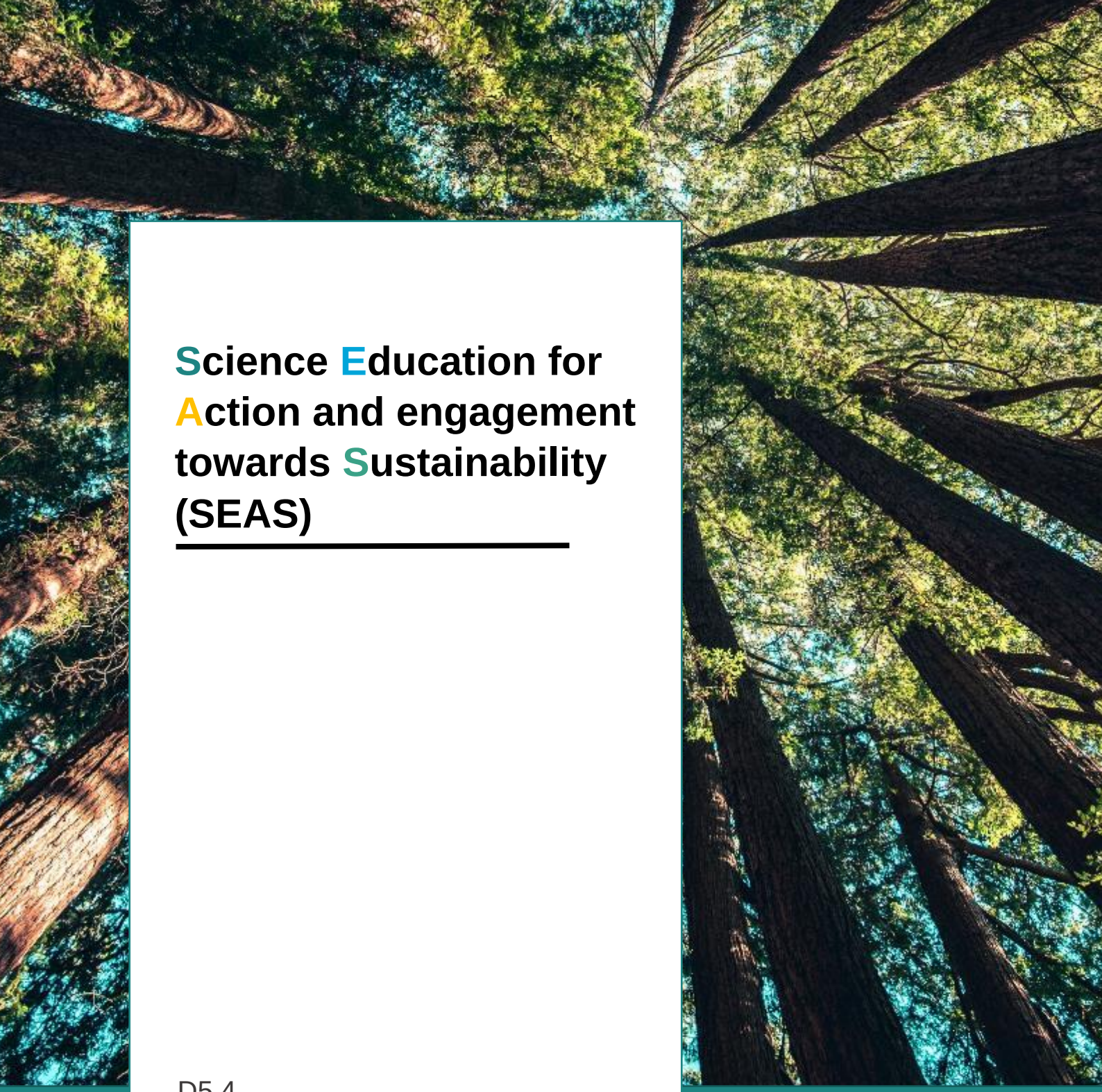


Science Education for Action and engagement towards Sustainability (SEAS)

D5.4

Report on models of teaching and learning scientific literacy

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1. Summary

This deliverable reports on a global assessment and synthesis of insights regarding teaching and learning scientific literacy that emerged from the six local SEAS open schooling networks in Austria, Belgium, Estonia, Italy, Norway, and Sweden. After describing this document's history and authorship (section 2) and situating it in the purpose and strategy of SEAS' global assessment and synthesis (section 3), we subsequently describe the following models of teaching and learning scientific literacy:

- Rethinking Quality Science Education
- Three visions on scientific literacy
- Three 'selective traditions' in environmental and sustainability education
- 5Es model
- Liminal Thresholds of Change in Schools

2. Document history and authorship

This document has been prepared by WP5 leader (Katrien Van Poeck), with contributions from all local network leaders as well as the leaders of WP2-3 (Alfredo Jornet) and WP4 (Stefan Bengtsson) and the SEAS project coordinator (Erik Knain). Below (section 3), we describe the strategy for global assessment and synthesis and, in particular, our approach to facilitate goal-oriented coherence between, on the one hand, the local assessment (WP3) and the work on tools (WP4) conducted in the six SEAS open schooling networks and, on the other hand, the global synthesis resulting in models of teaching and learning scientific literacy. Here we briefly outline the writing, reviewing, and editorial process that resulted in the D5.4 document.

A first draft of the document was circulated to the project members on the 21st of January 2022 and was meant as a template for collecting input from SEAS partners. The document was drafted by Katrien Van Poeck and discussed in a meeting with Alfredo Jornet, Stefan Bengtsson and Erik Knain (21/01/2022). During the Project Management Team Meeting (PMT) on the 2nd of February 2022, the draft was presented for and discussed with the WP leaders and local network leaders. Particular attention was paid to further developing and integrating the sections on 'Synthesis of findings' ('Updating and differentiating SEAS concepts, tools, and methods' – 'Conceptual model(s)' – 'Identifying Dilemmas') in the local assessment report D3.2.

By the 15th of March 2022, SEAS partners submitted drafts of descriptions of models for sections 4 and further. The aim was to obtain a clear and somewhat elaborated view on the content of this report on models (i.e. of sections 4 and further), on how each topic (model) would be developed, and by whom. Feedback on these drafts was provided in written form by the 31st of March 2022. This will be done by a group of D5.2 reviewers (SEAS partners), including the WP5 leader. Part of this review and feedback round was also to identify potential overlap and possibilities for integration

and/or cross-references. During the PMT meeting on the 6th of April 2022, the drafts and feedback was discussed in view of sharpening, finetuning, and integrating the contributions.

By the 30th of April, full texts were provided for each contribution to (i.e. section of) D5.2. This served as input for the global assessment and synthesis workshop during the SEAS consortium meeting in Innsbruck from the 4th to the 6th of May 2022. During this workshop, we discussed all the models separately in order to provide the authors with additional feedback and we discussed the overall collection of models and the co-construction of the report.

The PMT meeting on the 1st of June provided us with a last chance for reviewing, giving feedback, and discuss the different sections of this deliverable. We organised this in the form of 'consults', creating time and space to raise questions, doubts, ask for advice, etc. on each of the models (sections). After receiving the final texts by the 15th of June 2022, WP5 leader Katrien Van Poeck conducted the final editing of this report.

3. Introduction

SEAS aims to create knowledge in three areas: 1) the establishment and implementation of open schooling partnerships; 2) transformational engagement scientific literacies and motivation; and 3) teaching and learning scientific literacy. This 'object of knowledge' is addressed from a variety of perspectives in the six different local networks: very diverse 'objects of study' (practices/experiments across the local networks) as well as divergent theoretical approaches and analytical methods guided the local assessments. In order to use this rich (empirical, methodological and theoretical) diversity as a strength, we designed an approach to co-construct the global synthesis deliverables that allows to do justice to the local diversity while also making sure that each contribution is relevant and helpful to realise our joint goal, i.e. to create knowledge on our shared object of knowledge (SEAS concepts and tools related to the three areas).

