Flanders
State of
the Art

DESCRIPTION OF STEM KNOWLEDGE NETWORKS IN EUROPE

DEPARTEMENT OF
EDUCATION & TRAINING

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STEM
SCIENCE TECHNOLOGY ENGINEERING MATHS

The authors of this report wish to point out that the present report merely aims to describe STEM networks in several European countries. The idea is to allow Flanders to draw inspiration from these descriptions in order to deepen and further develop its own STEM policy and STEM initiatives.

The educational context in which these STEM networks have been created differs by country and consequently reflects a large variety of initiatives and approaches. Therefore, they can by no means be transferred to the Flemish context automatically. In most European countries STEM knowledge networks have arisen from an educational context and primarily focus on education. The STEM Ac-tion Plan is not supported by the Department of Education and Training alone. The Department of Economy, Science and Innovation and the Department of Work and Social Economy are involved in it as well. That is why the authors consider it appropriate to also involve these three Departments in the establishment and implementation of a STEM knowledge network for Flanders.

The authors of the report expressly thank all these STEM networks for providing information. Com-pleting this study would have been impossible without their contributions. The authors draw atten-tion to the fact that it was very difficult to obtain financial information. When any such information was provided, it was in the strictest confidence.

Introduction

The growing importance of STEM education

Over the past 20 to 25 years there has been growing interest in STEM[1] education in most European countries, as well as around the world. The implemented policy usually had or has a twofold purpose: to promote science literacy among all young people (and even adults) and to attract young people to science and technology disciplines in secondary and higher education, with the intention of encouraging them to move into science and technology professions and/or research careers. The reason for this is the global shortage of STEM graduates. At the same time increased attention was devoted to STEM education for girls and young people with vulnerable socio-economic backgrounds.

Since the turn of the century several countries have implemented an education policy which was specifically aimed at promoting STEM, even from as early as pre-primary and primary school. European countries like Germany, Finland, France, Ireland, the Netherlands, Norway, Austria, Spain and the UK designed a national STEM strategy since the late 90s/early 2000s. Other countries or regions have since followed their example, such as Flanders, Malta, Latvia, Portugal, Sweden, Denmark, Lithuania and the Czech and Slovak Republics. In these countries the Ministry of Education often developed strategies to promote STEM in collaboration with other stakeholders like ministries of economy, scientific research and employment, the business community and civil society. Other countries did not establish a national strategy, but limited themselves to a STEM approach promoting only specific elements or sub-areas within STEM. A large amount of information about these STEM strategies can be found in two publications of 2011[2] of the European Commission's Directorate General for Education and Culture (DG EAC) and in the 2012 study of the Vlaamse Raad voor Wetenschap en Innovatie/VRWI (Flemish Council for Science and Innovation)[3].

In the years 2000, DG EAC set up a Thematic Working Group on MST[4] (Mathematics, Science and Technology) with 13 European countries to exchange information about their STEM approaches and STEM strategies, in view of supporting and improving policy implementation. Peer learning visits (PLVs) allowed policy makers to get to know the policies of other countries and to compare their own strategy with that of the host country. Since 2004 this expert group has published several reports. A lot of STEM projects were also financed within the framework of the Comenius Programme (transnational cooperation projects and networks) as part of the LLP Programme which ended in 2013 and was succeeded by the Erasmus Plus (Erasmus+) Programme.

Since the EU Sixth Framework Programme (FP6), and especially since FP7 within the framework of the Science in Society (SiS) Programme, DG Research & Development (currently called DG Research & Innovation, DG R&I) has supported a large number of projects promoting STEM education at school, and in particular IBSME (Inquiry-Based Science and Mathematics Education). DG R&I also received assistance from a European working group of national experts. In 2007 the report "Science Education NOW: A Renewed Pedagogy for the Future of Europe"[5], the so-called Rocard report, was published. This report laid the foundations for many European FP7 projects which widely promoted IBSME in STEM education.

1 STEM stands for Science, Technology, Engineering and Mathematics

2 Two publications on STEM by DG EAC
- Science Education in Europe: National Policies, Practices and Research
  http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133EN.pdf
- Mathematics Education in Europe: Common Challenges and National Policies
  http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/132EN.pdf.

