PART 3

Systemic Change

CHAPTER 8

Regional Networks and Ecosystem Learning

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Abstract

The chapter addresses homeostasis and novelty on an organizational level. The successful Dutch regional networks (in Dutch: voortgezet onderwijs–hoger onderwijs netwerken) may serve as a best practice in Europe, and are strongly supported by the Ministry of Education and the National Platform Science & Technology (Platform Bèta Techniek). The Northern Netherlands Regional Network (in Dutch: Netwerk Noord), one of eleven Dutch regional networks, covers three provinces and brings together five universities, forty schools and a number of companies, reaching out to over 5000 pupils and 300 teachers with a yearly agenda of formal and informal learning activities with a strong local identity. The Dutch network approach has grown from one of the world's highest performing educational systems, that of the Netherlands. As the OECD stated, 'the excellence of the Netherlands is evidenced by its strong average performance and few low performers in the Programme for International Student Assessment (PISA) the Survey of Adult Skills (PIAAC). A leading principle in the Dutch educational system is how it balances a remarkable degree of freedom at the level of schools alongside strong national accountability mechanisms. And it is this that enables new balances of homeostasis and novelty. The chapter will critically discuss how a regional collaboration developed over the last ten years and describe the overall short term, medium, and long term impacts against a theoretical backdrop provided by OECD and (the former) Noyce foundation key publications.

Introduction

This chapter addresses homeostasis and novelty from a practical viewpoint, exploring the idea of regional networks and collaborations of schools, universities and other educational providers to design rich and comprehensive learning environments. Especially for those school systems where the curriculum has to meet rigid national regulations, homeostasis or the business-as-usual scenario, can be rather suffocating. For such schools, the possibility of engaging

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in extra-curricular and/or out-of-the-classroom learning environments offers much novelty. In this chapter, I argue that local networks may be helpful or even conditional to developing such environments and are also a possibility in responding to changing circumstances in short time frames.

The topic is explored mostly at an organizational level, discussing the practical experiences of many schools in Europe, and their networks with local education providers. What reasons lay behind regional networks? What organizations can have an added value? What theoretical framework can tie them together? How can the networks assure the quality of their work and what may learners gain from it? In responding to the questions, I introduce the successful Dutch regional networks (in Dutch: voortgezet onderwijs–hoger onderwijs netwerken also known as vo–ho netwerken) as a good practice for Europe, relate it to the concept of ecosystem learning and place it in a wider international context.

Dutch secondary and higher education has proved time and again to be a laboratory for educational renewal. Some innovations were driven by large political ideals, as for example, education as an instrument for social inclusion: the infamous long lasting discussions about the so-called middle school, or middenschool, forty to thirty years ago. Some innovations were introduced as outcomes of educational research (learner centered teaching) while some others were introduced by economic urgency. The campaign to address the low enrollment in Dutch STEM studies – science, technology, engineering and mathematics – is an example of the latter. Declining enrollments in STEM studies are described in many industrialized countries; in the case of the Netherlands the low enrolments were among the lowest (OECD, 2017).

What followed was a range of innovations with government support more or less between 2003 and 2015, to make science education more attractive and raise STEM enrollments in higher education and vocational education. Though in secondary vocational education (in Dutch: vmbo and mbo) large STEM related challenges still remain, the national innovations have proven a success in pre-university education and higher education. Between 50 and 60 percent of secondary education pupils choose science tracks in school now, and the enrollments in STEM studies have risen substantially. Some individual degree programmes in university have doubled or even tripled their intake over the last fifteen year. In the recent Strategic agenda education 2015–2025 the Ministry of Education no longer mentions low STEM enrollments as a major concern. But still, as the OECD states, Dutch STEM enrollments are low in international comparison. The STEM innovations ranged from renewal of the science curriculum in primary and secondary education to the introduction of cross-over degree programs in higher education, such as industrial engineering and molecular science and technology. This went together with growing media attention for science and engineering emphasizing positive values like the relevance and innovativeness of these disciplines.

Over the years, the choice to study itself has been analyzed more deeply by a number of researchers in the Netherlands. Torenbeek, Jansen and Hofman (2011) found that on average, almost a third of the students in OECD countries withdraw from higher education before obtaining a diploma. In that study, the researchers explain first-year success at the university level by focusing on the transition from secondary school to university, considering student characteristics and teaching approaches in secondary and higher education. The researchers do not focus on science students in particular, but their analysis informs us about the process of the choice to study itself and what drives students to successfully start and complete degree programmes in higher education. Korpershoek, Kuyper, van der Werf, and Borsker's (2011) research, on the other hand, does focus on science students. Their research addresses a group that has not made the likely choice to study science. These students possess a considerable amount of 'science talent,' but have not enrolled in advanced math/science courses in secondary education or if they did, have not opted for a science oriented study in higher education. The researchers explain the difference between science students and these 'science talents' with respect to ability, personality traits, study behavior and attitudes, also with attention to sex-differences.