In the second annual local assessment report (D3.2), each local network was asked to summarise the local assessment findings in the form of conceptual models related to each of the three reporting areas. This diversity of models is assembled and integrated in the WP5 deliverables and, thus, in this report on models of teaching and learning scientific literacy. As a whole, the work towards the three reports on models related to SEAS' assessment areas (D5.2, D5.3, and D5.4) was set-up to cover all SEAS' concepts, tools, and methods (see D2.2). With this in mind, the WP5, WP3 and WP4 leaders provided repeated intermediate feedback during the local assessment work and reporting. In addition, local networks were requested to identify how their findings and/or conceptual models contribute to scholarly debates on given dilemmas characterising the field of open schooling for sustainability in research fields such as sustainability education or science education.

The thus developed, diverse models and dilemmas related to teaching and learning scientific literacy are described in this report with the aim to provide educators, policymakers, researchers, etc. with guidance that helps them to reflect upon, discuss and develop their own approaches to open schooling in view of action and engagement for sustainability. Just as new or particular forms of

interdisciplinary science learning for action and engagement towards sustainability are expected in open schooling innovations, new challenges and opportunities to teaching in these types of innovative settings are expected too. These are described in the report on the local assessments of the SEAS local networks (D3.2). The models described below, provide insight into these challenges and opportunities as well as into possible ways to make progress in this regard.

4. Rethinking Quality Science Education

Author(s): Kubisch, Susanne and Lars Keller

Keywords/tags: scientific literacy as/for transformational engagement, open schooling, transdisciplinary education

Aim & focus:
This model for teaching and learning scientific literacy, called Transdisciplinary Education, aims to provide guidance for implementing and balancing all three visions of scientific literacy. It not only aims at supporting teachers in doing so but also at motivating educational researchers to analyze and discuss the model and its learning effects.

Target audience:
Teachers and educational researchers

Considering the Agenda 2030 with the Sustainable Development Goals (SDGs), which was acknowledged by 193 United Nation member states with the aim to achieve peace and prosperity for people worldwide and to protect our environment and climate, the role of education becomes apparent (UN, 2015). SDG 4 Quality Education with Education for Sustainable Development (ESD) as integral element is even recognized in the Agenda as a key to attain all other SDGs (UN, 2015; UNESCO, 2021).

The demands of ESD are ambitious and require rethinking today's formal school education (S. Kubisch et al., 2022; UNESCO, 2017, 2021). ESD demands not only the knowledge generation of learners of all ages, but also to develop competencies, attitudes and values to address and find solutions for todays' and future challenges. Moreover, education should empower learners to take responsible decision and finally (UNESCO, 2017, 2021), action for a societal transformation (O'Brien et al., 2018).

Young people hold an important position, since they are the ones who will bear the costs that arise from challenges, like anthropogenic climate change (CC), during their lifetime (Corner et al., 2015; Hansen & Kharecha, 2018). Besides, they are the decision makers of tomorrow (O'Brien et al., 2018), however, simultaneously they are the ones who are excluded from decision-making processes today as cited in the Brundtland Report "We act as we do because we can get away with it: future generations do not vote; they have no political or financial power; they cannot challenge our decisions" (Brundtland, 1987, p. 16). Despite the missing decision-making power at a political level,

via the Fridays For Future movement young people demonstrate in an impressive manner in regard to CC that they can be agents of change. While some actively engage via the movement, others feel a lack of self-efficacy in regard to climate action (O'Brien et al., 2018; Sanson et al., 2019), are disinterested (Ojala, 2021) or deny the seriousness of CC (Corner et al., 2015). Ojala (2021) additionally points out the importance of trust in science for everyday climate-friendly action.

4.1 The role of science education and scientific literacy

In regard to the importance of trust in science for (climate) action and various manifestations of young people's awareness and action, as well as due to the need for empowerment of young people with the knowledge and competencies to take responsible decisions and action, the role of science education becomes apparent.

Recent calls from educational scholars emphasize the need for science education that goes beyond teaching disciplinary knowledge to a transformative education which puts "science-in-context" (Bencze & Alsop, 2014). This demand is captured by the concept of socioscientific issues (SSI) (Zeidler et al., 2005; Zeidler et al., 2019), putting science knowledge in context, connecting it to issues of social significance (Bencze and Alsop 2014). Defining prerequisites for a transformative science education, Valladares (2021) demands for a comprehensive education that promotes the agency capacity of individuals and their communities to contribute through science to sustainable solutions. Therefore, she acknowledges that in order to achieve a transformative science education, students need to experience education that encourages them to "understand, value, and relate to the world differently in their everyday lives, not only through canonic scientific ideas", but through experiencing and exchanging different perspectives (1), getting to know different forms of knowledge (2) and through fostering student's active engagement with science and within their community (3) (Valladares, 2021, p. 581).

The concept of scientific literacy touches upon this idea, being considered to be one of the major goals of science education (Laugksch, 2000; OECD, 2017; Yacoubian, 2018). According to science scholars, scientifically literate persons should be able to make informed and responsible decisions that are based on scientific knowledge, which requires both content and process knowledge about science. Scientifically literate people know the opportunities of science, but are simultaneously able to take a critical view on science (Norris & Phillips, 2003; OECD, 2017; Yacoubian, 2018). Scientific literacy vision III, science for transformation (Sjöström & Eilks, 2018), aims at encouraging the critical engagement with science (Liu, 2013). Moreover, it aims to contribute to a critical citizenship and sustainability (Sjöström and Eilks, 2018) and is closely linked to transdisciplinarity, fostering student's dialogical emancipation and participation (Sjöström and Eilks, 2018; Valladares, 2021). In opposite, vision I is limited to and defines a scientific literate person in terms of factual and procedural knowledge, while vision II links science to students' lifeworld, with a focus on scientific knowledge and processes in students' everyday life (Roberts, 2007, 2011). Consequently, vision I targets at developing the mental capacity and preparation for a science career, whereas vision II aims at linking science and society. Vision III, the vision of "science within society" aims at encouraging students to actively engage in complex sustainability issues for seeking informed and responsible solutions (Liu,

2013). Whereas according to Roberts (2011), vision I and II are fundamentally different and competing, Liu (2013, p. 31) states that "focusing on one vision while ignoring others is undesirable" since the three visions of SL are interdependent and reinforce each other.

Coming up with present calls from science education scholars, the Austrian local network focusses on the concept of transdisciplinary education (TE) (Susanne Kubisch et al., 2021), in order to raise scientific literacy as/for transformational engagement.

4.2. Transdisciplinary Education for raising scientific literacy

In the Austrian local network teaching and learning scientific literacy is based on a conceptual model of TE (see Figure 1) which is aligned to the demands of ESD for transformative teaching and learning, requiring integration, participation and reflection (Balsiger et al., 2017; UNESCO, 2017, 2021).

