three – Shared repertoire - Identifying shared and joint knowledge the participants bring into the COSMOS project and contribute to achieving it	Activity: The participants return to the product of the first activity. They are requested to see if, following the previous discussions and ideas that came up in these discussions (and from other participants), they would add additional attributes or change the relationships among the attributes. Alternative activity: Group: Look at the set of common goals we created as a group. Create a list of requirements for achieving these goals; group these into categories. Individual: How do you see yourself contributing to achieving these goals – what can you bring in towards achieving these goals?	~15'	

goals			
Summary – Reflecting on the workshop	Individual: The participants are requested to reflect on the workshop around the following points: What was the aim of this workshop to your understanding? What did we do in these activities? What transactions took place? What are your insights from the activities (individual and discussions) - what did you learn about the group as a learning community and yourself as a member? What challenges do identify for the group? What are your ideas for overcoming these challenges? Summary (suggest conducting explicitly after participants share their ideas): We used the knowledges, modes-of-thinking and perspectives of each of the participants, as a shared resource – a shared repertoire – to create a common understanding of our group as a learning community around COSMOS. Part 1: We defined the meaning and essence of learning in/as a community using the different understandings and perspectives each of us contributed toward defining a set common goal/s of COSMOS. Achieving these goals is our joint enterprise – what characterizes our specific [COSMOS] professional learning community. Part 2: By looking at each of our [as members of the COSMOS CoP] individual motivations and discussing the relationships among them, we began to think how we engage among - our terms/norms of Mutual engagement - as a learning community toward achieving its goals. Part 3 Further contributed to this [mutual engagement] by thinking about how each of us can contribute to fulfilling the requirement needed to achieving COSMOS aims as well as fulfilling our individual goals in this project. This pool of our contributions creates our shared repertoire – the combined knowledge, perspectives, skills, etc. of our group towards achieving our joint enterprise.	~15'	

Figure 6. COSMOS partners and facilitators in a "Train the trainer" workshop engaging in the activity of clarifying what it means to learn in a community. Top image – Selecting squares, each reflecting a different aspect / attribute / component of learning in a community. Bottom image – Connecting among the squares to clarify the relations among these aspects/attributes/components.

2.1.4 Suggested reading for Unit 1 – Understanding the COSMOS method

Mezirow, J. (1997). Transformative learning: Theory to practice. *New Directions for Adult and Continuing Education*, *1997*(74), 5–12. https://doi.org/10.1002/ace.7401.

Mezirow, J. (2003). Transformative learning as discourse. *Journal of Transformative Education*, *1*(1), 58–63. https://doi.org/10.1177/1541344603252172

Senge, P., Cambron-McCabe, N., Lucas, T., Smith, B., Dutton, J., & Kleiner, A. (2012*). Schools that Learn: A Fifth Discipline Fieldbook for Educators, Parents, and Everyone Who Cares about Education*. New York: Crown Publishing Group. Available online at: at

https://www.tnteu.ac.in/pdf/library/School_Education/7%20%20Schools%20That%20Learn_%20A%20Fifth%20Discipline%20Fieldbook%20for%20Educators,%20Parents,%20and%20Everyone%20Who%20Cares%20About%20Education%20(%20PDFDrive%20).pdf

Suggest section II (p. 92) A Primer on the five Disciplines. These include:

- *'Shared Vision*' (p. 111; see Key Questions for a Shared Vision, p.122);
- *'Balancing Advocacy and Inquiry*' (p. 136; see 'conversational recipes for cultivating skills of balancing advocacy & inquiry', p. 137; see the 'advocacy/inquiry palette', p. 139;
- *'Team learning'* (p. 149) (see 'Mind-mapping techniques/associative conceptual diagrams' p. 157; and "World Café', p. 159).
- *'Systems Thinking'* (p. 160) with suggested excersizes

Sterling, S. (2010–11). Transformative learning and sustainability: Sketching the conceptual ground. *Learning and Teaching in Higher Education*, *5*, 17–33.

Wals, A.E.J. (2007). Social learning towards a sustainable world – Principles, perspectives, and praxis. Netherlands: Wageningen Academic Publishers

Wenger, E. (2002). Communities of practice and social learning systems. *Organization*, 7, 2002. doi: 10.1177/135050840072002

Wenger, E. & Wenger-Trayner, B. (2015). Introduction to Communities of practice: A brief overview of the concept and its uses. Available at: https://www.wenger-trayner.com/wp-content/uploads/2022/06/15-06-Brief-introduction-to-communities-of-practice.pdf

Following is an annotated list of (some of) these references.

Table 6. Annotated list of references for Understanding the COSMOS method

Suggested reference	Brief look at the reference's relevance for TPD in COSMOS
Mezirow, J. (1997). Transformative learning: Theory to practice. *New Directions for Adult and Continuing Education*, *1997*(74), 5–12. https://doi.org/10.1002/ace.7401.	Mezirow looks at changing individuals' frames-of-reference (assumptions that guide belief and action) as an essential component of transformative learning. One of the two major aims of COSMOS is changing the organizational culture of the school [toward an 'openness mode']. This essentially entails a transformative learning process of the school team (as well as the CORPOS and the CoP established around the Selected SSI), which entails changing the frames-of-reference of the teachers.
Mezirow, J. (2003). Transformative learning as discourse. *Journal of Transformative Education*, *1*(1), 58–63. https://doi.org/10.1177/1541344603252172	
Sterling, S. (2010–11). Transformative learning and sustainability: Sketching the conceptual ground. *Learning and Teaching in Higher Education*, *5*, 17–33.	Stephen Sterling elaborates on Mezirow's theory of transformative learning in the context of different orders of learning (first order, second order and third order) and how they relate to change, which is the aim of transformative learning.
Wenger, E. (2002). Communities of practice and social learning systems. *Organization*, 7, 2002. doi: 10.1177/135050840072002. Wenger, E. & Wenger-Trayner, B. (2015). Introduction to Communities of practice: A brief overview of the concept and its uses.	Etienne Wenger's theory of social learning which identifies Communities of practice as the basic unit of social learning.
Senge, P., Cambron-McCabe, N., Lucas, T., Smith, B., Dutton, J., & Kleiner, A. (2012*). Schools that Learn: A Fifth Discipline Fieldbook for Educators, Parents, and Everyone Who Cares about Education*. New York: Crown Publishing Group. Suggest section II (p. 92) A Primer on the five Disciplines. These include: *'Shared Vision'* (p. 111; see Key Questions for a Shared Vision, p.122).	Peter Senge is a central thinker on organizational learning. This book (download via the link) focuses on organizational learning of schools. All of the "five disciplines" (attributes) (personal mastery, shared vision, mental models, balancing advocacy and inquiry, team learning) of learning organizations are essentially relevant to the organizational change that COSMOS aspires for. Three are directly relevant: *shared vision* complements Wenger's 'joint enterprise', *balancing advocacy and inquiry* is a complementary approach to Wenger's 'mutual engagement' as it looks at how the members negotiate and

'Balancing Advocacy and Inquiry' (p. 136; see 'conversational recipes for cultivating skills of balancing advocacy & inquiry', p. 137; see the 'advocacy/inquiry palette', p. 139. *'Team learning'* (p. 149) (see 'Mind-mapping techniques/associative conceptual diagrams' p. 157; and "World Café', p. 159). *'Systems Thinking'* (p. 160) with suggested exercises	manage their interactions, *team learning* is basic to CoPs as learning communities. The five disciplines (attributes) complement Michael Fullen's attributes of teachers as agents of change. Furthermore, Senge's theory of learning organization also addresses the role of leadership, complementing Fullan's approach to educational leadership (see ref. Or WP2 – COSMOS Frame work) The Senge et al field book offers activities and exercises for each of the disciplines (see reference to these) which can be implemented as additional TPD activities.

Unit 2 – 'Community-oriented SSIBL' pedagogy – How to select a SSI and develop a learning unit within a CoP

The second component (i.e., conceptual stage) of teachers' PD reflects the adaptation of SSIBL's three stages (ASK, FIND OUT and ACT) to the COSMOS method. This entails developing the teachers' capacities concerning the process of identifying a SSI for study and creating a CoP around this SSI for the development and implementation of a science learning unit (or units).

In COSMOS, identifying an authentic and locally relevant socio-scientific issue for study ('ASK' stage of SSIBL) is ideally conducted within a community – preferably including CORPOS members, pupils and possibly other relevant stakeholders, who, together, as a CoP, identify and frame questions. TPD entails developing teachers' capacities for leading and brokering this process. Conducting SSIBL within a CoP has the potential to enrich and deepen the three stages of the learning process, as depicted in Figure 7. CoP members bring in different perspectives to understanding a SSI, thus mapping a SSI within a CoP will enrich the questions that can be raised about the issue (ASK). The FIND OUT (inquiry) stage will be influenced by the CoP members, who contribute perspectives, content and methods for the inquiry-based learning concerning the SSI. This is expected to enrich the inquiry process and its outcomes. As a result of this, it is expected that the ACT stage will reflect a more comprehensive and multidimensional approach to addressing the various problems [aspects] that comprise the socio-scientific issue.