In other industrialized countries such as the UK, Sweden, Finland, Italy and Germany, similar innovations developed, though not as ambitious as that in the Netherlands. Here, all education sectors were involved. National coordination, funding, local knowledge and good practices were carefully balanced. A striking similarity in a number of countries is the growth of local or regional networks of education providers, which is the very reason to explore these networks in this chapter. Some authors refer to 'ecosystem learning' for such networks, while others reject this name as not being scientific; but regardless of the name, these open-schooling or 'ecosystem' collaborations have proven relevant. For example, there is the national education policy of the Netherlands and a number of large international innovation projects stretching all over Europe.

The concept of a STEM learning ecosystem is described clearly by the former Noyce Foundation – created by the Noyce family to honour the legacy of Dr. Robert N. Noyce, co-founder of Intel. In two reports by Traphagen and Traill (2014) the Foundation explains a learning ecosystem as collaboration that 'encompasses schools, community settings such as after-school and summer programs, science centers and museums, and informal experiences at home in a variety of environments that together constitute a rich array of learning opportunities for young people. A learning ecosystem harnesses the unique contributions of all these different settings in symbiosis to deliver STEM learning for all children. Designed pathways enable young people to become engaged, knowledgeable, and skilled in the STEM disciplines as they progress through childhood into adolescence and early adulthood.

In practical terms, this chapter discusses why and how a regional collaboration may develop and prosper against the homeostatic pull of traditional approaches. It describes short, medium, and long term impacts against a more theoretical backdrop to help schools and other education providers further regional networks and inspire education researchers to analyze and support this relevant novelty.

Sense of Urgency

Europe faces systemic challenges in many areas. Political instability and social exclusion loom while at the same time the European Environment Agency[1] warns that recent analysis shows the strong interdependence between the resource use systems that meet Europe's need for food, water, energy and materials. Looking ahead, climate change impacts are projected to intensify, and the underlying drivers of biodiversity loss are expected to persist. Utilizing resource-efficiency within a low-carbon economy, the call for action remains very strong, although some short-term trends are more encouraging. And another major concern, health, especially that of an ageing population as well as possible unexpected effects of climate change, definitely need to be addressed knowledgeably.

As Jasanoff (2003) argues, it is our challenge to educate young people so that they may live democratically with the knowledge that our societies are inevitably 'at risk.' To grasp what this 'risk' means and what essential, though limited, contributions of science and technology there are, we are highly dependent on thorough scientific education for the young and a public understanding of science for a wider audience. Our future depends on how we handle very complex and life threatening challenges such as climate change, renewable energies, or biodiversity. Our contemporary societies, our health and well-being all require truth and fact and logic to be the basis of our collective decisions and actions.

We find that even countries with a strong academic culture such as the United Kingdom, report a clear deficit among the general public concerning their attitude to science. A public attitudes to science survey in the UK reported

45% of respondents over 16 feeling aware of science in general and 51% stating they received too little information. A study led by the Wellcome Trust found that public engagement is more firmly embedded in the context of the arts, humanities and social sciences than it is in STEM (TNS BMRB & PSI, 2015).

Education is at the root of societal development – social or technological – and science education especially is essential in a knowledge society. Therefore, this chapter aims to provide an example of novel, successful science education collaborations between schools and other education providers to foster the drive, ability and creativity we need to shape our future. And this future asks us to pursue a high level of scientific literacy for students as well as what many refer to as 21st Century Skills (such as critical thinking, problem solving, digital and communicative skills).

The uniqueness of the regional networks is that they may shape learning for pupils and their families and caregivers taking local circumstances into account. This is definitely a novelty compared to possibly important, but nonetheless slow and more distant national reform within the homeostasis of the regular curriculum. This scientific literacy of course may vary according to national and regional contexts. It's this sense of urgency that calls for the exploration of new ways of teaching and learning, in the classroom, and out-of-the-classroom. The out-of-the-classroom settings invite many more institutions than our traditional schools and universities to contribute to education, raising all sorts of questions about organization, objectives, learning methods and merits.