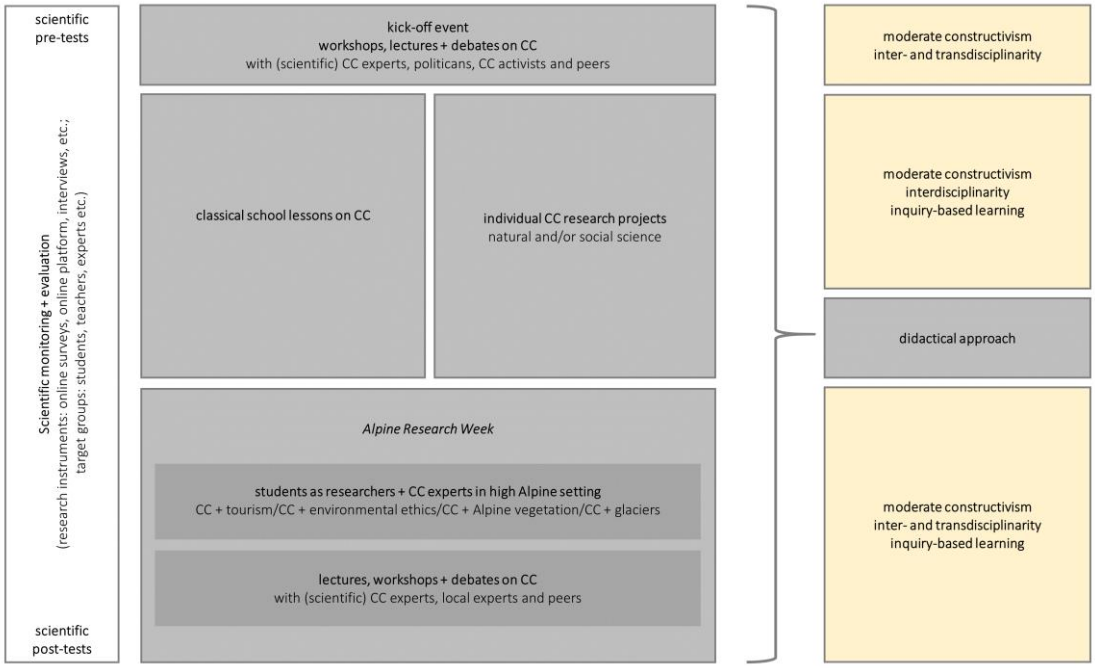


Fig. 1. The conceptual model of the Austrian local network (grey) and underlying didactical approaches (yellow). The abbreviation CC means climate change, source: own modification of (Keller et al., 2019).

The conceptual model of TE, bases on the principles of transdisciplinary research (Susanne Kubisch et al., 2021), a research approach, which increasingly gains in importance in sustainability science, and which promotes the collaboration of science and society in order to achieve socially acceptable and sustainable solutions (Lang et al., 2012). Likewise in transdisciplinary research, a SSI is the starting point of TE, which is addressed in different in- and out-of-school modules, which are aligned to a moderate constructivist understanding of learning (Riemeier, 2007), inquiry-based learning (Pedaste et al., 2015) and the principles of inter- and transdisciplinarity (Lang et al., 2012). The transdisciplinary approach is of utmost importance within TE, allowing students to jointly do research without of school partners within their lifeworld and actively engage in a SSI (Susanne Kubisch et al., 2021).

The modular structure of TE, enables to balance all three visions of scientific literacy and allows integration in current subject-driven school curricula. While all modules and in particular the module *classical school lessons on CC*, foster scientific literacy vision I, since they focus amongst others on knowledge generation, the module *individual research projects on CC* especially promotes vision II and/or III, since students have the possibility to develop and reflect on their individual projects which are linked to their lifeworld and hence to society. Some of the projects, which were developed already were transformative, focusing on a change in prevalent patterns of behavior. The out-of-school module *Alpine Research Week* enables students to actively engage in researching a SSI, promoting the exchange of different perspectives and critical thinking and thus the transformative vision of scientific literacy, vision III.

A moderate constructivist understanding of learning (Basten et al., 2015; Riemeier, 2007) is the basis of all teaching and learning modules within TE (Susanne Kubisch et al., 2021). A moderate constructivist understanding of learning originates from the idea, that learning is an active, situational, emotional, social and self-regulated process and consequently a constructive process. This process builds on available conceptions, originating from individual experiences and previous knowledge and is dependent on social and emotional processes and the learning environment (Riemeier, 2007). In order to foster individual knowledge construction processes, students need both the space to follow their interest and to tie up with their preconceptions and experiences (Widodo & Reinders, 2004), simultaneously a moderate constructivist learning environment provides support and guidance by teachers.

In order to consider students interest and pre-conceptions, some in- and out-of-school modules (*individual CC research projects*, *Alpine Research Week*) are designed, following the approach of inquiry-based learning. Herby students are empowered to follow their interest, identify problems, formulate their own research question, build hypotheses, collect data and find answers to their questions. From a didactical point of view, students are guided through a complex scientific process which is didactically reduced to its single phases (Pedaste et al., 2015). Additionally, by means of inquiry-based learning, students learn not only factual but also procedural knowledge about science. Further approaches, which are part of the didactical concept of the Austrian local network are inter- and transdisciplinarity (*kick-off event*, *classical school lessons on CC*, *Alpine Research Week*). In regard to the challenges of the 21st century an interdisciplinary approach is of utmost importance since social relevant issues cannot be reduced to a single perspective, neither sustainably approached without those affected by a problem. The latter calls for transdisciplinarity, fostering research processes on SSI and the exchange of different perspectives between diverse stakeholders (citizens, scientists, politicians etc.) (Lang et al., 2012). In TE inter- and transdisciplinarity are approached in the *kick-off event*, the starting event of one full school year's collaboration, where students and teachers meet (scientific) experts and politicians to jointly discuss about CC. During the school year students get *classical school lessons on CC*, where CC is approached in an interdisciplinary manner from different subjects. Furthermore, they develop *individual CC research projects* which are located at the interface of social and natural science, hereby they are supported by their teachers. At the end of the school year students meet (scientific) experts in the *Alpine Research Week* a high Alpine

mountain area, where they do research on CC in different fields (tourism, environmental ethics, glacier retreat, vegetation/soil/nutrition). In particular, within the *Alpine Research Week*, but also during the *kick-off event* and the development of their *individual CC research projects*, students actively engage with a SSI in their lifeworld and consequently get the opportunity to connect the topics they learnt during the classical school lessons with their everyday life. Hence, like already mentioned before, all three visions of scientific literacy can be promisingly approached by TE, as scientific findings within the network demonstrate.

4.3. Possible dilemmas of implementing the conceptual model of Transdisciplinary Education

Liu (2013) argues that all three visions of scientific literacy need to be considered in order to contribute to a transformative science education. However, implementing the three visions of scientific literacy within TE in an even manner, teachers might face challenges similar to those experienced within the realm of ESD. Even if ESD is now an educationally well-justified concept (Burmeister et al., 2013; Burmeister & Eilks, 2012), the implementation of ESD in formal school schooling still remains rare. In particular scientific literacy vision III demands the generation of competencies like critical thinking, however, teaching and learning in formal education is still mainly content-driven (Ingo Eilks, 2015). Burmeister et al. (2013) ascribe the emphasize on knowledge production to a lack of teachers' knowledge about the necessary pedagogy, as well as limited resources, which are required by ESD. This might be true for TE as well. Sjöström and Rydberg (2018) emphasize possible didactical dilemmas that might arise, if teachers aim at a balance between the three visions and hence knowledge transfer, competency generation and students' participation. Since TE requires a lot of effort from teachers as well as from their partners (Susanne Kubisch et al., 2021), the emphasize might be laid on scientific literacy vision I and in-school activities, than fostering students active engagement within their community and hence vision II and III. In particular vision III, however, demands a teaching and learning which goes beyond school boundaries and takes up students' lifeworld, acknowledging the significance of inter- and transdisciplinary approaches and students' active engagement with SSI (Hodson, 2003; Sjöström & Eilks, 2018; Zeidler et al., 2019). Through the modular structure of TE and its underlying didactical approach, didactical dilemmas can be prevented, since it is aligned to current subject-driven school curricula and allows both in-school subject-specific learning on CC and students active engagement in in- and out-of-school modules (Susanne Kubisch et al., 2021).