3 2012 study of the Flemish Council for Science and Innovation: "Choosing STEM": http://www.vrwi.be/pdf/Choosing%20STEM.%20Young%20people's%20educational%20choice%20for%20technical%20and%20scientific%20studies.pdf

4 http://eacea.ec.europa.eu/LLp/events/2012/documents/comenius_thematic_cluster_meeting/new_session-3-ws4-seamus-knox.pdf

5 Science Education NOW: A Renewed Pedagogy for the Future of Europe, (Rocard report) 2007. More information is available at https://ec.europa.eu/research/swafs/pdf/pub_science_education/report-rocard-on-science-education_en.pdf

Within this framework several projects for the dissemination of IBS(M)E were financed, of which the Fibonacci Project was one of the most successful[6]. Initially, this project brought together 36 networks and institutions and, in the end, even 60. They all promoted IBSME and were able to deepen, improve, broaden and disseminate the IBSME approach through cooperation at the European level.

Over the past decade several STEM (education) networks have thus arisen in Europe which generally link up closely with the STEM policy, as well as support it. Most of these networks receive(d) government funding because they contribute to the implementation of the policy. They were gradually set up and extended, mostly from 2000 onwards. In 2015 the UTRECHT STEM Think Tank was established by seven of these networks with the aim of promoting collaboration to enhance the quality and impact of their activities. So far they have no website

European Schoolnet, i.e. the network of 31 European Ministries of Education, of which the Flemish Ministry of Education is an active member participating in various projects, seeks to stimulate innovation in education, and in particular in the fields of ICT and STEM. They engage in direct cooperation with ministries, but also with teachers, school management teams, teacher trainers and other education partners, like AHOVOKS[7]. To promote STEM. European Schoolnet also works closely together with the business and research communities. These past 15 years European Schoolnet coordinated over 30 large-scale STEM projects. Especially the FP7 inGenious project[8] on cooperation between education and industry for promoting IBSE in STEM education had a great impact on the approach to STEM. For several years now European Schoolnet has managed the SCIENTIX Programme[9] (2009 – 2015 and maybe until 2018) on behalf of DG Research & Innovation. This programme fosters good practices and cooperation between all the STEM actors in Europe. Finally, European Schoolnet stages the annual EMINENT conference where people in charge of STEM and IT within ministries meet. In 2016 a working group of representatives from ministries will also be set up within European Schoolnet, with a focus on STEM education. Flanders will be a member of this working group.

In July 2015 the new European report "Science Education for Responsible Citizenship"[10] was published which highlights six objectives for Science Education and mentions many good STEM practices, including several FP7 projects. The STEM Action Plan in Flanders is also mentioned as one of the good practices in this report. Hopefully this new European report will lead to new STEM projects within the framework of the EU Horizon 2020 Programme.

6 Fibonacci Project: Designing, implementing, testing and formalising a process of dissemination in Europe of inquiry-based teaching and learning methods in science and mathematics in primary and secondary schools. More information is available at http://www.fibonacci-project.eu/
7Agentschap voor Hoger Onderwijs, Volwassenenonderwijs en Studietoelagen (Agency for Higher Education, Adult Education and Study Grants)
8 FP7 inGenious project: It is a joint initiative launched by European Schoolnet and the European Roundtable of Industrialists (ERT) aiming to reinforce young European's interest in science education and careers. http://www.ingenious-science.eu/web/guest;jsessionid=C0139710404AECB-218B5C184E58DAD94
9 SCIENTIX: Scientix promotes and supports a Europe-wide collaboration among STEM (science, technology, engineering and maths) teachers, education researchers, policymakers and other STEM education professionals. More information is available at www.scientix.eu
10 Science Education for Responsible Citizenship, DG R&I, 2015. More information is available at https://ec.europa.eu/research/swafs/pdf/pub_science_education/KI-NA-26-893-EN-N.pdf

1. Initial Request and Methodology of the Report

1.1. Reason for the Request from the Department of Education and Training

The Government of Flanders has opted in favour of a strong focus on STEM (Science, Technology, Engineering and Mathematics). This policy is implemented in an integrated manner through the STEM Action Plan 2012-2020.