Policy framework

An outspoken international context for these developments is also found in a number of European policy plans. A defining policy framework for science communication and education is set by the massive EU Framework Programmes for Research and Technological Development, such as FP7 (2007–2013) and Horizon 2020 (2014–2020). The H2020 specific programme *Science with and for Society* chapter aims to: (a) build effective cooperation between science and society; (b) recruit new talent for science; and, (c) pair scientific excellence with social awareness and responsibility. Open schooling or ecosystem learning addresses these three aims effectively, as follows:

– Regional networks build, sustain and disseminate collaborations in STEM learning ecosystems: regional networks that bring schools, universities, science centres, cities and industry together to foster science learning for European citizens.

– New talent for science is won by engaging learners in cutting-edge research with immediate relevance for global and local Sustainable Development Goals (such as food, health, water, energy), presented in regional learning environments with ample presence of scientific female and male role models.
– Scientific excellence is implicitly and explicitly paired with major social challenges identified by the local communities that shape the networks, and so it gives practical meaning to Responsible Research and Innovation. By involving industry and innovative SME's in the STEM ecosystems, learners are introduced to innovative practices that will spark future career choices.

Building on these principles, the regional networks relate to four out of six recommendations in the leading EU-report Science education for Responsible Citizenship (EC, 2015):

a Science education should be an essential component of a learning continuum for all, from pre-school to active engaged citizenship;
b the quality of teaching, from induction through pre-service preparation and in-service professional development, should be enhanced to improve the depth and quality of learning outcomes;
c collaboration between formal, non-formal and informal educational providers, enterprise and civil society should be enhanced to ensure relevant and meaningful engagement of all societal actors with science and increase uptake of science studies and science-based careers to improve employability and competitiveness;
d emphasis should be placed on connecting innovation and science education strategies, at local, regional, national, European and global levels, taking into account societal needs and worldwide developments. These recommendations are directly addressed in this chapter as:
  – Regional networks may foster learning continuums through cross-sector collaboration of regional stakeholders in sustainable networks with an emphasis on young people, primary and secondary pupils, exploring a fundamental change in education.
  – Regional collaborations support the quality of teaching by building much richer learning environments that bring together the best of formal, non-formal and informal learning and challenge, equip and support teachers, and staff in informal and non-formal education to integrate these.
  – Innovative network governance beyond traditional leadership is recognized as key in open science education; insights from complex systems and network theory are applied to cultivate their growth to excellence.
  – Bottom-up renewal strategies that meet regional challenges go hand-in-hand with national educational policies to support such initiatives. For example via local workshops to draw up regional cross-sector science

education policy agendas as frameworks for regional science education calendars.

In the following sections I'll introduce the bottom-up development of regional networks, drawing on one of the world's highest performing educational systems, that of the Netherlands.

Dutch Education and the Development of Regional Networks

NUFFIC, the Dutch organisation for internationalisation in education, describes the Dutch system as follows. It consists of eight years of primary education, four, five or six years of secondary education (depending on the type of school) and two to six years of higher education (depending on the type of education and the specialisation). Both public and private institutions exist at all levels of the education system; the private institutions are in most cases based on religious or ideological principles. In higher education a distinction is made between research-oriented education (wetenschappelijk onderwijs) and higher professional education (hoger beroepsonderwijs). This difference in orientation has continued to exist even after the introduction of the bachelor's-master's degree structure in 2002.

The Ministry of Education is responsible to a large extent for the financing of the education system, defines the general education policy and specifies the admission requirements, structure and objectives of the education system on general lines. At all levels (primary, secondary and higher education), there is a general trend towards fewer rules and regulations, so that institutions can break away from the general lines, away from homeostasis – so to speak, and take responsibility themselves for the implementation of government policy or even go beyond that, as described in this chapter.

A leading principle is that the education system in the Netherlands balances a remarkable degree of freedom at the level of schools alongside strong national accountability mechanisms. This freedom also plays a large role in the development of local networks as it leaves schools and other stakeholders wiggle room to develop networks that reflect regional characteristics. To shape open schooling collaborations where stakeholders from education and research, industry, local authorities and civil society find each other in a wide variety of contexts, the former one-size-fits-all (homeostatic) approach would fall short.

Regional SE-HE Networks

In 2003 the Dutch government launched an ambitious innovation programme to stimulate STEM studies. Backed up by the national *Science and Technology*

Delta Plan specific programmes were developed in all education sectors. The annual innovation budget climbed up to over 60 Million euro nationally in 2010. A growing number of universities and universities of applied sciences set up regional science networks, together with secondary schools. Special attention was given to high-quality education, career prospects and a good throughput. The ministry of Education strengthened and supported these networks with programs such as *Universum* (2004–2010), *Sprint* (2004–2010) and *Sprint-UP* (2007–2012).