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5. Three visions on scientific literacy

Author(s): Katrien Van Poeck & Leif Östman

Keywords/tags: Scientific literacy; Socio-scientific issues; Complexity/wickedness; LORET

Aim & focus:
This model aims to provide guidance to reflect upon, discuss, and position oneself in different approaches to scientific literacy. It can be used to develop open schooling in science education by not only addressing key concepts and principles of science ('induction into science') but also how science plays a role in our everyday life and socio-political issues ('learning from science').

Target audience:
Teachers – teacher trainers – educational policymakers – school coaches – NGO staff – educational researchers

5.1. Introduction

Vision I, II, and III on scientific literacy provide us with a suitable model for understanding and investigating scientific literacy in the context of open schooling and sustainability.

Roberts (2011) describes the school curriculum as 'an object of political and professional struggle' (p. 11) and distinguishes between two fundamentally different, broad visions on scientific literacy: Vision I and Vision II. In doing so, he draws attention to the substance of curriculum policy as it is reflected – and encountered by teachers – in a required set of learning outcomes, a syllabus, a textbook, etc. Vision I and II have their roots in two competing curriculum sources; (I) internal: the discipline of science itself, the products, processes, and characteristics of the scientific enterprise, and (II) external: situations in which science demonstrably plays a role in human affairs. Distinguishing the divergent characteristics of both visions, Roberts argues, is important to avoid confusion that can occur if the term 'scientific literacy' is used to refer to the whole array of long-term outcomes of school science associated with both visions. Vision I and Vision II 'envision' the scientifically literate person – and what that person should know and be able to do – in very different ways. In both visions, students will learn the scientific meaning of concepts, laws, theories and procedures but they will do so with a different purpose.

5.2. Vision I

Vision I, as argued, focuses on the internal aspects of the discipline of science itself and thus envisions the scientifically literate person as someone who understands key concepts and principles of science, is familiar with the scientific process and method, has acquired inquiry skills, uses scientific knowledge and ways of thinking, etc. Curriculum policies in line with this Vision I are, according to Roberts, oriented towards developing a pool of potential scientists. This logic of scientific literacy as a matter of getting students 'ready for the next course' (Roberts 2011, p. 14) brought Sjöstöm and Eilks (2018, p. 78) to label Vision I as 'pipe-line science'. It is 'about learning about scientific content and scientific processes for later application' (p. 65 – our emphasis). Thus, the assumption is that if students acquire the necessary, basic scientific knowledge and skills, they will be automatically able to apply it for individual and social purposes. The focus is epistemological, and explicitly limited to that. As Östman (1996) argues, an abundance of things is said and done during any lesson. It is impossible for the students to learn all of that – and this is also not what the teacher expects. S/he wants the students to pay attention to the essentials and thus prepares and performs lessons that try to govern students' attention to this 'primary focus' (Östman 1996, p. 40) of the teaching. To refer to this primary focus, Östman introduced the concept of 'subject focus'. Drawing on the work of Fensham (1988), he labels the subject focus that characterises Vision I as 'induction into science'. The primary object, the aim for the students is to learn general scientific knowledge. Phenomena and events in the world are thereby used in an illustrative way, i.e. as instruments for the students to learn the concepts of the natural sciences. They are, so to speak, reduced to 'means' for the 'end' that is internally situated in the discipline of science itself.

5.3. Vision II

Vision II has, as indicated, an external focus. It envisions the scientifically literate person as someone who is able to, for example, appreciate and understand the impact of science and technology on our lives, to take informed personal decisions about topics that involve science, to understand media reports about issues that involve science, etc. (Roberts 2011). Again, it is obvious that here, too, the students are expected to learn scientific knowledge. Yet, the focus is not limited to this but explicitly expands towards how science plays a role in human affairs. Östman (1996, p. 41), referring to Fensham (1988), has called this subject focus 'learning from science', characterised by the use of natural science concepts to explain phenomena and problems arising when human beings interact with nature. Instead of pipe-line science to prepare future scientists (Vision I), this focus on usefulness reflects an idea of 'science for all' (Sjöstöm and Eilks 2018, p. 78).

5.4. Vision III

Several authors (e.g. Millar and Osborne 1998, Aikenhead 2007, Sjöstöm and Eilks 2018) have emphasised the need to add a Vision III on scientific literacy. Focusing on so-called 'socio-scientific issues' (SSI) (Zeidler et al. 2011) and what it requires from a scientifically literate person to deal with these, this third perspective expands the focus from 'science for all' to 'science for transformation' and engagement in socio-political action (Sjöstöm and Eilks 2018, p. 78). This expands the focus of

Vision II from 'learning from science' in order to understand and be able to handle everyday and technological sustainability problems towards 'learning from science' in order to understand and be able to handle the ethical and the political dimension of sustainability problems. Here, the scientifically literate person is envisioned as someone who is able to critically reflect on societal issues involving science, to take part in discussions on it, to use scientific insights for suggesting proposals to solve societal problems, to do so while taking into account concerns for democracy and justice, etc.

5.5. LORET-based open schooling

LORET-based open schooling, with its focus on realising curriculum goals through engagement with real-world problems, is designed in line with the philosophy of 'learning from science', both for handling everyday problems and for engaging with socio-political issues and societal transformation. The methodology can serve as a vehicle for supporting teachers in the didactical work involved in implementing Vision II and, especially, Vision III in the design of their lessons. In the philosophy of LORET, with its interest in offering students unique educative opportunities such as experiences of commitment, resistance, conflicting values, divergent ideas about how to solve a problem, etc., (science) education is more than only transferring scientific facts but also exposes students to sustainability challenges as 'socio-scientific issues' in view of progressing their capacities to handle their ethical and political dimension or, in other words, their 'complexity/wickedness'.

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6. Three 'selective traditions' in environmental and sustainability education

Author(s): Katrien Van Poeck & Leif Östman

Keywords/tags: Scientific literacy; Socio-scientific issues; Complexity/wickedness; LORET

Aim & focus:
This model aims to provide guidance to reflect upon, discuss, and position oneself within three selective traditions in environmental and sustainability education. It can be used to develop open schooling a a pluralistic practice that provides students with competences to critically evaluate different perspectives and to take a stand in debates and decision-making at both the private and societal level.

Target audience:
Teachers – teacher trainers – educational policymakers – school coaches – NGO staff – educational researchers

6.1. Introduction

In environmental and sustainability education (ESE) three so-called 'selective traditions' (Sandell et al. 2005, Öhman 2008, Öhman and Östman 2019) have been distinguished: a fact-based, normative and pluralistic tradition. Historical didactic research shows that there are different traditions in selecting teaching materials and methods. Williams (1973) called these 'selective traditions' and emphasised that the approach to knowledge and to educational practices is always chosen (selected) within the framework of a particular culture. Over time, the developing selection patterns form a selective tradition. Each tradition represents specific answers to the question of 'what is the best teaching method for a subject/theme/content?' and includes a number of specific approaches and choices in teaching content and teaching methods.