Unit objectives:

- Understand the rationale and three stages of SSIBL (ASK, FIND OUT, ACT), how these play out when conducted within a CoP, and the benefits of conducting SSIBL within a CoP
- Cultivate the capacities to mediate the selection of a SSI and the process of creating a community of practice around the SSI ('ASK').

Table 7. Outline of Unit 2 - Community oriented SSIBL

	Aim	**Content focus**	**Suggested duration**	**Materials**
2.1 SSIBL pedagogy	Understand the rationale and three stages of SSIBL (ASK, FIND OUT, ACT) and how these play out (are influenced) when conducted as a learning community.	Principles of SSIBL (based on PARRISE) toward inquiry-based learning in COSMOS. Overview of SSIBL pedagogy with the presentation and discussion how the three stages may be influenced when conducted as a community	1.5 hours	Overview of SSIBL pedagogy
2.2 COSMOS 'ASK'	Develop teachers' skills for leading the process of selecting a SSI and creating a CoP around it Developing brokering/mediating capacities for SSIBL ASK, FIND OUT, ACT	Selecting a SSI and creating a CoP around it - connecting the process of identifying a SSI with creating a CoP	~2 hours	Table 8 - framing a methodology for thinking with guiding and reflection questions

2.2.1 Understanding SSIBL and how conducting it within a CoP influences the three learning stages

This TPD component provides the foundations (conceptual and practical) for implementing SSIBL in the context of COSMOS.

This TPD component focuses on:

1 Understanding what comprises a socio-scientific issue and what characterize SSIs.

2 Understanding the rationale and aims of the SSIBL model (developed in the PARRISE project): ASK – selecting a relevant SSI, mapping it as a multidimensional and controversial issue, and formulating questions for investigation; FIND OUT – Inquiry-based investigation of the questions; ACT – Taking socially-responsible action on the issue based on the inquiry findings.

3 Demonstrating with the teachers (engaging them) learning activities on which SSIBL is based (e.g., mapping the controversies, the stakeholders and their positions relating to the SSI and debates that arise from these) - **scaffolding their skills to implement the process with their students**.

4 Discussing how conducting the process within a CoP influences (enriches) each of the SSIBL learning stages (see Figure 7).

The **resource** for this PD component is a **generic** power point presentation ('SSIBL pedagogy in a CoP') that introduces the SSIBL model (three learning stages), goes through the different stages, each in which it provides examples of content, some suggested activities and guiding questions supporting the teachers' capacities to guide activities, and raises discussion how conducting SSIBL within a CoP may influence each of the stages.

This is a **generic resource**. It is important that you **adapt it to your context** in terms of (1) the content, specifically the example SSIs, so they are contextually (i.e., geographically, students' age-level) relevant, (2) the teachers interests and capacities, (3) the time available for investing in this TPD component. Not all of the slides are crucial - the presentation includes enrichment slides.

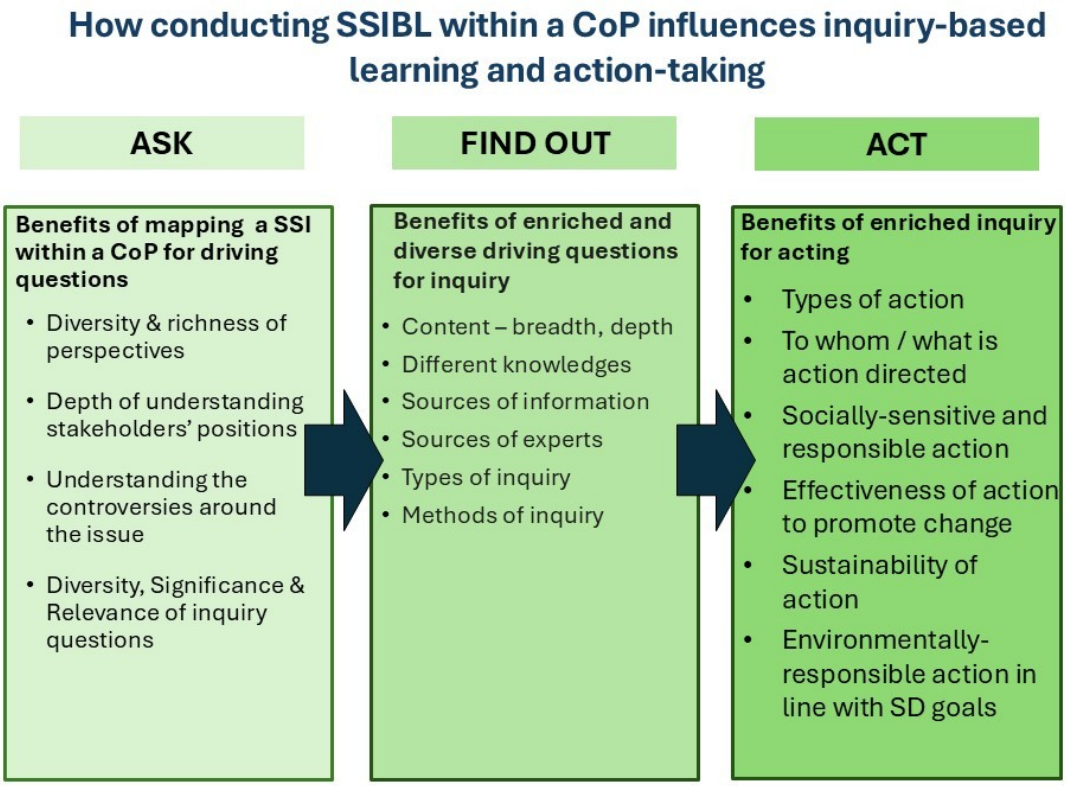


Figure 7. How conducting SSIBL within a CoP enhances the different SSIBL stages.

Figure 7 offers an outline for a guided discussion that enables teachers to critically reflect on how conducting SSIBL within a CoP contributes to the SSIBL process. This reflective discussion may be guided around the following points:

- How does mapping a SSI within a CoP enrich the diversity, depth and significance of perspectives and, hence, inquiry questions around the SSI (ASK)?
- How do the enriched and more diverse driving questions contribute to enriching inquiry (FIND OUT)?
- How does richer and more diverse inquiry, that includes scientific, social and personal inquiry, benefit meaningful action-taking (ACT)?

2.2.2 Selecting a SSI and creating a CoP around it – COSMOS ASK, FIND OUT, ACT

While this can be conducted as a distinct TPD activity, in practice selecting the SSI and creating the CoP is a component of implementation. The process of selecting a SSI and creating the CoP around it is **emergent**; there is no one "recipe" for this process. It may take different courses depending on the teachers that are involved - the ideas they raise, the different actions they may take in the process of selecting and engaging various stakeholders as a CoP.

Objective:

Scaffolding the teachers' capacities to lead and mediate/broker SSIBL within a CoP by raising awareness to various considerations in the mingled process of selecting a relevant SSI and establishing a CoP around the issue.

The following tool (see Table 8) is not a structured learning activity with the teachers but offers a generic framework of questions to be considered that support the teachers' capacities to **lead and mediate/broker** the process of SSIBL-CoP development and implementation. In the previous TPD component (section 2.1) teachers have engaged in some of these questions.

Some examples of socio-scientific issues that were used in an international COSMOS TPD workshop with teachers participating in the COSMOS project are provided in Figure 8.

An example of practical strategies for implementing SSIBL in the classroom is provided in the Classroom strategies for implementing SSIBL.