Together with the introduction of new multidisciplinary subjects (natuur, leven en technologie) in secondary schools, bottom-up regional support centres for pupils and teachers were established. In other science subjects similar structures were initiated or strengthened, most often under the name of regional school networks (regionale vo-ho netwerken). A unique feature of all these networks, using the already mentioned freedom in the educational system, is that they were developed bottom-up, without any shared blueprint. This is where the theme of this book comes in; this is where homeostasis and novelty are balanced at a regional or local level. The Dutch regional networks have grown from the priorities of the local stakeholders. A necessary precondition was that stakeholders shared the above sense of urgency, and connected with each other with the aim to strengthen STEM studies. And the Ministry supplied reasonable innovation funding with a rather open character. As a result of the networks, secondary and higher education worked together with increased intensity, shaping a chain approach in education.

The Dutch networks consist of a varying number of secondary education teachers, teacher educators, researchers and businesses to support and supervise the professional development of teachers. They also introduce subject innovations and the exchange between teachers in secondary and higher education. The networks develop activities with three dominant characteristics:

a Continuous learning between secondary and higher education (and the business world) and orientation towards studies and career. Examples include masterclasses, science labs, web classes or junior/pre-university lectures for pupils. The subject content furthers the orientation towards studies and career.
b Subjects and curriculum innovations in secondary education. Exchanges and teaching material development by teachers take place in teacher development teams and professional learning communities. School teachers, (science) teacher educators, teacher training schools and the business community come together in these.
c Professional development of teachers, technical education assistants, school management and academic staff. Examples include

subject-related and didactic courses for teachers relating to subject innovations, or meetings for school heads and team leaders on themes such as interdisciplinary education, 21st-century skills, and the role of technology tools.

There are now ten regional networks in the Netherlands. Together, the networks provide almost full national coverage, and they enjoy broad support. Twenty-two universities of applied sciences, twelve universities and 350 schools (some 60% of all pre-university institutions) are contributing. The government also shares in the costs. Each year, the activities reach more than 27,000 pupils and 3800 teachers. Nationally, the ten networks are also part of an overarching consultation body. This national council (Steunpuntenraad) is therefore a network of networks. The Steunpuntenraad has developed over the years into a platform for the exchange of cross-regional collaborations, the exchange of good practices, and peer learning.

Peer learning as a way of quality assessment has been adopted by the ministry as a demand for the future funding of individual learning networks. The national council meets a limited number of times a year; each network sends a delegate. The chairmanship rotates among the member networks, and the council is supported by the national body for curriculum development, the Stichting Leerplan Ontwikkeling (SLO).

Local collaborations #1: Weizmann Institute of Science, Israel

To develop their awareness about renewable energy sources, students visit the Weizmann Institute's outdoor science park, the Garden of Science, to learn about alternative energy and participate in an experiment on dye-sensitized solar cells. Then in school they discuss a question that is relevant to their real life: "would they agree to replace the windows in their school by photovoltaic cells?" Based on the knowledge they gained in the visit, they further explore this question and create exhibits to address this question. These exhibitions are presented at their schools to their fellow students. Selected exhibits are presented in Garden of Science.

Funding

Given the wide support for the networks and the importance of regional chain cooperation, the Ministry of Education, Culture and Science developed specific programmes between 2012 and 2017 to support networks financially to further strengthen the established chain approach, and make them sustainable. The goal was for networks to strive for independence, supported by local stakeholders only.

Funding for the networks involves three investing parties. Two of these are higher and secondary education. In the case of the schools, there is usually a contract with fixed membership contributions. The level of this contribution varies per network, per region. The third investing partner is the national government. At the time of writing, assessments are being made as to how development can take place from a more sustainable (organisationally and financially) perspective from 2018 forward. In the next sections I'll introduce a methodology and a framework to describe and develop open schooling or 'ecosystem' collaborations and describe how these provide a sense of novelty.

Concept and Methodology, Coordination and Support

Schools, science centers, universities, local communities, companies, libraries and fab labs just to mention some providers, already offer a rich variety of in and out-of-school science education opportunities. The above school networks offer a foundation for further and much richer networks. But despite social and economic needs, many rich bottom-up initiatives still are fragmented and unstructured. This fragmentation stands in the way of incremental quality improvement. Science education stakeholders together can be seen as an ecosystem where diverse relationships tie many species together in strong interdependence. But where an ecosystem resists change and remains at a homeostatic equilibrium, our cities and regions require more effort in science education to improve effectiveness and meet local and global sustainability goals, as they grow to excellence.