In the first three years during which the action plan was in force a lot of actions were already set up and results were achieved. This has led to an increased knowledge amongst the different stakeholders. However, this does not necessarily mean that the actions have become more visible for the intended target groups (teachers, parents, young people).

In its section on Economy, Science and Innovation the 2014 Coalition Agreement states that a STEM knowledge centre will be established. For this reason the STEM Steering Committee considered it important that a concise comparative study be carried out which would place some of the existing European STEM knowledge centres/knowledge networks in a comparative perspective (objectives/operating budget/impact/...).

In July 2015 the Department of Education and Training put out a call for a comparative study of several STEM networks, with the aim of gathering detailed information.

In this context the Horizontal Policy Division of the Department of Education and Training wanted a study which concentrated on the following elements:

1) a list, description, analysis and critical evaluation (best practices, critical success factors, reasons for failure, obstacles, etc.) of a number of existing European knowledge networks [11] (at least 5) which are mainly engaged in STEM

2) recommendations for a Flemish STEM knowledge network on the basis of this analysis, including concrete steps in terms of cost price, content, organisation and partnerships

3) forward-looking recommendations

4) introduction to a number of relevant services within European institutions which are dedicated to the STEM knowledge networks

11 The authors have decided to use the term "knowledge network" from this point onwards, since the concept "knowledge centre" is not used anywhere, as will be seen later in this text.

1.2. Educonsult Proposal Accepted by the Department

The proposal of Educonsult, which was accepted by the Department of Education and Training, proposed to describe and analyse the following 5 knowledge networks:

- the network of 11 Regionale Bèta-steunpunten (regional science support centres) in the Netherlands
- the National Science Learning Centre (York) and the regional partners plus the 52 Science Learning Partnerships of schools in the UK
- the network of 10 Maisons pour la science (Houses for Science) which is run by the Fondation La main à la pâte of the Académie des sciences in France
- LUMA Centre Finland with its national LUMA centre and the 13 regional LUMA centres in Finland
- the IMST (Innovationen Machen Schulen Top) initiative in Austria, coordinated by the University of Klagenfurt, Austria

In the end Educonsult decided to also collect information about two other knowledge networks:

- Scientiam Inquirendo Discere (SID), a network of 10 STEM pilot centres in Italy
- the MINT Forum which brings together some thirty organisations in Germany that work around STEM. The MINT Forum is actually a forum and network of independent networks and other STEM partners which join forces in several domains.

The present overview has been drawn up by comparing the mission, vision and concrete goals of seven (knowledge) networks and examining to what extent the partners structure their knowledge sharing. It was also studied whether the centres are only targeted at formal education or also at non-formal and informal education and how they interact with each other. In addition attention was devoted to the link these networks have with innovation and research and with the business community. The management structure, personnel, finances and reach of the networks were described as well.

As for the activities, it was studied which actions were set up by the knowledge networks: professional development activities (including blended learning) for various target groups (teachers, trainers, educators, head teachers, entertainers, etc.), the development of pedagogical/teaching materials, the provision of examples of good practice, the organisation of seminars, workshops for policy managers, the compilation of reports and publications for policymakers, etc.

It was also examined which connection the networks have with the government, a steering committee and/or science committee, industry and other stakeholders like higher education, research centres and science and technology centres (like Technopolis in Flanders).

Finally, quality assurance is discussed as well.

At the end of each description the strengths and special characteristics of the networks concerned are listed. After the description of the 7 knowledge networks conclusions are drawn on the basis of the networks' success factors. These conclusions may be an incentive for Flanders to consider the possibility of establishing such a knowledge network. The conclusions contain information about the creation, operation, finances, activities and evaluation of such knowledge networks. All these elements increase the sustainability of a knowledge network, especially when they are proactively considered in the planning.