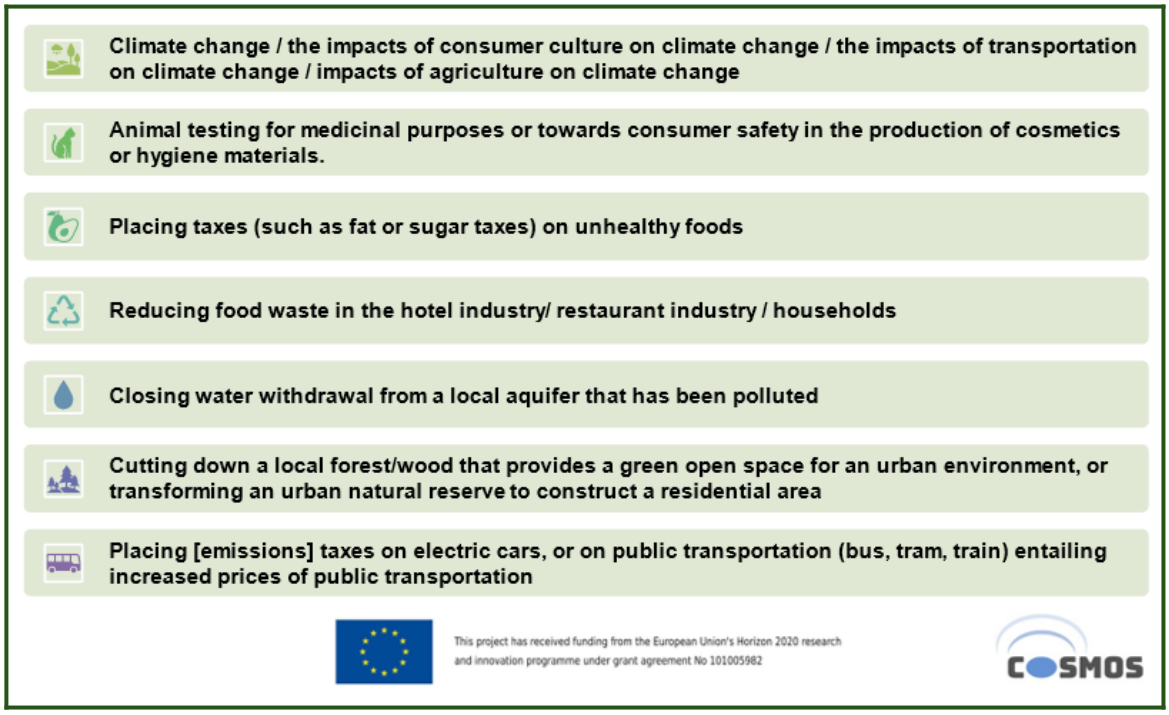


Figure 8. Some examples of socio-scientific issues

Table 8. Selecting a SSI and creating a CoP around it

Component	Guiding questions	Aspects for reflection
Selecting an authentic SSI (Part of ASK)	? What is an authentic SSI - What makes an issue authentic and socio-scientific? ? How does the process of selecting a SSI look like – is it pre-determined (e.g., by one of the teachers or a CORPOS member) or an emergent process? ? Who decides the SSI: What kinds of inputs are needed from the community, including the students (in-school and/or out-of-school) when selecting an SSI? Who can we involve in the process of selecting the SSI? ? How can I, as a teacher, involve the CORPOS in the process of selecting the SSI? Does the CORPOS decide on a general issue which is the made more accurate by CoP members? ? How can the students be involved in selecting the SSI? ? Does the process you experienced resonate with the outcome of the openness assessment and the aims that emerge from that More questions to consider?	⁎ What is important to look at when selecting an SSI? How does it relate to the science curriculum conducted in the school? ⁎ Is it important that everyone agrees on the same SSI? Should a democratic process (e.g., voting) be employed? ⁎ What should I/we do with those who do not "connect" to the issue – How do we promote their motivation to be engaged if they don't affiliate with the selected SSI? ⁎ How can I/we promote more critical attitudes regarding the social environment via the selection process? ⁎ How do I/we promote student and community member motivation for engaging in the issue? ⁎ What happens with myself/other teachers/students when the selection process is shared among community members? ⁎ What could have been done differently in the selection process that could have produced better results? More points to reflect on?
Mapping the SSI - framing it for inquiry – (Part of ASK)	? What are the different lenses to look at the selected SSI? ? What are the controversies / dilemmas involved in the SSI? Who are the stakeholders in this SSI and what are the interests of each stakeholder? What are the different / conflicting interests involved in this SSI?	⁎ How do we ensure that all the central lenses (scientific-environmental, social, economic) are taken into consideration in the framing of the SSI? ⁎ How can I mobilize the school community (to the CORPOS or other in-school and out-of-school members) to contribute to the

	? What are the various inquiry questions that this SSI raises? Which questions facilitate 'good' (meaningful) learning? More questions to consider?	mapping of the SSI (framing it for inquiry)? ⁎ What kinds of questions facilitate meaningful learning? How can we select among different questions ⁎How do I feel regarding possible lack-of-knowledge in the different lenses of this SSI? More points to reflect on?
Recruiting a CoP and identifying (mapping) its members & engaging them	? What kinds of knowledges (e.g., content, method) are needed to address the SSI? ? Who can contribute from the in-school community (other teachers, families)? How can the CORPOS contribute? ? How do I/we approach and engage out-of-school stakeholders (to be a member of the CoP) ? How can the students be engaged as active participants of the CoP? ? What knowledge can each CoP member contribute? What can each bring into the process? ? Are additional community members needed (relevant to the CoP of the learning process)? What can each bring into the learning process? ? How to engage SSI stakeholders in the learning process? ? Who is actively involved in designing the learning process? Who supports the community from the outside – as an external source of information?	⁎ What is the best way to involve members and how to facilitate the process to them? ⁎ What need be considered when approaching stakeholders? What is the best way to involve each member and how should the process be presented/explained to them? ⁎ How does the CoP members involvement effect the learning process of the other members? ⁎ Do we need additional information / stakeholders for addressing the SSI? ⁎ What are the gains and price of extending membership? ⁎ Do all the CoP members feel they are contributing to the process? Are they aware how their participation in the CoP contributes to them?

	? What is the role of each member of the community? Who does what?	
Brokering the process. This is exemplified for FIND OUT; Questions can be adapted to pertain to the ACT stage	? What do the CoP members or stakeholders need to know in order to contribute to the inquiry-based learning process? Do they know their role (contribution) and is the process clear to everyone involved? ? How to communicate the process to non-educational members / stakeholders? ? What can each CoP member contribute to the inquiry (in terms of content, methods, etc.)? What can each bring into the process? ? Is additional information (including stakeholders) needed for inquiring the inquiry questions the emerged from the SSI (and possibly during the inquiry itself)	Brokering the learning process connects to the 'FIND OUT' stage of SSIBL. In COSMOS, the aim is 'SSIBL via CoP'. Following are points for reflection regarding SSIBL via CoP: ⁎ Is the inquiry process clear to everyone? Do all community members know their role in the process? ⁎ Do all community members feel they are contributing to the inquiry-based learning process? ⁎ How to address tensions or disagreements that may arise among SSI stakeholders involved in the inquiry process? ⁎ Are they aware of how other community members contribute to them? ⁎ Are the students engaged in the process? What are the dynamics among the students and what brokering strategies need to be taken to lead to more effective and deep learning?
Additional for ACT	? How do we support students in taking action? ? What strategies do we put in place to support that the pledges for action materialize? ? Have we revisited the actions that were planned?	⁎ Do the actions being undertaken feel uncomfortable to any of the CoP members? Does their need to be consensus on the kinds of actions being taken?
Whole SSIBL process		Reflection on the whole process - See Unit 3 reflection activity (a)

2.2.3 Suggested reading for Unit 2 – Understanding SSIBL pedagogy

'COSMOS Framework'; Section 5 - What is SSIBL: key ideas and terms.

Amos, R., & Christodoulou, A. (2018). Really working scientifically: strategies for engaging students with socio-scientific inquiry-based learning (SSIBL). *School Science Review*, 100(371), 59-65

Amos, R., & Levinson, R. (2019). Socio-scientific inquiry-based learning: An approach for engaging with the 2030 Sustainable Development Goals through school science. International Journal of Development Education and Global Learning, 11(1), 29-49. DOI https://doi.org/10.18546/IJDEGL.11.1.03

Ariza, M. R., Christodoulou, A., Harskamp, M. V., Knippels, M. C. P., Kyza, E. A., Levinson, R., & Agesilaou, A. (2021). Socio-Scientific Inquiry-Based Learning as a Means toward Environmental Citizenship. *Sustainability*, *13*(20), 11509.

Christodoulou, A., & Grace, M. (2024). Becoming 'Wild Citizens': Children's Articulation of Environmental Citizenship in the Context of Biodiversity Loss. *Science & Education*, 1-29. https://doi.org/10.1007/s11191-024-00558-4

Knippels, M.C., & van Harskamp, M. (2018). An educational sequence for implementing socii-scientific inquiry-based learning (SSIBL). *School Science Review, 100*(371), 46-52.

Levinson, R., Knippels, M.C., van Dam, F., Kyza, E., Christodoulou, A., Chang-Rundgren, S.N. et al. (2017). *Science and society in education: Socio-Scientific Inquiry-Based Learning: connecting formal and informal science education* with society. http://eprints.soton.ac.uk/id/eprint/493745

Levinson, R. (2018), Introducing socio-scientific inquiry-based learning (SSIBL). *School Science Review, 100*(371), 31-35.

Suggested additional resources for TPD on SSIBL pedagogy developed in the EU PARRISE project

Outline of a workshop course for TPD sessions on SSIBL with lesson plans, for pre-service science teachers in lower secondary education, University of Southampton.

Materials for TPD on SSIBL, University of Southampton

SSIBL TPD lesson plans for in-service, upper- and lower secondary education, Universiteit Utrecht

Selected TPD resources developed and implemented with teachers during the COSMOS project (SSIBL-CoP)

Following is a selection of additional pedagogical resources that were developed by the partners during the project and used with participating teachers in the teachers' professional development sessions.