6.2. Fact-based teaching

In the fact-based tradition, sustainability issues are regarded as knowledge problems: they arise because the public is ignorant and/or because we do not have the necessary knowledge to tackle problems in the most effective way. From this perspective, sustainability issues are issues for science – especially for the natural sciences. More research and technology and more information are assumed to lay the foundation for a more sustainable development. Educational practices in this tradition therefore solely focus on transferring scientific models, facts and concepts – as is the case in Vision I on scientific literacy. There is a strong belief that only science and scientific facts form a

reliable basis for knowledge about sustainability issues. From that point of view, only scientific facts and models are important in educational practices. It is expected that students themselves will draw the correct conclusions based on these facts and act accordingly. Teaching is therefore strongly focused on transferring subject knowledge, often through teacher-led lessons. In this tradition, facts are strictly separated from values. The latter are regarded as subjective, as belonging to the private sphere of the students and therefore as something that cannot be discussed in rational discussions. Consequently, ethical and political aspects are considered as something that has no place in education. Objective education is paramount and it is not seen as the school's job to influence the ethical and political views of students. The guarantee of such objective education is a focus on teaching facts based on scientific knowledge. The underlying idea is that scientific research is a value-free, neutral practice and that science can provide us with the necessary knowledge to solve sustainability problems. In this sense, the democratic role of education is limited to offering objective facts on the basis of which students can form an opinion afterwards. By acquiring more knowledge, the students are assumed to be gradually enabled to fulfil their democratic rights as citizens.

6.3. Normative teaching

Within the normative tradition, sustainability issues are primarily regarded as moral problems that can be solved by adopting environmentally friendly and sustainable values, norms and lifestyles. These values and norms are based on scientific knowledge. In this way, science is seen as a practice with ethical implications: from the facts that science provides us, it can be deduced what the correct values and standards are for sustainable development, the reasoning goes. If people act accordingly, the whole society can be reformed in accordance with scientific knowledge and predictions. This philosophy is also known as 'scientism'. According to this tradition, experts from various fields should advise people and guide their choices. Adopting an eco-friendly lifestyle is seen here as an individual responsibility. In this tradition, the answers to value-laden sustainability issues arise from discussions between experts and policymakers based on scientific facts. These are then translated into the curriculum. This is based on the assumption that it is possible to find universal solutions for sustainability issues. Schools are expected to teach sustainable values and standards in order to steer the behaviour of the students in the right direction. Key ambitions here are to engage students in sustainability issues, encourage responsible behaviour and teach practical skills to apply theoretical knowledge in practice. Although the lessons are based on scientific facts, values and emotions are also considered important for promoting engagement.

6.4. Pluralistic teaching

Central to the pluralistic tradition is the increasing uncertainty about sustainability issues and the proliferation of differing opinions in the debate on them. Sustainability problems are seen as political issues: conflicts between different interests, values and ideologies. Different groups with equally differing values and perspectives have divergent views about what the problem is and how serious it is. Even when one agrees on the facts, the reasoning goes, one can have differing ideas about what is the best approach to sustainable development based on divergent ideological convictions.

Because science is limited to providing facts, it is not seen as the one and only source of guidance when it comes to ethical and political aspects of sustainability issues. This tradition strives to highlight different, sometimes conflicting, perspectives, visions and values about the future of our world. In contrast to the fact-based tradition, it is assumed that not only facts but also values and emotions can be the subject of rational discussions. These are open-ended and do not target predetermined ideological positions. Much emphasis is placed on developing a shared understanding of how to use facts for making choices and judgements, recognising and accepting different points of view, and democratic discussion. The latter is seen as an essential part of education in the pluralistic tradition. The aim is to provide students with competences to critically evaluate different perspectives and to take a stand in debates and decision-making at both the private and societal level. Discussing a wide range of points of view is seen as an important aspect of ESE. This aligns well with Vision III on scientific literacy.

LORET-based open schooling, with its ambition to take students along in an authentic, open-ended quest for solutions for sustainability problems and to let them explore a diversity of options, opinions, perspectives, preferences, etc. can obviously be understood as a way to operationalise and implement pluralistic sustainability teaching.

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7. 5Es model

Author(s): Katrien Van Poeck

Keywords/tags: LORET - Locally Relevant Teaching; Co-design for social innovation

Aim & focus:
This model aims to provide guidance to reflect upon and discuss open schooling as a practice through which students can engage with action and engagement for sustainability in a democratic and participatory way. It can be used to develop open schooling by helping teachers to make the content of their lessons and the activities offered to the students more concrete and to do so with a broad view on obstacles and opportunities for making our society or local community more sustainable.

Target audience:
Teachers – teacher trainers – educational policymakers – school coaches – NGO staff – educational researchers

7.1. Introduction

In open schooling partnerships, the relation between students, teachers and partners outside the school can take shape in varied ways. LORET (Locally Relevant Teaching) – one of the tools used in the SEAS project (see also above) – aims to shape these partnerships and relationships in accordance with two crucial principles. First, LORET aims to connect engagement with societal problems with the realisation of pedagogical aims and objectives – the core task and 'raison d'être' of schools. Second, LORET supports teachers to approach students as subjects of change – part of the solution – instead of as objects of change – part of the problem. This reflects, on the one hand, a normative position about the role of education in relation to societal problems, a topic of lively debate in educational scholarship (see below: Learning *for* versus learning *from* sustainable development). As it is not the responsibility of students, teachers and schools to solve societal problems, LORET supports teachers in their didactical and pedagogical work and deliberately aims to avoid the instrumentalization of education (Van Poeck and Östman 2020, Säfström and Östman 2020). On the other hand, the guiding principles behind LORET are built on the assumption that working with real-world problems offers unique pedagogical opportunities. 'Not only does it offer students the chance to acquire specific knowledge, insight and skills, it also fosters creativity, experiences of being able to make a difference and space for engagement and commitment. Furthermore, the students can experience how different people may each have their own idea of how they can / want to solve this problem. Engaging students in the quest for solutions hence enables educative moments that would not emerge during theoretical lessons or mere reflections in classroom discussion where no 'real' challenge is at stake. When dealing with real-world problems, what is said and done is not non-committal. One has to find a solution together. Not everyone thinks the same, there may be resistance. And finally, the work of the students results in something that is practically useful which in itself is more satisfying than if one sticks with the theory.' (https://loret.se/background/)

An earlier described model that shares these principles, is the '5Es model,' as described by Van Poeck (2010) in response to the way in which DEFRA's 4Es model (see below) has been used in educational contexts. Within the SEAS project, the open schooling experimentation with LORET and the assessment thereof in the Belgian local network (see D3.2) reveals how LORET can be employed to support teachers in the didactical work needed to implement the 5Es model and how LORET and the 5Es can be used as complementary didactical guidance for designing and performing open schooling practices.

7.2. DEFRA's 4Es model

DEFRA (2008), the UK Department for Environment, Food and Rural Affairs, developed a framework for designing effective behavioural change strategies based on a mix of tools, the 4Es: Enable, Encourage, Exemplify and Engage. The 4Es model assumes that the gap between environmentally

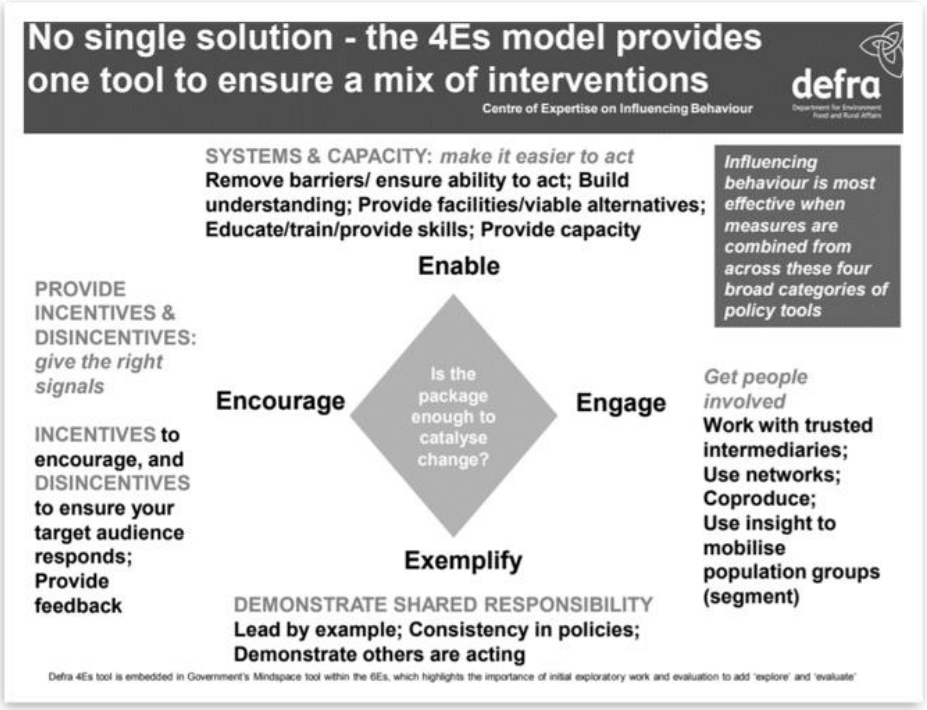
friendly attitudes of many people and the lack of sustainable behavioural patterns is caused by a variety of barriers. These obstacles are situated at the level of structures (e.g. institutions and power relations), culture (e.g. worldviews and values) and practices (e.g. routines or rules). Deploying the 4Es should make it possible that cultural-psychological changes and structural changes go hand in hand – a prerequisite for the transition to a sustainable society.[2]