1.3 Methodology

Within the framework of the contract the following interviews were organised by Educonsult (in the period from 15 October to 15 December 2015):

- Drawing up a questionnaire as guideline for the interviews. A questionnaire was compiled which was sent to the organisations involved. The idea was to have the requested interview run smoothly. Most organisations (from Austria, UK, France, the Netherlands, Italy, Germany) thoroughly completed this questionnaire. Finland used the questionnaire as a guide for preparing the interview.

  The blank questionnaire and the 5 completed questionnaires (two expressly preferred an interview) are appended to this report.

- Interviews (each time lasting 2 to 3 hours) with the leaders of the seven networks.

  First interview with Pieter Boerman[12], National Coordinator, and Toine Pieters, Regionaal Steunpunt Utrecht Coordinator (28 October).

  The interviews regarding Les Maisons pour la science (Houses for Science) were held with David Jasmin, Foundation Director of the Fondation La main à la pâte, and with Laurence Fontaine, Director of la Maison pour la science of Brittany, on 12 and 29 October.

  The interview on the LUMA Centre Finland with Prof. Maja Aksela and Dr. Lauri Vihma took place in Helsinki on 2 November.

  The interviews with the British organisation SLCY took place both by telephone (29 September) and during two meetings (27 October and 20 November). Interviews with David Thorpe, Pauline Hoyle.

  The interview with the Austrian delegation was only held by phone (3 November), but was richly supplemented with the completed questionnaire and several research articles on the activities and achievements of IMST. Interview with Prof. Konrad Krainer.

  The interviews for the SID (Scientiam Inquirendo Discere) network were held with Dr. Anna Pascucci on 20 October and 18 November.

  The interview about the MINT Forum and the Stiftung Haus der kleinen Forscher, which is one of its members, took place with Dr. Ute Gallmeier and Dr. Janna Pahnke on 20 October.

- Following the interviews several e-mails were sent to the networks to obtain further information, especially about their finances. Several networks stressed that this information is highly confidential and only intended for the contracting body or bodies. This information must by no means be disseminated or published.

- Desktop research during which key documents, reports and the websites of the networks concerned were studied in depth.

- Participation in a two-day meeting of five STEM networks (Germany, France, Italy, the Netherlands, UK) on 19 and 20 October 2015. This resulted in the establishment of the UTRECHT STEM Think Tank. Meanwhile, this group has been extended to include Austria and Finland.

- Participation in a two-day professional development course for the people in charge of the 10 Maisons pour la science in Strasbourg on 14 and 15 October 2015. Work was done on knowledge management (capitalisation) within the network of the Maisons pour la science.

12 On 24 March 2016 Agnes Kemperman succeeded Pieter Boerman as president of the VO-HO regional networks

- Participation in the international meeting in Amsterdam which led to the creation of the EU STEM Coalition on 2 October 2015.
- A visit was paid to one of the regional STEM support centres in the Netherlands (in this case that of Zeeland) on Wednesday afternoon 3 November 2015; interview with Pieter van der Heiden, Coordinator of the regional science support centre in Zeeland[13].
- A work meeting with three members of the national coordination group of the Dutch regional support centres in Utrecht on 28 October 2015. Participants: Pieter Boerman, University of Twente, Maarten Pieters (SLO) and Harrie Eijkelhof (University of Utrecht).

- Participation in the EMINENT conference of EUN Schoolnet in Barcelona on 19 and 20 November 2015. At this conference 89 countries, including Belgium (Flanders), explained their STEM policies or STEM strategies in greater detail.
- Gathering information and writing out the report.
- First a Dutch version was made of the report. This version was made available to the Ministry of Education at the end of December 2015. The Dutch version was sent to all the networks with the invitation to react to the text and send their suggestions and / or corrections.

From their reactions it appeared that in several cases like UK and the NL major changes had occurred or were in the process of occurring since the interviews had taken place and the Dutch version of the text had been drafted.

Hence the authors of the text stress that the situation for several of the networks may change over the next months.

All the Networks agreed to the English version of the text to be published.