- **Practical strategies for implementing SSIBL in the classroom**
- **TPD and co-design session with primary school teachers in the UK** - This presentation was developed and used with primary school teachers in the UK. It guides teachers through several of the TPD components: revisiting the school openness wheel; thinking about what it means to learn as a community; connecting to important dimensions of learning science; walking the teachers in a practical way through the SSIBL stages.
- **TPD and co-design on biodiversity loss for primary school teachers in the UK** – This resource is similar to the previous but exemplifies implementing the TPD components in the context of the SSI of Biodiversity loss in the UK.
- **TPD2 Workshop for mutual learning around key COSMOS concepts** - This resource was used for a workshop conducted in the international teacher conference with teachers who had experienced one implementation year in the COSMOS project. The workshop focuses on three core aspects of OS in SE that were found challenging for the teachers: creating a CoP around a selected SSI, modelling the three stages of SSIBL (ASK, FIND OUT, ACT) when designed and implemented within a CoP, the role of the 'open schooling team' (CORPOS) in sustaining change to OS within the school. **These workshop guidelines are also provided as a word document.**
- **TPD2: Community engagement and socioscientific inquiry based learning** - offers another resource for guiding teachers on the core aspects of OS in SE.
- **SSIBL workplan** – This worksheet was used in the Netherlands to support secondary schoolteachers in designing their SSIBL lessons.
- **Exercise on argumentation around SSIs** – This exercise was presented to teachers in Sweden during their PD and then used by them with their students when the ACT stage of SSIBL was a debate.
- **The Alma Löv collaboration** - This special structure of work was conducted in Sweden when the schools collaborated with the Alma Löv museum and exemplifies how working around art can be part of OS in SE. It was conducted as part of the SSIBL ASK stage. The scheme outlines what is conducted with the museum staff, the school teachers, and the students.

Unit 3 – Developing Reflective Capacities concerning the COSMOS Approach

As part of the capacity-building activities regarding OS in SE, TPD actions focus on honing teachers' reflective thinking competences, particularly as these pertain to teaching and learning in and as a community. Reflection – as an activity - is embedded and promoted throughout the various TPD stages (TPD process) and should be encouraged throughout the various design and implementation stages. Reflection is specifically aimed at gaining a better understanding of the process as a whole in two main respects: (1) developing the skills and competences for designing and implementing community-oriented inquiry-based science education around SSIs (*task-reflection*); (2) developing and enhancing Open Schooling mindsets and teachers' professional identity as 'reflective practitioners' (*self-reflection*). These two aspects are entwined and mutually support each other in this unit's activities.

To promote these two PD aspects, Unit 3 offers three tools (preferably one after the other):

1 The first tool (see Table 9), elaborated in section 2.3.1 (Honing reflective capacities), offers a **generic framework** for supporting educational teams' reflective questioning activities organized according to central principles of the COSMOS method and the three main attributes of CoPs (joint enterprise, mutual engagement, shared repertoire) addressed in Unit 1.

2 The second tool, elaborated in section 2.3.2 (Assessing the school's openness post process), is a return to the openness dimensions and conducting a reflection on the movements of the school from a more inward to more outward position in these dimensions between the initiation stage and the end of implementation.

3 The third tool (Figure 9) is comprised of think points for a group discussion guiding teachers to reflect on their perspectives concerning community-based learning, OS and their benefits for science education and for education more broadly. Such reflection, by guiding the teachers to critically examine their experience from a broader perspective, contributes to the process of reframing their thinking. This critical reflection addresses the teachers' professional identity,

2.3.1 Honing reflective capacities

The following tool (Table 9) can be applied in a single "reflection" session. The suggested timeframe for this session is between 1 - 1.5 hours. This activity is aimed at teachers who directly participated in the various stages of the design and implementation of the SSIBL-CoP (SSIBL within a CoP). Having said that, the participation of others is advisable – certainly open schooling team (PLC) members, who will possibly be responsible for promoting and engaging in reflective activities during and after the project lifecycle. The sequence of reflective questions offered here are *suggestions* for dialogue and conversation and can be modified (together with educational teams) to accommodate the specific educational context. The final question in each section should be the last to be addressed.

Table 9. Framework guiding reflective questions around the central principles of the COSMOS method and the three main attributes of CoPs

COSMOS principles	**CoP attributes** (see Learning *in* and *as* a Community Workshop)	**Questions directing reflective activities with educational teams** In hindsight or after the fact:
Selecting an SSI and designing an appropriate learning process for inquiring and addressing the SSI within a community	**Joint enterprise**	• Was the SSI selected meaningful to all participants? Was the SSI sufficiently authentic: was it relevant to all learning community members? • Was the SSI a fruitful issue: one that involves various and conflicting stakeholders (namely, a wicked problem)? one that initiated meaningful questions for inquiry? • Was the SSI selected age appropriate? • How much were the partners/stakeholders involved in the SSI selecting and design process? Could the process be more fruitful if other stakeholders were involved? Conversely, was the involvement of multi stakeholders in the selection and design process useful and contributing? • What could I/we have done differently in the selection and design process to make the learning more meaningful and educating for all learners? What did I learn from this experience? • Contribute more questions
Identifying and selecting relevant partners for the CoP	**Joint enterprise**	• Throughout the stages of CoP design and implementation, what were the contributions of the 'external' stakeholders to the learning process? Could these contributions be enhanced? • How did the in-school community contribute to the process? Were teachers of other subjects involved? Did the CORPOS contribute to the process? If not, how could I/we have engaged the CORPOS?

		• Was it possible/desirable to add more stakeholders/partners to the community during the FIND OUT stage? • What could I have done differently in the partner identification and selection process to promote more rich and meaningful learning experiences? What did I learn from this experience? • Contribute more questions
Engaging in a learning process that is based on participation and shared authority	**mutual engagement**	• Was there sufficient participation by all involved in the learning process? How was the nature of participation (frequency, authenticity, level)? • Were there voices that were not heard or muted as a result of the design of the learning process? • Who was involved in decision making processes throughout the process? Were others (besides myself) part of the decision-making process? • What could I have done differently to promote more participation and engagement? How did I feel or experience my authority as a teacher in the CoP and did this experience change in any way my understanding of teacher authority or responsibility? • Contribute more questions
Mediating different points of view within the CoP	**Mutual engagement/Shared repertoire**	• How much conflict (in point of view, interests) was experienced among the partners/stakeholders? Was conflict an issue that needed more attention? How were these disagreements addressed - were the conflicts properly handled? • Were the participants able to share their ideas freely and was I able to bridge gaps in understanding, point-of-view or approaches to addressing problems that arose in the design and learning process? • Was I sufficiently attentive and sensitive to opposing views or gaps in

		understanding? Were minority views expressed and properly addressed? • What could I have done differently to promote better communication among community members and more engagement, particularly between diverse community members? What did I learn about myself as a mediator of different individuals and points of view? • Contribute more questions
Creating new knowledge as an outcome of the participation of divers community members	**Shared repertoire**	• What do the students know after learning in the CoP? How can I/we assess the knowledge that was acquired-created? • Did all the community members contribute knowledge? Did different community members contribute different types of knowledge? Was the knowledge created evenly distributed and dispersed among all community members? • Was the knowledge created appropriate for conducting the inquiry-based learning (FIND OUT)? For taking action/addressing the SSI (ACT)? • Was it possible to gain the knowledge created in 'regular' classroom activities? Did the participation of community members enable richer and more diverse types of inquiry? • What new knowledge did I acquire? What new knowledge did the community members benefit? What benefits do the community members identify for themselves from the process? • What could I have done differently to promote further knowledge? What would I do differently in future CoPs?

2.3.2 Assessing the school's openness – movement from inward to outward mode

This assessment component of PD employs the 'school openness assessment tool – post process'.

Objective:

The objective of this additional component to the teachers' points of discussion (Table 9) is to reflect on achieving the **Horizon** identified/envisioned by the team as a result of discussing openness attributes at the onset of OS in SE process, reflecting on how to improve practice, and thinking about future development. This is conducted as a critical discussion guided by the following points:

- **Realizing the Horizon** - How do we feel regarding the Horizon we envisioned at the onset of the process? In which of the dimensions is change more evident, in which- less?
- **Impact of conducting as a community of practice** - How did the process of working as a community of practice contribute to the different dimensions? What challenges did we encounter and how did we address these?
- **Strengthening the school as a community** – In what ways did the process align with the school's vision? Has it contributed to addressing specific challenges confronting the school community? Has it opened new venues for learning?
- **What is our new Horizon** regarding dimensions that were the focus of the implementation, and other dimensions? Can we identify new dimensions? What important things/features should be kept? What needs to change (and can we change) in order to reach the new conditions?