- 'Enable' is about making sustainable lifestyles easier by providing people with the support they need to make responsible choices. These must be available, simple and self-evident, while unsustainable alternatives should be excluded from the range. Barriers should be removed and the ability to act ensured by, for example, providing facilities, viable alternatives, skills, etc.

- 'Encourage' is about giving the right signals. It means that sustainable behaviour is not only made possible but also encouraged through providing incentives and disincentives. This can be done through pricing, by stimulating sustainable choices (for example via subsidies) and discouraging unsustainable choices (for example fiscally). External costs must be internalised.

- 'Exemplify' is about demonstrating shared responsibility. It involves leading by example, consistency in policies, and demonstrating that others are acting. It explicitly refers to the exemplary role of governments.

- 'Engage' is about getting people involved. It involves raising awareness, involving people early on so that they understand what they need to do and develop a sense of personal responsibility, using networks and working with trusted partners and intermediaries to develop 'social norms', and moving entire communities.



[2] Note the similarity with the 'Three spheres of transformation'.

(source: https://www.sustainabilityexchange.ac.uk/files/defra_sustainable_lifestyles_framework.pdf)

The 4Es model thus also sees a role for learning processes and education. However, a risk is that everything related to learning is situated exclusively under the 'Engage' pillar (e.g. Jones and De Meyere 2009) in order to engage as many people as possible in realising the desired change together. Education and awareness-raising should, in this perspective, provide the necessary support for the desired transition. However, reducing education to the 'Engage' pillar implies that determining the goals of the transition as well as choosing the means to realise these goals falls outside the scope of the teaching and learning process. In other words: it is only after deciding what needs to be done, that students can get involved. Another risk is that education is, as in the figure above, reduced to 'training' in view of acquiring the skills needed to be able to act in the desired way, as part of 'Enabling' the desired transition.

Such approaches provide students with the kind of solutions we currently go to for the problems that arise today. But what is the shelf life of ready-made solutions in our complex and rapidly changing world? And what if a 'solution' later turns out to be a (new) problem? Or when we are confronted with conflicting arguments for and against proposed solutions? How can students learn to deal with that if the crucial decisions are made in advance, by others? How can we move beyond treating students as consumers who must learn to make sustainable choices ('objects' that need to be changed) and treat them as citizens who are able to critically question and try to transform structures, cultures and practices ('subjects' that contribute to realising change)?

7.3. A 5th E

These questions inspired the introduction of an adapted framework: a 5Es model (Van Poeck 2010) in which education is approached differently. After all, there are crucial differences between 'education' and 'influencing behaviour'. Teaching and learning are in the 5Es model not limited to the 'Engage' pillar – in order to create support for changes desired and proposed by others – nor to a matter of training specific skills in order to 'Enable', again, what others have decided. Only if 'Education' – the 5th E – involves the students in exploring and experimenting with all of DEFRA's 4Es, they can learn to find solutions for complex and unpredictable problems themselves, now and in the future, and take on their role as citizens.

Education as a 5th E aims to equip people with the capabilities and the commitment to actively contribute to sustainability transitions. Not with the intention of solving sustainability problems once and for all – besides that this is not the responsibility of schools it would reflect an overestimation of the potential of education – but to offer students the opportunity to develop themselves as citizens who are willing and able to participate actively in a democratic, socially just and environmentally sustainable society. The purpose of education then moves beyond equipping students with the 'right' knowledge, skills, and attitudes to function efficiently and obediently in a society as it is conceived for them. Instead, it offers them opportunities to become involved in envisioning a sustainable society and ways of realising it. They think about what behaviour should be possible ('Enable') and how this can be stimulated ('Encourage'). They critically examine the government's exemplary role

and denounce inconsistent policies ('Exemplify'). And they themselves look for ways to involve as many people as possible with diverse backgrounds in this process ('Engage').

7.4. LORET and 5Es

Obviously, LORET and the 5Es model share a similar philosophy in that they aim to offer students unique educational opportunities by taking them along in an authentic quest for tackling real-world sustainability problems. In other words: they strive for learning from a quest for sustainable development rather than learning for a sustainable development predefined by others. The 5Es model, however, can be seen as a general principle/idea and does not offer any didactical support for teachers with respect to how to design and implement that sort of education. LORET can fill that gap. It helps teachers to select a suitable focus (i.e. a locally relevant sustainability problem that is manageable for the students while still being an authentic challenge) as well as to select teaching content and design lessons that take the students along through all phases of a sustainability problem-solving process (i.e. exploring the problem, coming up with possible solutions, implementing solution proposals, and evaluating the problem-solving).

Through LORET-based open schooling, teaching can – in line with the 5Es – make students attentive to and let them experiment with the 'Enable', 'Encourage', 'Engage', and 'Exemplify' dimension of creating a more sustainable society. While exploring a locally relevant problem, they can address questions and gain insight into which sustainable choices and alternatives are (locally) available and which are not, why this is the case, whether or not policymakers and/or the school management lead by example, which choices are encouraged or discouraged, etc. In the phase of coming up with possible solutions, the students can look for answers on questions such as which sustainable alternatives should be enabled, which incentives could be employed for encouraging sustainable choices, how to remove 'wrong signals', and which partners in the local community could be helpful for engaging people. While implementing solution proposals, they can engage with trying to make sustainable choices possible, seeking support from the management or municipality, making sustainable alternatives more attractive, trying to demonstrate action, involving more people, etc.

While LORET adds didactic guidance to the 5Es model, the latter can in return help teachers to make the content of their lessons and the activities offered to the students more concrete and to do so with a broad view on obstacles and opportunities for making our society or local community more sustainable. This is important, especially since we learned from our analyses of working with LORET in the Belgian SEAS open schooling network that teachers can use more guidance in how to teach about (generating) possible solutions for sustainability challenges, about alternatives for the future and about strategies for realising change (see D3.2 Local assessment report).

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https://www.sustainabilityexchange.ac.uk/files/defra_sustainable_lifestyles_framework.pdf

https://loret.se/background/

8. Liminal Thresholds of Change in Schools

Authors: Martin Lee Mueller, Alfredo Jornet Gil, George August Pound Sekkelsten

Keywords: liminal thresholds, transformation, broadening domains of significance, scientific literacies, agency

Aim & focus:
Identify transformative moments in learning and teaching scientific literacies.