This calls for a methodology that invites regional stakeholders to define common goals and foster 'open-schooling' or ecosystem learning that brings formal, informal and non-formal education together, tailored to students, families and the general public.

We define formal, informal and non-formal education, following a fair degree of consensus in the literature, as:

– Formal learning is always organized and structured, and has learning objectives. A typical example is learning that takes place in primary and secondary schools.
– Informal learning is never organized, has no set objective in terms of learning outcomes and is never intentional from the learner's standpoint. Often it is referred to as learning by experience or just as experience. An example is the learning environment one is exposed to by individual free-choice visits to a science center.

– Mid-way between the first two, non-formal learning is the concept about which the least consensus exists. Most authors describe it as rather organized and possibly having learning objectives. Examples are visits, projects or courses a learner engages in at community centers or fab labs.

To steer STEM collaborations to excellence one could embrace a range of proofs of concept. In its essence a methodology was already present in large scale European projects, where cross-sector communities of learners (Communities of Learners: teachers, science center educators and industry) developed rich science teaching materials with strong societal relevance accompanied by teacher training programs.

The STEM Ecosystems Report outlines how the above approach can be replicated from individuals who work together in a community of learners, to organizations that collaborate in STEM ecosystems. As such, it 'builds capacity' for the region. I endorse the logic model of Traill and Traphagen (2015):

– establish and sustain cross-sector partnerships to cultivate ecosystems,
– create and connect STEM-rich learning environments in rich settings,
– equip educators to lead active learning in diverse settings, and
– support youth to access pathways and exploration to further learning and careers.

This approach benefits science education stakeholders: pupils and the general public who take part in activities. It has the potential to support these stakeholders in shaping community well-being. The novelty here is in the network structure that offers more room for individuals or organizations to engage in science subjects, academic or professional skills or societal interests than the structured learning environment in a school can. For the learner, the variety of learning styles or preferences that can be accommodated is much wider.

Local collaborations #2: University of Groningen, The Netherlands

A yearly training for STEM teachers to develop sustainable cooperation between schools and industry in the North of the Netherlands: as part of the training, school teachers visit companies in the region and meet the professionals who work there. Teachers gain knowledge about the newest technology and innovations, and learn how to use this in their lessons. As a result, teachers can provide their students with up-to-date knowledge and challenging education. In this way students can cultivate an interest in the natural sciences and its applications in school. And the students get a better picture about the jobs in industries, and the skills required.

The three recent examples of collaborations highlighted in the text boxes, give examples of the variety of local collaborations.

A Step-by-Step Methodology: From Regions to Countries and Beyond

Building on the model proposed by Traill and Traphagan (2015) and combining it with the experiences in the Dutch networks, I suggest the following approach to further regional learning networks:

– bring together regional stakeholders – among them schools and companies, to establish regional networks as touchstone collaborations of schools, universities, cities, science centers and industry in regions;
– have regional networks each articulate a regional science agenda and set a science education calendar, culminating in tracks integrating formal, informal and non-formal learning to meet specific regional demands and at different educational levels;
– provide professional development (guides, workshops and webinars) for teachers in formal, non-formal and informal education to use their regional learning environment to the fullest;
– provide a network governance toolkit (whitepapers, workshops and webinars) for present and future network facilitators to support their work to grow to excellence;
– assess the impact of the networks beyond the mere economic value: measure the social value created;
– establish and supply innovation nodes to encourage and support the formation of new regional networks;
– disseminate the STEM networks through existing professional networks, such as NARST, ECSITE or ASTC, to wide international advantage;
– propose evidence-based recommendations for effective models of cross-sector collaborations of education providers (formal, informal and non-formal) in a variety of cultural contexts.

For interested stakeholders it can be difficult to initiate a network; where to begin? There is no theory of learning networks yet, no proven method to follow. The above approach doesn't require establishing a full-grown network right from the start, it offers a model for organic growth, starting small with only a few interested partners, and only one or two subjects. In the first two steps partners can thoroughly explore who actually makes up their science education region by facilitating a structured regional open dialogue with leading stakeholders. A network preferably is composed of stakeholders from different sectors, as in Figure 8.1.