Open schooling

- How do you relate or what are your personal feelings, as an educator, to the idea of 'open schooling'?
- What can 'open schooling' contribute to your school? to the community?

Learning in/as a community

- What does it mean to you to learn in/as a community? In what ways is learning in a community different or similar to teamwork?
- What do you identify as the aims of learning in/as a community? What do teachers need, or need to know, to initiate and lead a community of learners?
- How does learning in/as a community implicate your individual perception of the teaching profession?

Context of science education

- How does learning in/as a community (CoP) influence your perspective (and approach) as a science educator to teaching science?
- In what ways does the involvement of non-science teachers contribute teaching science? to your perspective of science education?
- How does the COSMOS approach promote quality science education? What change/s can you pinpoint in the science classes in school? In the students' learning experience and outcomes?
- Those of you who are not science teachers: How do these questions relate to your subject (or role in the school)? How can your role / subject contribute to meaningful and quality science education?

Figure 9. Guiding points for reflective group discussion on open schooling and community-based learning in the context of science education.

Section 3 - Adapting TPD for different contexts

This section focuses on the how to adapt TPD on OS in SE for different school contexts. Based on the insights obtained from analysis of TPD implementation in six different countries and 24 school contexts, it offers a practical view of different factors/aspects that should be taken into consideration when designing and implementing TPD for applying OS in SE, such that that the TPD process will be most effective within the given set of educational circumstances or settings. Different factors may serve to support the process of TPD or stand as obstacles to enabling an effective TPD process. **It is important to be conscious of the different factors and how they might influence TPD in the given circumstances, so as to either build on those that support and serve to enhance effective TPD and avoid those factors that may inhibit the TPD process**.

The analysis of the TPD implementations is grounded in the identification of two sets of conditions and factors that influence teacher professional learning: *Macro societal conditions* and *Micro-context conditions* (Avalos, 2011[3]). Briefly, *macro conditions* refer to the nature or and the way educational systems work, the nature of policy environments and reform, teachers' working conditions, and also historic and cultural factors regarding what may be suitable or not suitable models of PD. *Micro conditions* refer to school cultures – the administrative and organizational structures and how these institutional arrangements interact to either support and facilitate or hinder options for teachers' learning in their workplace. To these two sets of influencing conditions, we've added a third group/category of factors related specifically to the teachers, such as the individual teacher's needs or objectives, their incoming familiarity and capacities concerning the content domain and pedagogical skills, or their previous experience in collective learning.

The following presents an outline of different factors, organized in the three high-order groups/categories (macro conditions, micro conditions and teacher-level, see Figure 10) and then provides examples of how the different factors influenced conducting COSMOS OS in SE TPD (including the co-design and implementation of SSIBL-CoP) in the six different countries and 24 different school contexts.

- It is important to keep in mind that the different factors do not work in isolation but rather there are interrelations among them, thus the circumstances of a given school are the outcome of the interplay among several factors from different categories.
- Several of the factors, specifically school organizational and teacher-level, correspond with 'school openness' dimensions. Thus, identifying potential influential factors can be integrated within the discussions regarding school openness dimensions.
- The experience from conducting COSMOS OS in SE TPD indicates that school level (primary/ secondary) was not a significant factor that influenced how TPD was conducted.

[3] Avalos, B. (2011). Teacher professional development in *Teaching and Teacher Education* over ten years. *Teaching and Teacher Education, 27*, 10-20.

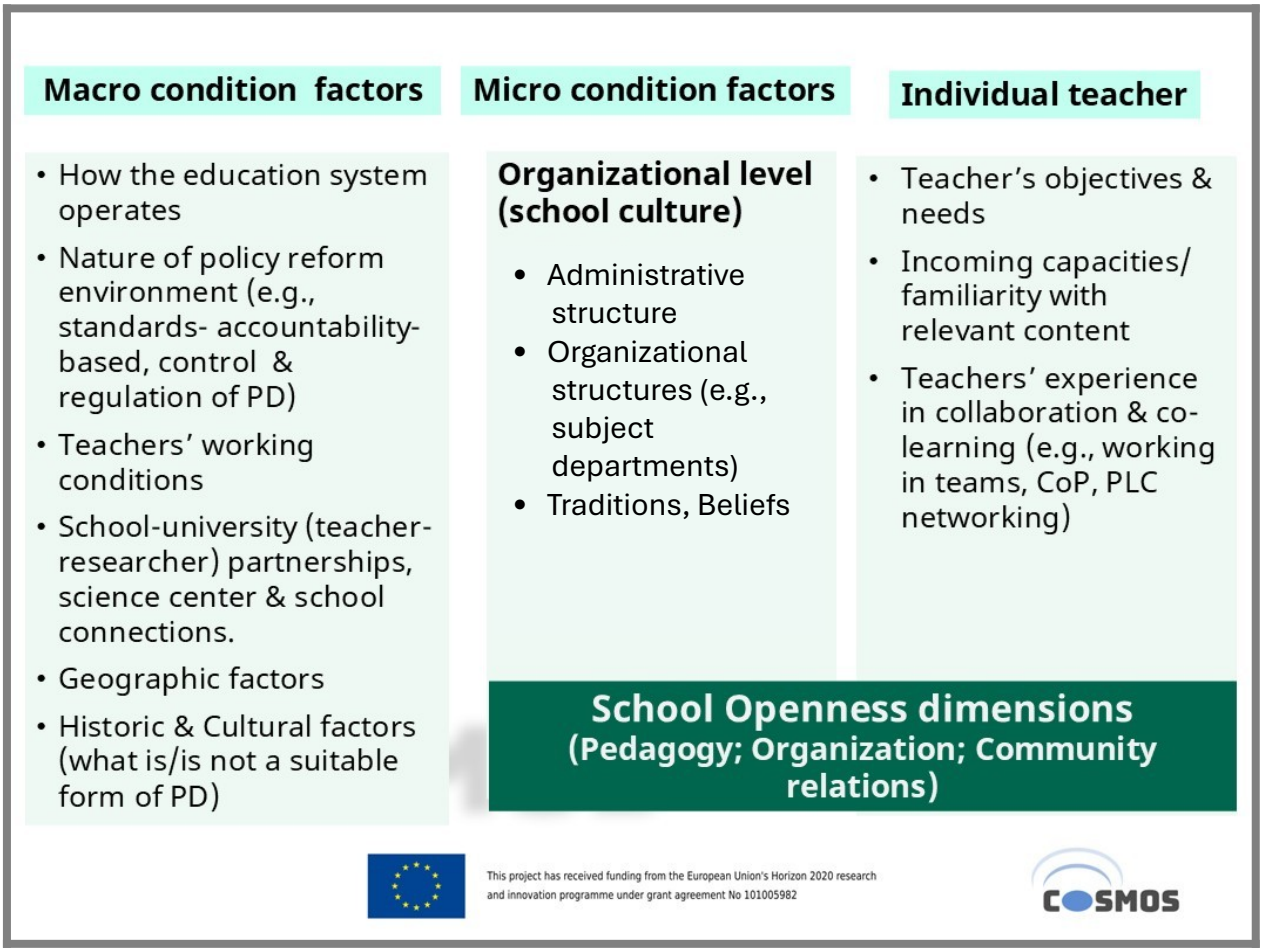


Figure 10. Outline of factors and conditions that influence teacher professional development (adapted in part from Avalos, 2011)

Macro Condition Factors

How the education system works – The governance of compulsory education and schools by a national curriculum, and the extent to which the curriculum is open to changes, initiatives and curricular discretion of the teachers or to collaborations between the school and out-of-school organizations is a crucial factor that impacts TPD in terms of both the opportunity for TPD and its focus. For instance, in **Sweden**, while compulsory school is governed by a national curriculum, which teachers read and follow quite rigorously, the curriculum is open to interdisciplinary collaboration and collaboration with societal partners. This contributes to making teachers positive to participation in TPD. In this case, despite the school curriculum being controlled by a national curriculum, this curriculum does offer some flexibility in leaving room for teachers' initiative. This circumstance is such that supports opportunities for TPD. Conversely, In **the United Kingdom**, "the school regulator (OFSTED, Office for Standards in Education, Children's Services and Skills) was identified as a barrier to teachers' innovation and stepping outside the box in science education as well as in other subject areas. OFSTED inspectors expect to see uniformity across classes and teachers in a school (e.g., in how learning objectives are introduced, on the way materials and presentations are used by the teachers, questions asked and assignment tasks). The drive for consistency within a school imposed by OFSTED imposes a challenge that teachers need to overcome. This restrains creativity and imposes ways of doing things that are not necessarily consistent with the teacher's own style of teaching, perspectives on pedagogy, etc. This impacted TPD by limiting to some extent how much SSIBL-CoP implementations could vary from 'normal school practices' and limited the capacity for openness – if the system imposes an inwards/consistent/uniform approach, then schools cannot take measures needed across openness dimensions to move outwards.