Target audience:
Teachers

8.1. Introduction

Our contributions to this area focus on the notion of *liminal thresholds of change*, which seems to us appropriate for a time of qualitative changes in our climate and of looming no-return thresholds of catastrophe, and where change towards new forms of production and consumption, of relating to each other and our natural environment, and across all personal, institutional, and international levels is demanded. In these times, understanding and generating opportunities to cross critical thresholds of social change towards real transformation is crucial, a notion that we apply as well to teacher's professional development.

Indeed, system theories developed in other disciplines to account for sudden change in physical phenomena, including catastrophe theory, have been applied in our field to account for educational change (Roth, 2017).

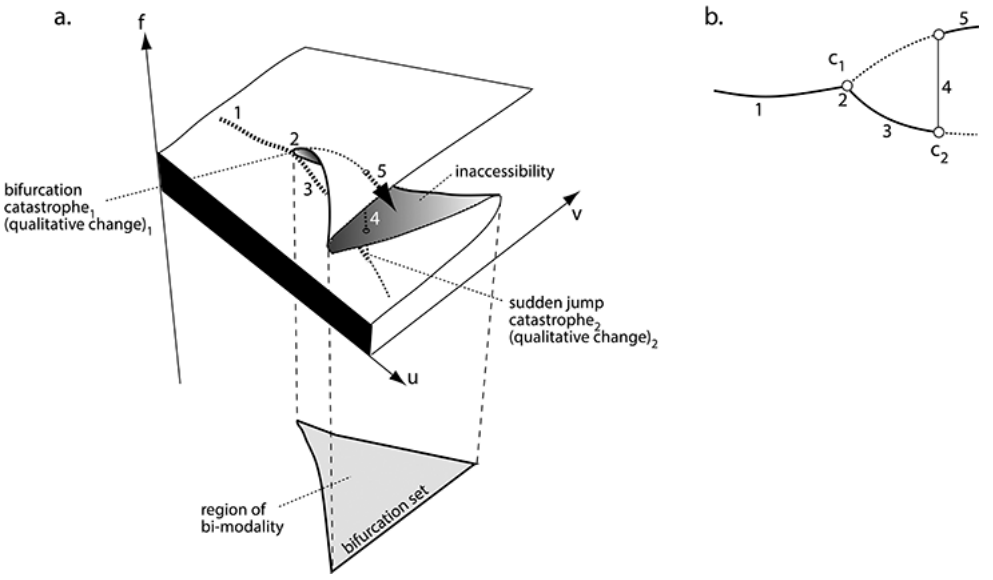


Fig. 1. Roth, 2017

In our research, we have documented multiple instances, specially but not only involving the teachers level, of crossing transformational thresholds in which teaching/learning practices go over a qualitative shift after a series of interventions, quantitative or other. Once the thresholds are crossed, new ways of seeing, thinking, and acting are established that present new horizons previously not accessible.

We observe across several of our cases a need to focus more attentively on specific moments of transformation in individual and shared learning trajectories, moments where critical thresholds appear to be reached and then breached. Developing a keener eye for the enabling factors of such critical thresholds is relevant for the question of how to conceptualize questions of agency, as well as how to speak more alertly about narratives of transformation. Theoretical angles that can be relevant to develop in more detail in relation to this include 1) systems theory (including the literature on ecoliteracy), 2) Vygotsky (1987) and his work on the "liminal" (i.e., questions of what boundary conditions need to be met, and 3) Roth's differentiation between "learning" and "development".

Here, we will develop the notion of liminal thresholds further by leaning into a discussion begun in the Norwegian network's report D5.3, on Models of Transformational Engagement, Scientific Literacies and Motivation, in particular the model "Broadening Domains of Signifiance". We will develop the discussion in relation to a case from the local network. This being a continuation of that discussion, it makes sense for the reader to familiarize themselves with that first step before continuing.

8.2. Revisiting the model "Broadening Domains of Significance"

We offer the model on "Broadening Domains of Significance" as a modulation of O'Brien and Sygna's (2013) "Three Spheres"-model. This present model can be considered a thinking aide into

performative processes of transformation in schooling. Being process-oriented, the model lends itself to various aspects of transformation in schooling. The model covers the spacious and fluid terrain between A) Values & Worldviews, B) Systems & Structure, and C) Practice. We will review these briefly before zooming in on the particular aspect of teaching and learning scientific literacy which is relevant for the present discussion, namely what we call liminal thresholds of change. Like its predecessor, the "Three Spheres"-model, so too the model of Broadening Domains of Significance recognizes three interdependent areas of transformation (in the model designated A, B, C (see below)). Where the models differ is in the relative composition and dynamics between the three areas of transformation. Rather than theorizing these areas as being firmly embedded inside one another (rather, that is, than visualizing these areas in a relatively static relationship to one another), the present model theorizes them as interrelated and non-hierarchical impulses in ongoing, coherent, fluid events. The model lends itself to various readings and interpretations of what constitutes such events, including such events as 'learning', 'teaching', 'narratives of change', a combination of these, and more.

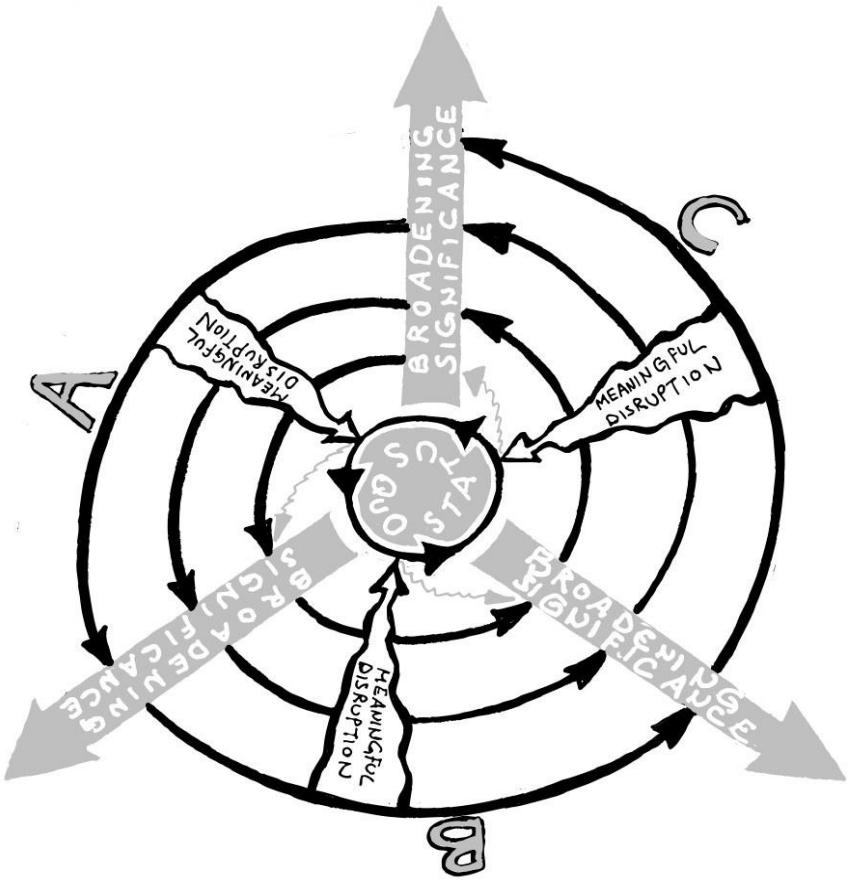


Fig. 2. Broadening Domains of Significance

The designated areas in the model – A, B, and C – are those interrelated, non-hierarchical, and fluid impulses of which we have spoken. Specifically, they are impulses regarding A) Values & Worldviews, B) Systems and Structure, and C) Practice. Together they constitute a continuum which we will call an 'event'. We can understand an 'event' to mean, alternatively, a 'learning event', a 'teaching event',

a 'narrative of change', a combination of these, or other open schooling-related events. In D5.3 report on scientific literacies for transformational change, the following qualifications are elaborated:

A. Values & Worldviews

Unlike in the Three Spheres-model, we refrain from calling this area 'personal'. Beliefs, values, paradigms, worldviews and cosmologies are not neatly contained in a 'personal' sphere but extend into the vaster terrain of shared culture-making, including its foundational myths and narratives, including its dominant and marginalized paradigms, including its linguistic conventions, etc.