The partners and stakeholders involved represent (local) networks of schools and/or schools and industry, universities, museums and science

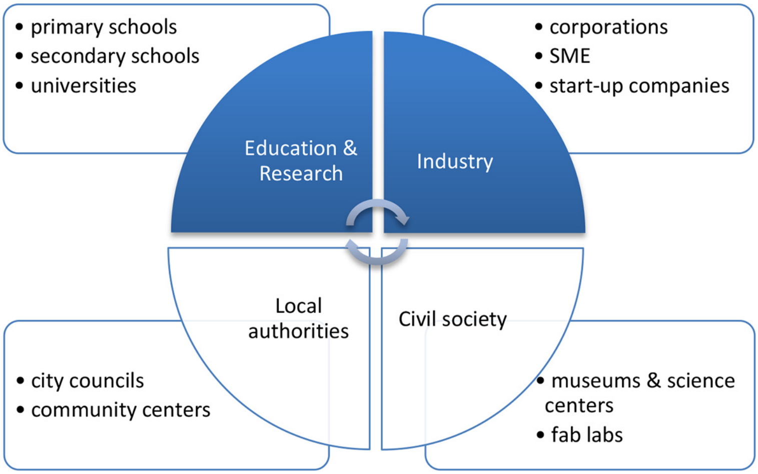

FIGURE 8.1 Possible partners and third parties in a learning network, by sector

centers, or for example Cities of Science.[2] Of course the involvement of schools is fundamental, and usually only a local university can provide the resources necessary to coordinate a learning network.

The expertise of the network partners together ideally encompasses student and teacher oriented activities, ranging from science festivals, science cafés and participatory events, continuous professional development, developing blended learning materials (e-learning and face-to-face) and bringing informal learning into the classroom and formal learning to museums and science centers.

In order to build the network, stakeholders should engage in mapping their interests and developing a shared science education vision to join forces in annual regional science calendars. These calendars lay out the formal, non-formal and informal education activities provided in the region, i.e. the ecosystem. Different activities may be aimed specifically at pupils, teachers and management.

Local collaborations #3: University of Lisbon, Portugal

The city of Mafra hosted an exhibition "Geoengineering" developed by students of a local school, integrated in the World Children's Day commemoration. This annual event is developed by the City Hall and has wide media coverage by the largest local radio (RCM). Students, teachers and university researchers were interviewed to explain the idea of Responsible Research and Innovation. The Lisbon Institute of Education also contacted Portuguese International Broadcasting to further dissemination.

A key element for the implementation of activities is the formal/informal educators' support. A professional development programme can be shaped bottom-up through Communities of Learners (CoLs). Communities of Learners have proven to be a powerful means of training educators (Louck-Horsley, Stilles, Mundry, Love, & Hewson, 2010).

Within a Community of Learners participants each have a different role: teachers have expertise working in the classroom; science educators have a large theoretical background about education; science centers have experience in informal learning activities; researchers bring in cutting edge science research and professionals from industry know about applications of STEM. Each Community of Learners might include four to five formal/informal educators, along with the researchers and professionals from industry. As indicated by Shulman and Sherin (2004) both experienced and novice educators can participate fruitfully in these communities. Special care has to be taken to allow the teachers to take part in the CoL. Most work in the CoL will be outside of normal teaching hours to accommodate differing schedules of the members. It may be necessary to ask for specific measures in regions to allow teachers to participate.

The topics for innovative learning materials follow from a regional science education agenda. Reform recommendations call for introducing learners to cutting edge research in local universities and industry to show what is often referred to as 'science in the making.' Cutting-edge scientific and technological matters highlight developing science that is preliminary, uncertain, and under debate. The controversial dimension refers to "differences over the nature and content of the science such as the perception of risk, interpretation of empirical data, and scientific theories, as well as the social impact of science and technology" (Levinson, 2003).

Building on these foundations regional networks can stretch their reach and offer educational services at different levels and advance networks in other regions. A network may involve science centers and museums credibility in their regional or national community to develop an innovation program to support new generations of network facilitators. In this way, new networks can expand over a country.

When more than one network exists in a country another opportunity comes up; it lays the groundwork for a form of quality assurance. A network of networks is more sustainable than single ones. The Dutch example shows how project partners benefit very much from organized peer learning – learning from experiences of other networks – and align their local networks, copy grassroots practices from each other, making the networks more efficient and effective.

What Might Be the Impact of Learning Networks?

Learning networks or ecosystems enable non-formal science education to have impact on the education system. Through local networks the homeostatic tendency of regular formal education systems open up to a variety of other education providers. Table 8.1 specifies earlier work by Traphagen and Traill (2015) and gives an overview of the wider impact for networks, the main barriers or framework conditions that determine the expected impact are listed in the following table.

Table 8.1 sums up the potential far-reaching potential of local networks. These are only possible by building on existing best practices, monitoring and carefully adjusting progress to local circumstances, and through a step-by-step approach: first it identifies regional stakeholders and good practices, then it develops a regional policy agenda – taking into account relevant regional and national regulations and policies, and only then sets a regional science education agenda with learning activities. This regional approach is the key to success. Cooperation with secondary schools and vocational institutes for example, is largely determined by proximity. Intense relationships are mostly found within the same geographical region.