These two exemplar situations concerning the macro condition factor 'How the education system works' demonstrate a rigid national system and a national system which offers more flexibility and how these two different circumstances challenge or support TPD. In the **Netherlands**, "national exams prohibit the time teachers can and are willing to spend on pedagogies, such as SSIBL, that are less content related to learning goals".

Nature of policy reform environment (e.g., standards-, accountability- based, control & regulation of PD) - The previous **UK** example also reflects a situation concerning the 'nature of policy reform environment' by which the school regulator's emphasis on uniformity is a barrier to change – to innovation and stepping 'outside the box' such as moving outwards toward more school openness, and there is more regulation of teachers' PD. Conversely, in **Israel**, the policy reform environment of the Ministry of Education (MoE), at both national and regional levels, is such that promotes change process initiatives of schools. At the national level, the MoE has a Department for Research and Development, Experiments and Initiatives, that is specifically dedicated to educational innovation and reform such as OS in SE and beyond. At both the national and regional level, the MoE provides financial support as well as formal accreditation for teacher's PD. Such conditions concerning the 'Nature of policy reform environment' are conducive to TPD in two crucial aspects: (1) dedicating school hours to TPD supports conducting constructed TPD programs; (2) additionally, dedicating school hours in the school schedule as well as formally accrediting teachers for PD contribute to the teachers' willingness to participate

in TPD. Teachers' motivation for PD is further supported by the MoE's openness to educational reform processes.

Teacher's working conditions – In many instances, teachers' working conditions in terms of time constraints came up as a difficult issue challenging TPD. For example, In the **Netherlands**, teachers felt "like they have to work on the COSMOS project outside of their normal working hours." In order to make the teachers' participation in OS in SE part of their 'normal workweek', it was decided that participating in such a project would entail conducting a meeting with the schoolboard in which not only the aims of the project are addressed but also "how to incorporate it within the planning of the school year of the participating teachers". The Netherlands case provides one example how to respond to the constraint of time as part of the 'teachers' working conditions'. Another example of the role of 'teachers' working conditions', in **Portugal**, a teachers' and school-workers' strike demonstrate how the 'teachers' working conditions' can hinder opportunity for TPD. The teachers' careers and salaries had been frozen for seven years with the government's promise to compensate them when financial conditions improved. After this period, despite better financial conditions, the government refused to compensate them, meaning that they would reach retirement with a big salary cut. This led to a situation in which teachers in many schools refused to participate in extra projects, hindering the opportunity for extensive TPD. This situation was coped with by flexibility in the design of the TPD process.

School-university (teacher-researcher) partnerships, science-centre & school connections – Partnerships between schools and institutions of higher education – between educational practitioners and educational researchers - as well as between schools and science centres, offer valuable opportunities for TPD and improving science teaching. This is nicely demonstrated in **Portugal** where a culture of strong relations exists between the University of Lisbon Institute of Education and school teacher teams ('*clusters*', described further on). A long-term and sustainable (14 year) CoP had been established between this university institute and teachers, some of whom also took Master and/or PhD degrees at the university institute around students' and teachers' activism via collective and democratic problem-solving processes concerning socio-scientific issues or socio-environmental problems affecting their communities. This strong pre-existing collaboration and shared culture (interest) centred on students' and teachers' inquiry and activism initiatives provided a strong platform for the OS in SE COSMOS initiative. This was further supported by the Ciência Viva Interactive Science and Technology Museum that supported a 'Science Club' aimed at developing collaborative projects among students, teachers, scientists, science-centre members, parents and other community members. The unique Portuguese case serves as an example of the important role school-university and school-science centre partnerships can play towards professional development of teachers. This strong existing CoP (partnership) also provided a buffer to the previously described teachers' strike, in that it enabled to conduct TPD in a more condensed manner building on their existing background in activism initiatives and projects.

Geographic factors/conditions – Local geographic conditions can also influence TPD around innovation projects such as OS in SE. For example, in **Sweden**, a major challenge was not the TPD but rather putting together a CoP, resulting from the situation that in rural, sparsely populated areas where schools are located in small municipalities, there are few community stakeholders such as companies or organizations with which to create CoP. In contrast, one of the participating

schools in **Belgium** is located in the center of a large city, near a park. These conditions offered inspiring settings from which to choose a SSI, leading to many collaborations in the proximity of the school for exploring the SSI and taking action.

Micro Condition Factors – Organizational level (school organizational culture)

Several aspects of the school's organizational culture, that also reflect some dimensions of school openness (most specifically, the dimension of *inner-school communities* within the *organization* category and *learning communities* within the *pedagogy* category) strongly influence TPD and should be considered when planning TPD. School organizational culture refers to the administrative and organizational structures or arrangements, how they operate and how these interact to either facilitate or restrain TPD and teachers' growth in their workplace. Several of these came up in the different educational contexts of COSMOS OS in SE.

Organizational structures – The existence of built-in structures, such as subject departments or embedded teacher teams or networks that function as communities-of-learning, influence the school's culture of teachers' co-learning and engagement in pedagogical development. For example, in **Portugal**, the schools worked in *clusters* – "groups of schools from different levels of education (primary, secondary) that function under the same directive board and develop a common educational project they consider adequate for their social and cultural reality". The fact that schools work in organized clusters provides a context in which internal collaboration is facilitated. Furthermore, these clusters worked in affiliation with the Ciência Viva science centre (school – science centre connections, see above) and in collaboration with the Lisbon University Education Institute (school – university partnerships, see above), further strengthening the CoP around TPD. The Portuguese example demonstrates a productive interplay among school – university – science centre (macro condition factors) and school organizational culture (micro condition factor) that is supportive of teacher pedagogical development around innovative educational reform such as OS in SE. In **Israel**, at the school organizational level, the existence of subject teams provides built-in learning communities, creating a suitable context for collaborative teacher learning. Furthermore, the ***school culture*** (i.e., tradition) of *shared governance* (see Figure 1 school openness dimensions) promoted by the school principal proved significant in facilitating change processes such as the OS in SE project including the motivation and resources (e.g., time) for TPD. The attitude of the school leadership (i.e., principal) also came up in other contexts, such as **Sweden**, as a significant organizational factor that effects how teachers are supported in allocating them time for PD. The **United Kingdom** demonstrates a different model of school organizational conditions that influences opportunities for TPD. The school organizational and leadership model in the UK context for primary schools is such that the leadership assigns teachers who are responsible, as subject leaders, for a subject area. While the school leadership may be supportive of change processes such as OS in SE, including developing the teachers' competencies for this, in practice realizing this in both primary and secondary schools is largely dependent on the availability and readiness of the individual teachers, with support or approval by the headteachers. This UK condition also demonstrates the influence of 'school administration'.

School Administration – Situations related to school administration, such as the **UK** example presented above, or the involvement of school administration in other administrative change processes can influence options for teacher workplace learning. For example, in the **Netherlands**, changes on a higher level, by the school board, in the school programs, specifically implementing a new school curriculum, limited the availability for TPD. While this example of the Netherlands reflects the impact of a macro conditions (national curriculum), it also demonstrates how a macro condition filters down to the level of school administration (connection between macro- and micro conditions).

In **Sweden**, a process of change in one of the primary school's ownership created a situation of teachers' uncertainty regarding the future, specifically regarding school leadership. In **Israel**, as well, one of the participating primary schools was in a process of merging with another [primary] school, a situation which required meticulous planning of the teachers' availability for additional parallel change processes. These examples demonstrate that when entering TPD processes, it is important to take into consideration how involvement of the school administration and teaching staff in other major administrative processes may impact their availability for TPD.

Individual Teacher Level

Understanding how the teachers work together and share practices (i.e., Teacher's experience in collaboration & co-learning), what are their specific needs and objectives, as well as their incoming familiarity and competencies with relevant content and pedagogical skills are crucial for TPD and, therefore, important aspects to consider in the planning of TPD around OS in SE.

For example, in **Portugal**, previous experience of some of the teachers with a similar approach of "implementing activism initiatives based on inquiry-based science approach" facilitated their understanding of the COSMOS OS in SE approach. In the **Netherlands**, contact was made with a teacher who had previous experience in projects that involved various community stakeholders and had interest in bringing in the concept of OS around socio-scientific issues. Similarly, in the **United Kingdom**, the lead teachers in all the participating schools had a special interest in science education, open schooling and/or research, which provided additional motivation to engage in the process. These examples indicate the value of capitalizing on teachers' previous experience in relevant pedagogical initiatives.