B. Systems and Structure

This area corresponds roughly to the 'political' sphere of transformation, in that it highlights the transformative potential for broadening significance in relation to systems, structures, and infrastructures.

C. Practice

This area corresponds roughly to the 'practical' sphere of the original model, in that it is concerned with concrete behaviours as well as technical responses to given paradigms, values, beliefs, worldviews, and cosmologies.

It is inside this context that we can now consider the notion of 'liminal thresholds for change' more closely. We will do so through a case example. This example, too, figures in D5.3, in the discussion on SSI (Socio-scientific issues), and our expanded model thereof.

8.3. Liminal Thresholds in Teaching and Learning for Transformation

Our proposed model considers scientific literacies as the ability to trace, map, anticipate, enable, or otherwise navigate specific performative processes of broadening significance across the fluid fields we call 'values & worldviews', 'systems & structure', and 'practice'. Scientific literacies can be thought of as ways of knowing, and of doing, which gain broader significance as they are being performed concretely, in specific terrains, sociocultural settings, and historical contexts.

To exemplify the relevance of thinking more closely about enabling factors for liminal thresholds of change in teaching and learning, particularly in open schooling, we draw on the experiences of a case cited in D5.3, which was centred around a year-long iteration involving a local IB school, a range of local NGOs and interest groups, and the SEAS research community. The collaboration gradually developed to centre around the making of a student-led documentary film on the life cycle of salmon in the local Akerselva River. The teacher and other adults repeatedly sought to hand ownership and agency over to the students. Teaching consisted of careful scaffolding intended at opening the complexly layered socio-scientific issues (SSI) of salmon in relation to ethics, industrial farming, ecology, and sustainability. The students were tasked to research their own material, to shoot their own footage, to develop editing skills, and to be the authors – in groups – of the scripts which would become the basis of the film narrative. The basic scaffolding included tasking the

students to work in groups, each group being in charge of one season in the fishes' life cycle between river and ocean.

In the context of this longer iteration came a moment when the teacher made one small but – in retrospect – critical adjustment to the working task. The students were no longer to write their script 'about' the fish – as if the salmon were objects of study, as it were, objects which could be easily and comfortably gazed upon with a purely scientific lens. They were now to write from the point of view of the fish themselves. The teacher's adjustment explicitly involved encouraging the students to experiment with multiple ways of speaking and knowing.

The students had at this point conducted thorough research on the science aspects of the narrative. They had become reasonably competent with regards to fish biology, migration patterns, the fishes' morphological changes as they move from salt water to freshwater, etc. This was partly due to the design involving close dialog with experts in the field, who were invited into teaching situations repeatedly to act as mentors and to help with the science.

Later analyses of this transformation involved not only pre- and post-adjustment manuscripts, but also interviews conducted both before and after the shift. We were able to document that the minor adjustment of perspectives can be reasonably considered an exemplary case of at least two *liminal thresholds* crossed simultaneously, one with regards to teaching in an open schooling setting, the other with regards to learning in such settings.

In terms of teaching, the teacher's decision had not come out of a void but grown from within a collaborative open schooling design which placed the school and out of school actors into a situation of shared, open-ended, and non-hierarchical inquiry on one specific socio-scientific issue. The teachers found themselves at a particular liminal threshold, namely that between mediating between out-of-schools experts on the SSI and his learners. They began to interpret their teaching role as an active and involved mediator between a variety of knowledge arenas, skills, and experiences. The teacher went to great pains to establish an atmosphere of collaboration and shared inquiry. Through their mediating efforts, expert knowledge became far more accessible to his learners. Meanwhile, the experts were given the opportunity to collaborate closely with the learners and to witness as learners slowly – across the longer iteration – began to express that the particular SSI in question was gaining *broadened significance*. This is where the first liminal threshold overlaps with the second, which concerns learning.

If, as we suggest in D5.3, we can theorize learning as fluid, performative processes or events between individuals and collectives, precisely as broadening domains of significance – if, in other words, we can consider learning events through a narrative lens –, then it becomes possible for us to inquire into specific transformative moments in such processes or events, precisely liminal thresholds that needed to be crossed for a certain event to unfold, a certain horizon to open that would have remained closed otherwise. In this case, the moment of shifting from "them" to "we" was such a moment. In descriptive terms, the students were invited to reconsider the fish, no longer in a purely subject-object relationship, but in a subject-subject relationship. This went along with an invitation

by the teacher to allow additional ways of knowing into the script: additional, that is, to the familiar and more straightforwardly 'scientific' way of relating to those sentient beings as 'objects of study'.

In both the scripts composed afterwards, in interviews, and also during the film premiere, the students gave various expressions of the critical threshold they had crossed then. Some originally described the change as 'weird'. Several had begun to mix into to their scientific descriptions moral reflections, with some of those coming across as sharp critiques against 'the humans'. Some articulations developed a downright activist tone, that is, a sense of caring coupled with clear expressions of having become mobilized – and wanting to mobilize others – as a result of having crossed this liminal threshold.

In terms of the model, the teacher's intervention can be described as a moment of 'meaningful disruption', of course.

8.4. Discussion

The case is specific, localized, and concrete, but it speaks to the potential of thinking more carefully into the role of disruptive elements in teaching and learning, and to the ways in which such meaningful disruptions can push – nudge – assist – guide – empower – authorize teachers and learners alike to choose to step across liminal thresholds. Meaningful disruptions – at any scale, even at so microscopic a scale as changing a personal pronoun in a piece of shared writing – can trigger cascades of transformation across the various impulses here described, from values & worldviews to structures & systems to practices (and forward). Change here is holographic; it is the name given to developments which can happen through countless fractal interventions at all scales and levels of complexity.

Importantly, the transformative moments here described as 'liminal thresholds' are not linear in character, and they cannot be described as 'mechanisms'. They are systemic. They are inter-relational. They are events in larger and more complex events. They are impulses where a given status quo – an equilibrium – is tipped out of balance – into a disequilibrium –, whether consciously or unconsciously. When that happens, stakeholders must reorient inside novel terrains. They must take risks that were unnecessary prior to the disruption. Reorientation can take the form of negotiating language anew, or collaboration with peers. It can take the form of opening moral dilemmas that had remained invisible or irrelevant prior to the disruption. It can take the form of reconceptualizing a given socio-scientific issue in a novel light, one which demands that stakeholders articulate more explicitly their own standpoint. It can take the form of enriching 'scientific knowing' in a more traditional sense with artistic or literary ways of knowing. It can take the form of clearing paths of thinking or ways of action which had remained unclear prior to the disruption.

Importantly, our model still shows that a threshold crossed in any impulse or area of transformation – whether it concerns values & worldviews, structure & systems, or practice – can ripple onward across these various areas, taking a variety of forms and expressions as it moves fluidly between and across these.

Growing an awareness of such liminal thresholds in teaching and learning scientific literacy can mean to prepare for the possibility to master the dynamics of becoming change agents. That is because it can help understand more concretely the specific dynamics of change in any given knowledge system, value orientation, socio-political structure, or practical habits or skills. And it can help stakeholders locate themselves more ably – and, indeed, more caringly – within such dynamics. We still think of such an ability as agency.

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