TABLE 8.1 Impact of a regional network, overall, and short term to long term

	Expected impact	**The network approach fosters this by**
Overall	The creation of new partnerships in local communities to foster improved science education for all citizens.	The collaborations will lead to cycles of recurring activities that can be embedded in the governmental structures in that region.
Short term	The development of new partnerships between schools, local communities and local industry should contribute to a more scientifically interested and literate society and students with a better awareness of and interest in scientific careers.	Local working plans, objectives and collaboration agreement(s) Evidence of initial financial and human capital support Secure stable financial/human capital support for infrastructure and evaluation of the partnership

(*cont.*)

TABLE 8.1 Impact of a regional network, overall, and short term to long term (*cont.*)

	Expected impact	The network approach fosters this by
Medium term	Activities should provide citizens and future researchers with the tools and skills to make informed decisions and choices.	Following from the regional science education agenda, resources and policies supporting cross-sector work are institutionalized Better resources and spaces to facilitate scientific inquiry, engineering design, collaboration, and problem-solving Articulated pathways guide pupils to higher education in STEM careers and engage a wider audience in STEM subjects Increased parent/family involvement and support of their child(ren)'s pursuit of STEM learning
Long term	Increasing the numbers of scientists and researchers in Europe.	Measurable population level improvement in STEM learning and engagement outcomes for young people Increased understanding by youth and parents/caregivers of the requirements and pathways to pursue STEM careers Increased self-identification of youth as scientists Increased parent/caregivers and educator support for youth in pursuing STEM interests in different settings Increased number of students persisting along articulated pathways and succeeding in post/secondary education and careers Increased understanding among youth and families of the importance of STEM skills and literacy for Europe's grand challenges, even for those not choosing a STEM career

Short-term framework: New local networks are best started with limited numbers (a dozen, with the intention to expand) of highly motivated schools and other education providers. The innovation projects mentioned earlier illustrate that it is not necessary or even desirable, to try to involve all possible regional actors. It's best to build collaborations that prove their added value year after year, exploring promising initiatives, expanding good practices, keeping close contact with education institutes, and education providers (teachers and communities of learners). This can be set out by local working plans that describe how to progress and develop a regional science education agenda to secure stable financial/human support for the partnership.

Medium-term framework: New collaborations risk having a volatile character as there is no shared history yet. As a result, regional actors don't fully embrace ownership. But European and American experiences show how an ambitious setting feeds a dynamic of new partnerships to the advantage of local stakeholders. The leading power of universities and city councils is not to be underestimated here. As robust organizations rooted in their region they can 'make or break the game' of new collaborations.

Long-term framework: The evidence for success of the Dutch networks has been shown, (among other things) to increase in the number of pupils opting for science subjects in pre-university education and the enrollments in STEM programmes. The infrastructure of the regional networks in the Netherlands was also used for updating individual science and technology subjects; it encouraged the top talent in motivated STEM pupils; it introduced new science and technology examination programs. The long-term impact, or the outcomes of the networks, will always be a complex and dynamic combination of the multiple initiatives in and outside the project, beyond the first vision. With this impact the regional networks show themselves as a "tool" with strategic impact and cost effectiveness: a novelty in itself among the usual high costs of change.

Governance of Networks

In the last section I discuss a few ideas related to implementation and governance of network programmes to encourage network learning and capacity building for quality science education improvement. In doing so, I emphasize specific crucial concepts: cooperative culture, diversity, openness, autonomy, and meta-networks.

To create spaces of dialogue for learning networks where different stakeholders find each other a one-size-fits-all approach would fall short. Rigid governance would frustrate these diverse and complex systems. The network approach builds a shared vision and goals in the regional networks, fostering open exchange and co-creation. It provides continuous monitoring and peer learning, strongly supporting actors to reorient and align their activities for a regional science education calendar. The leadership required to build regional ecosystems with innovative governance therefore has to embody the spirit of innovation and 21st century key understandings such as agility and network learning. Social systems theory lists three principles as essential for stable and alive complex systems: diversity, openness and autonomy.