Alternatively, in another school in the **Netherlands**, the teachers struggled in grasping the concept of socio-scientific issues and the stages of SSIBL pedagogy, thus more time and emphasis was required to develop the teachers' competences in these core concepts of COSMOS OS in SE. In **Israel**, as well, the teachers' incoming foundations regarding learning in/as a community and inquiry-based learning according to the SSIBL pedagogy were significant in impacting how TPD played out and required creating an understanding of these concepts and how to translate them into practice in school. Likewise, in **Belgium**, the influence of the participating teachers on how TPD played out was substantial. In one school setting, the teachers' interest and objective was how to put emphasis on involving the environment in the project, as well as concrete ways of working with the students in a more socially oriented way. Conversely, in another school, the teachers had no experience with teaching science, so the

emphasis shifted to translating government-imposed attainment goals towards working with the students.

Overall, in relation to influencing factors concerning the individual teacher's level, the experience gained from implementing TPD on OS in SE with 39 teacher teams from 24 different schools in six countries, indicates the importance of meticulously addressing the core COSMOS concepts/components:

- Discussing the potential SSI and mapping it (both in content and in stakeholders),
- Identifying and recruiting CoP members and engaging them in the TPD. This also leads to their meaningful involvement in the co-design and implementation of the inquiry-based learning units.
- More deeply addressing the three stages of SSIBL (ASK, FIND OUT, ACT).

Experience indicates the importance of deepening the teachers' competencies in these skills. This leads to creating more diverse CoPs around the SSI, and a more significant SSIBL-CoP process.

Section 4 – Reflections on opportunities that TPD on OS in SE creates

This final section looks key success factors for TPD and illustrates opportunities COSMOS TPD creates for the teachers, the school and community. This section also opens a window to 'The teachers' voice' with a selection of quotes provided by teachers who participated in the COSMOS project, communicating their personal reflections about how their experience in COSMOS, via its professional development, has influenced their teaching in science education, professional identity as science educators and perspectives of open schooling in science education and as a broader educational approach.

Key Success Factors for conducting TPD on OS in SE

Following are [evidence-based] insights for conducting TPD on OS in SE based on the COSMOS approach, grounded in the experience gained from implementing TPD with 39 teacher teams, from 24 different school in six countries:

- **Cooperation and mutual learning in a professional learning community** – Peer professional learning is a crucial component. The collaborative environment fostered by creating a CoP enriches teachers' opportunities for PD, including sharing knowledge and mutually reflecting. It enriches and improves their teaching methods, leads to adopting more innovative and constructive teaching methods and bringing current and relevant topics into the curriculum, and contributes to honing their capacity as reflective practitioners. Additionally, CoPs contribute [to TPD] to developing teachers' community engagement strategies, and equipping teachers with skills to facilitate open schooling models.
- **Pedagogical relevance** (for teachers and students) - The shift from traditional teacher-centered lecture-based methods to more inquiry-based and student-centered learning was highlighted by teachers as a significant benefit. Not only did the teachers benefit from enriching their teaching practices but their students as well. Learning was more engaging for the students, leading to increased student interest and motivation to learn, which, in turn, led to improved learning achievements.
- **Value of relevant real-world issues and involving external community members** – The practical focus on locally-relevant SSIs and topics that are relevant to the students' everyday lives, combined with the involvement of local authorities and bringing community members into the classroom is valuable not only for adding real-world relevance to TPD, but also in terms of how science is presented to children, how different perspectives become part of science lessons and provide the students with a broader perspective on real-world issues. This, combined with the pedagogical relevance contributes to enhancing students' interest and motivation to learn, and led to improved learning attainments.

- **Context-specific TPD** - Context-specific PD that is deeply integrated with the implementation of innovative educational practices like learning in/as a community, SSIBL and OS as a broader educational approach, is important. This implies working in accordance with the school culture. The school openness wheel provides an effective tool for the teachers to critically examine their school culture in terms of openness dimensions and determine the goals to address in line with the school culture. The implication for TPD is the importance of employing this tool throughout the process of TPD (and implementation of SSIBL-CoP learning units) – at the onset for identifying goals, during – for formative assessment of change and deep reflective discourse, and post – to enhance an iterative and action research approach.
- **School leadership** – The school principal has a central role in setting a productive climate for TPD, by facilitating teachers' positive attitudes towards TPD and actively supporting and participating in TPD.
- **School organizational culture** – A pre-existing collaborative organizational culture provides a strong foundation for learning and working collaboratively with both internal and external stakeholders.

Opportunities COSMOS TPD creates for the school, teachers, students and broader community

This closing section reveals some overall reflections provided by the participants from the different countries on the COSMOS TPD experience and its impacts. Reflections of the partners who led and facilitated the process are accompanied by quotes from the teachers concerning the impacts of their experience, contributing to the handbook 'the teachers' voice'. Importantly, when teachers reflect on the impacts of their participation in the COSMOS project, their experience in professional development and experience in engaging in the process of design and implementation of learning units cannot be separated. The co-design and implementation of these lessons are a part of the TPD process. **Teachers' participation in COSMOS OS in SE comprises a holistic experience of a well-integrated process of learning and doing. It is this holistic process that had impact**; attempt to strictly differentiate the impact of the PD from that of developing and implementing the OS in SE educational interventions does not reflect the reality of the teachers' experience in the COSMOS project.

Belgium - The TPD worked to **suit the needs of very different schools and teacher teams**. For some schools, whose teachers had little experience in science education, the learning curve was greater in the didactics in science education than in connecting to the school environment. For other schools that already had a pioneering role in science education, the learning gain resided more in the different components of the COSMOS process: focusing on the more outward oriented dimensions of school openness, working on structural collaborations with people and organizations from the school environment, combining different types of inquiry- scientific, social, personal.

A teacher noted on the impact of her experience in the SSIBL pedagogy on her practice as a science teacher, "*I certainly see the value of this [SSIBL didactics] when working out a scientific project. It gives me guidance on how to build such a project*". [B2D2] Another teacher took this to the school level, identifying the value of more systematically embedding SSIBL within the school in STEM education,

"[...] *If that remains a singularity in the third year in STEM, then that's not going to have much body. But, if we can get the whole SSIBL method broader within the school, I think that's going to have a lot more body and then also the research centers in the higher grade might be able to benefit from that*". [B2C2]

For Belgium teachers, the international teacher conference was a pivotal moment in their PD by providing the opportunity for peer-to-peer exchange among schools, "*I did want to say that I really liked the feedback from Prague*" [B2C2]; "[...] *that first day in Prague was super fascinating for me to discuss SSIBL with other colleagues in Europe, which made it clearer to us how the other schools implemented it and how we did it*" [B2C2]. This value of engaging with peers for developing their understanding of OS in SE, that is enabled in a professional learning community which includes teachers from different schools, is clearly articulated by another teacher,

"*During the training* [in Prague] *we were given examples. There's a school that did something about volcanoes and they looked into how to better prepare for earthquakes, there's a school that did something around meals at school. Only then did we understand: Aah, that's what the project can look like and that's what it is supposed to look like*" [B2D2].

The following teacher's statement underscores their overall sense of achievement and success in the COSMOS OS in SE initiative:

"I do think we have achieved the COSMOS goal tremendously. That is, ***to link science to society*** *within our target group, with our students. I think we did achieve that enormously and that we did struggle a little bit there. That, really, all those students do realize that certain things that we choose in society, that can be explained scientifically, but in the long run can also bring us positive things. I think we definitely achieved that with our students*" [B2A2]

Israel –The COSMOS approach, especially via its TPD, created opportunities and offered benefits for many aspects of the school, and these were identified differently by the teams in different schools. A stated by the principal in a participating secondary school,

"*The conceptualization you brought in has helped us understand what we are doing and not doing, and what we want to do. The work on this project has made me, as a school leader, view other projects we are involved in from a broader perspective. For example, we are trying to promote students to be active partners in the planning and teaching of the syllabus of an interdisciplinary subject. COSMOS has helped us understand that this approach is very right. Despite all the complexities, this is the right thing [...] we cannot be disconnected from the children, the parents or our partners. This includes the teachers' room*" [I2E2].

The science education coordinator in this school noted the challenge of entering a learning process such as COSMOS, in which you know the starting point but not the end point, "*the uncertainty is challenging but it was fascinating to experience a project in which decisions are made during the project and I gained confidence in this*"[I2E2].

While this science coordinator is expressing how her experience has changed her perspective with regard to how science education can be implemented in school, the principal is expressing how the school's experience in COSMOS has reinforced his perspective with regard to the approach to creating a learning environment and learning experiences, beyond science education, that are significant for their students, their families and community.

Peer learning, inherent to COSMOS TPD, was central in enriching the teachers' repertoire of teaching approaches,

"*Peer professional learning was a central element. The principal and teachers from the first year assisted new teachers to develop professionally. The project developed science education in the school, producing new and innovative ways to learn and teach science, particularly with a community of stakeholders. The continuity of the project was also a factor in its success*" [I2C2].