Contrary to projects where only strictly defined roles ensure efficient implementation, the strength of networks or ecosystems lies in redundancy and its dynamic nature, allowing creative, flexible and adaptive processes. Network facilitators have to see to it that differences between partners are appreciated so that a dynamic between network stakeholders can develop. This is why existing and new networks should carefully balance clear accountability at the level of the network with room for cities or regions to define local science education objectives and have schools and other education providers act upon it. A network only builds a cooperative structure by understanding different interests of the partners and making them a principle of the work. The goal is a collaboration where all partners contribute according to their individual strengths and abilities, while at the same time receiving incentives for their own activities. This asks for a culture of openness and mutual trust, where differences become useful for co-operation and are transformed into synergies.

Through guided self-organization individual stakeholders are supported to find added value in the network. A network pursues well defined collective goals, but also fosters room for a collection of individual goals for stakeholders or groups of stakeholders. The coordinator has a task in understanding individual differences, monitoring developments in and outside of the network and providing impulses for new initiatives. For example, by supporting stakeholders as they connect and engage in evaluation and peer learning, they can appreciate the expertise of each in ways that can include organizational or financial support. As the infrastructure of the regional networks is very suitable for connecting with other programs and themes, networks can grow to regional meta-networks. In other words, ecosystems in the region are structured so that relevant partners repeatedly encounter one another, and they can achieve things rapidly on the basis of existing relationships.

Regional Networks and Ecosystem Learning – The Novelty?

For more than ten years many regional networks proved themselves trustworthy frameworks for regional cooperation between secondary and higher education and other providers. In the Dutch case three characteristics were always there: (1) continuous learning of pupils and students between secondary and higher education and other partners, (2) subject and curriculum innovations in school, and (3) the professional development of teachers and school management.

The effect of this chain approach has been shown, among other things, by the increase in the number of pupils opting for science subjects in pre-university education and higher enrollments in STEM programmes. The Dutch learning networks proved themselves an example to follow, together with many other examples all over Europe. When considering the young, schools are the foundation of a learning network. They have to own their agenda in the dialogue with universities and others to develop education for their pupils. In this, they are embedded in a social assignment – the needs of the region and its labour market. Each region, and school and teacher has different needs, after all.

The role that these networks can have in training teachers is unequaled, ranging from support for beginning teachers or novices to peer-to-peer learning for experts, and in-depth research activities at universities or companies. Here lies the novelty of ecosystem learning:

- Students learn to appreciate the added value of STEM studies for society, through 'show – don't tell'.
- Students learn to appreciate expertise and skills of stakeholders in different domains, preluding future professional settings.
- Teachers learn skills and build networks to engage in a variety of learning activities beyond the classroom and as a result improve the quality of teachers and the attraction of the teaching profession; teacher training could come to reflect this.
- Partners learn to develop attitudes and skills for cross-border work, from education to libraries, companies and museums; reflexively new roles for libraries, companies, museums and other stakeholders require schools and universities to respond accordingly (capacity building).
- Partners find that networks are a springboard for future renewal. New initiatives may easily be fitted into an existing network to test and develop them and have them find their way to students, teachers and schools if they successfully fit needs.

Some networks, set up for science education, are now also inspiring arts, humanities and social studies subjects: general academic orientation, languages and business subjects. They are moving from STEM to STEAM, and connecting science, technology, engineering, arts and mathematics. The cooperative models developed in science and technology are gradually being expanded to other fields, an expansion where experience is now growing in all networks. Other opportunities lie in the cooperation with/expansion into primary education and vocational education, which also bears their own responsibility in this.

Learning networks or ecosystem learning brings together a number of rather fuzzy concepts such as informal learning, learning networks, and 21st century skills. Informal learning quickly has grown in importance over the last dozens of years, driven by a growing number of science museums and science centers with increasing visitor numbers. Though fully endorsed by the museum sector, for most educators in schools and universities informal learning is too fluid to trust for the key learning outcomes that have fueled the tendency to remain the same – the homeostatic tendency. Do learners acquire essential knowledge or skills? Can that be assessed? Do academic or professional attitudes develop, and if so is it sustained beyond incidental activities? And, as for the network learning systems themselves, even though there are a number of examples all over Europe, they are often specific for a region and possibly difficult to transfer. Are there common theoretical frameworks, key concepts and theory that can be used to understand and build sustainable collaborations for future learning? The developing learning networks in a great many countries would be helped by systematic study and analyses of the existing practices. The challenge of the systemic novelty of learning networks is the break from the comfort of the familiar and often well-established homeostatic structures.

Notes

1 Ministry of Economic Affairs and PBT (2016). Monitor – Fact and Figures Bètatechniek. Retrieved from https://www.pbt-netwerk.nl/media/files/publicaties/Techniekpactmonitor%202016.pdf

2 https://www.euroscience.org/news/next-european-city-science-host-euroscience-open-forum-2020/

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