Enhanced student-centered learning and social learning, in turn, generated students' interest and enthusiasm and encouraged them to act and have impact on their environment – to express their opinion, organize and act for change as responsible citizens by choice, which had a positive "spill over" into families and the community. The COSMOS project, via its TPD, was significant in "[...] *creating collaboration among students, teachers, school management, the CORPOS and CoP towards creating rich and meaningful learning units that focused on developing citizenship and community capacities – the students' capacities to be responsible citizens and have positive influence on their environment by choice*" [I2D2]. Together, these contributed to an enhanced sense of community: increased awareness and involvement of all the community - students, parents and residents working together toward a mutual goal, and creating a strong sense of community around the project. As expressed by the principal of the Lapid elementary school:

"Establishing the learning community in the framework of the project had significant impact on different aspects of the school system and the broader community [...] The learning community established around this project had a significant impact on all aspects of the school's system and community. School openness increased, the teachers had an opportunity for PD, the students became more involved and responsible, and the community partners came to understand the importance of social-environmental involvement. ***Together, these created a strong sense of community around the project, contributed to creating a stronger and more unified community, that is prepared to address future challenges more efficiently and meaningfully***."[I2D2]

This expresses the significant impact of TPD on the teachers' professional identity, particularly in terms of their role as *'community educators'*. The focus on learning as a community and OS in SE helped the teachers see themselves as **facilitators of community-based learning**.

The Netherlands – TPD provided teachers with time and opportunities to reflect on their own lessons and goals and those of other teachers. As expressed by teachers,

"[...] *I really enjoyed having time, or actually being forced to have time, because at the delusion of the day, it's just hard to really sit down and then think very specifically about your own lessons [...]*" (T2). "[...] *I still liked the fact that we got together every now and then to give feedback on each other's thing [lesson plans]*" (T3) [N2B2].

At the end of the process, the teachers were self-confident in reaching the SSIBL-CoP goals they had set without the help of the COSMOS project members. As expressed by a teacher,

"*We set up three very different projects, [...]. Since I had the same working method [SSIBL approach], and some variation in it for my lessons,* ***I am now well experienced in that. So now, should there be a topic in the future, I can work on that myself to develop another beautiful lesson as well***" (N2B2).

Teachers at both schools, including the new teachers, successfully implemented the SSIBL-CoP approach. These science teachers especially appreciated the social and engagement aspects that SSIBL brings in to learning science, such as students doing social inquiry and the ACT phase. A teacher commented on this,

"*Well, look at the ACT phase, I find that very interesting because I think students feel so little ownership of the world, little influence, and it's really nice to do something that they can actually make something and possibly change something in the world [...] I really like that, because that is something we don't think about very often while it is very important*" (N2A2).

This teacher went on to emphasize this contribution of social inquiry that SSIBL offers for STEM education,

"*Social science research, so doing something where students actually go out and interact with people [...] I personally notice with many students that STEM education is something a bit of a distant concept because they don't really see how it affects them yet. [...] so I notice with students that it's harder for them to see how they have an impact and what they do affects them. And I think that with social research like this, you're going to hit that, I Hope, I think"* [N2A2].

Along this vein, the coordinating science teacher in a secondary school commented,

"*The inclusion of social inquiry (humanities) in science education, and ACT phase that shows the students the relationship with their everyday lives, and the impact they can have, and SSIBL pedagogy is the way I learned it*".[N2B2]

These teachers' reflections highlight the contribution of connecting among science education, socio-scientific issues and OS, and the role of SSIBL as an effective method for achieving this. In one school, it took two rounds to fully grasp and implement all aspects of the SSIBL-CoP approach. Crucial aspects were finding time and opportunity to develop lessons, implement projects outside the regular school schedule, and setting up sustainable relations with stakeholders. The TPD sessions **motivated them to keep working on citizenship aspects in science education in daily practice and provided them with a pedagogy to actually put it into a really good, responsible form**.

Portugal - The COSMOS project, through its TPD, achieved a well-rounded and impactful educational experience for both students and teachers. The initiatives undertaken were effective in **bridging theoretical knowledge with practical applications**, making learning more engaging and relevant. The shift towards inquiry-based learning and student-centered approaches marked a significant departure from traditional teaching methods, enriching the educational landscape. The collaborative environment cultivated within this project encouraged the exchange of teaching strategies and innovative approaches. The project not only fostered professional growth among teachers but also fostered in the students a sense of responsible citizenship, empowering them to take an active role in their education and community and towards improving their environment. The teachers accentuated the significant benefits of the **collaborative approach** of OS in SE for them and for their students:

"*The collaborative environment fostered by COSMOS has allowed us to exchange teaching strategies and explore innovative approaches. Moving away from traditional lecture-based methods to more inquiry-based, student-centered learning. This shift not only makes lessons more engaging for students, but it has also* ***enriched my own teaching practices in ways I hadn't anticipated***" [P2A2].

"[...] this experience highlighted the need for stronger community involvement and for real world issues to be part of our curriculum. When students work on topics that directly impact their lives, they're more invested and motivated. Partnerships with local entities were vital. They provided resources and made the learning experience more engaging. Including external experts and environmental groups offered our students firsthand insights into sustainability, ***showing the power of strong community ties in enhancing educational projects***" [P2B2].

A teacher commented on the value of engaging and collaborating with peers beyond the scope of one's school cluster or country,

"*Reflecting on our experiences, I can say that the meeting in Prague [International COSMSOS TPD conference] was incredibly effective in helping me and my colleagues develop our skills with the COSMOS approach and gain a better understanding of conducting SSIBL-CoP [...] we had a valuable opportunity to connect and collaborate with colleagues from Portugal and other countries. This interaction allowed us to select a common SSI for both our school clusters, which was a significant step in our work*." [P2A2]

The collective desire and enthusiasm of the participating teachers to "*innovate and try new methodologies in our classrooms*" was a significant factor that helped them overcome challenges that faced TPD, like time constraints and work overload. Despite these challenges, the project successfully **promoted a culture of collaboration, innovation, and sustainability** within the participating schools. The collective efforts and the enthusiasm demonstrated by all participants reflect a positive overall balance, highlighting the project's success in fostering a more open and engaged school community.

Sweden - A strength was the teachers' interest and engagement, willingness to develop and learn more about **how to make SE more interesting and motivating for their students**. The TPD served as an **eye-opener** for the teachers of new

possibilities to collaborate with the Higher Education Institutions and societal partners, but also with other organizations. A teacher reflected on how the COSMOS approach to OS in SE aligns with her approach to teaching science, "*This way of working [SSIBL-CoP] is really in line with the way I work and how I want to work. The challenge is mostly to find partners for collaboration*" [S2]. Another teacher reflected on the opportunity for mutual learning provided in the international COSMOS teacher conference, "*The TPD in Prague [international COSMOS teacher conference] was especially good, because there were many teachers from different countries, and it was great to share ideas and experiences from more people than only from my own school*" [S2]. This teacher's reflection underscores the desirability of a diverse professional learning community that includes teachers from different schools, as it enables exposure and enrichment of diverse perspectives and ideas, fresh insights and reinforces motivation.

UK –The TPD exposed teachers to a **different way of thinking about their science curriculum**. This is in relation to two key points: (a) how they can make their **science provision more personally relevant to the children, in a way that then motivates them to be more active learners and have more autonomy** and (b) how they can **incorporate action** as part of what they do for science education, which they identify as important but missing from their curricula. One teacher commented on the experience of taking part in the COSMOS project,

"*it's made me re-evaluate my teaching to think is there a way I can teach the curriculum in a more engaging manner and try and related it mote to real life and get students thinking for themselves a bit more, which is what they need*" [secondary school teacher, round 2].

The teachers also noted the impact on them in terms of their confidence in trying out different ways of working and courage to pursue collaborations with external stakeholders and the community, as there is a mutual benefit from this collaboration. Stated by teachers

"*I think it's been great for me as a new teacher. To know that there's that flex, like T3's alluded to, you know, that flex to do something different. And you know, it's allowed me to build my confidence and maybe I don't need to do it exactly that way. I could do it in a different way. SO, I think that was quite, you know, interesting for me from that point of view*" [Year 3 teacher, school 3].

"*I think knowing that we can be a bit brave, and trying out new things, also understanding how to approach community collaborations, e.g., stakeholders have also to gain from this collaboration, and so teachers should not hesitate to reach out*" [Year 4 teacher, school 3]

Project partners

Utrecht University, Freudenthal Institute (Project Coordinator) The Netherlands

University of Southampton England

Karel de Grote University of Applied Sciences and Arts, Centre of Expertise in Urban Education, Belgium

Karlstads University, Research Centre SMEER (Science, Mathematics, Engineering Education Research), Sweden

University of Lisbon, Institute for Education, Portugal

Beit Berl College, Faculty of Education, Israel

Euroface Consulting, Czech Republic

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Winchester Science Centre (WSC), England

Alma Löv Museum, Sweden

Ciência Viva, National Agency for Scientific and Technological Culture, Portugal

Ministry of Education, Department. for Research and Development, Experiments and Initiatives