13 http://www.betasteunpunten.nl/steunpunten

2. Description of the Knowledge Networks

By way of introduction it is important to stress that all the interviewed parties call themselves networks, but that none refer to themselves as "knowledge centre". Nevertheless, they agree to saying that they actually operate as a knowledge network because they pool and share all the information that is available on STEM activities (with great focus on education: see below) in their country. They describe what they do and how, mostly in the context of research and evaluation. The networks that explicitly conduct (action) research in particular can be regarded as knowledge networks, because they generate new knowledge through research, which enhances the sustainability of STEM innovation in their country.

2.1 Les Maisons pour la science (MPLS), France

1. **Goals of the network**

- The **development of a close network** of 10 Maisons pour la science (Houses for Science) - 9 regional and one national - spread over several regions in France: Alsace, Alpes-Dauphiné, Aquitaine, Auvergne, Brittany, Centre-Val de Loire, Lorraine, Midi-Pyrénées and Nord-Pas-de-Calais.
- To organise quality professional development for teachers on the basis of strong cooperation between education and the research and business communities. The science and research communities are involved in the creation and implementation of professional development initiatives. At least 50% of the trainers in the professional development sessions must be researchers: in the first three years 950 researchers were involved in the co-creation and co-implementation of professional development sessions.
- To bring together and share the knowledge and expertise of all the Maisons pour la science (MPLS) through knowledge management or capitalisation.

2. **Initiator / geographical spread of the network**

The initiative was taken by the Fondation La main à la pâte (Lamap): http://www.fondation-lamap.org/. This is a foundation established in 1996 by the French Académie des sciences (Academy of Science) and more specifically by Nobel Prize Winner Georges Charpak. Its primary goal is to promote STEM in general and IBSE (Inquiry-Based Science Education) in particular.


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Apart from the MPLS, this foundation also manages some twenty STEM pilot centres where pupils can experience IBSE in the context of their regular school activities. It also organises professional development for teachers in connection with the EIST project of the Ministry of Education (Enseignement Intégré des Sciences et de la Technologie/Integrated Science and Technology Teaching): http://eduscol.education.fr/cid57927/eist-en-sixieme-et-cinquieme.html. In addition it coordinates the ASTEP project (Accompagnement en Sciences et Technologie à l'Ecole Primaire/ Assistance in Science and Technology at Primary School) during which master's and PhD students assist primary school teachers during science lessons in the classroom (http://cache.media.eduscol.education.fr/file/sciences/37/8/guideASTEP_FR_web_dec2013_289378.pdf).

The 9 regional MPLS's are spread throughout France. To offer teachers even more opportunities to participate in professional development courses, nearly each Maison has one or several satellite offices which organise some of the professional development sessions closer to the teachers. To overcome geographical problems, use is of course also made of online courses. The national centre in Paris is mainly training the trainers.

3. **Target groups**

The target group of the 9 regional MPLS's and the 10th national MPLS encompasses science teachers in primary and lower secondary education (collèges). In principle the teachers of the lycées (higher secondary education) do not belong to the target group. However, some of them do sometimes attend professional development courses. The MPLS's also want to place special emphasis on socially disadvantaged and less able-bodied children at school.

Teacher trainers or educators form the target group of the 10th MPLS (i.e. "la coordination nationale"/ Paris).

Some Maisons organise professional development sessions for other groups like STEM facilitators in informal STEM education, young STEM teachers who are coached at the start of their careers and documentalists who are employed in the schools. Researchers participating as trainers or educators are also trained to make sure they can work together efficiently with the teachers. Three MPLS and the National Coordination organise a special 80-hour professional development course for teachers who want to promote STEM at school. This training course results in an official recognition. The idea is for these teachers to also be able to take part in the launch of STEM school development projects[14] or to be able to act as trainers in the MPLS' network.

4. **Focus / activities**

The primary emphasis is on the organisation of short (one half to one full day), half-long (2 to 5 days) and longer (80 hours spread over 2 years) professional development courses for STEM teachers in primary or lower secondary education, mostly during the school year. Activities are also increasingly organised during holidays, like summer universities. Professional development courses of longer duration often take the form of "blended learning" into which the follow-up of teachers is integrated as well. A great deal of attention is devoted to online professional development courses which can be found under "parcours m@gistère"[15]. For small primary schools in remote locations the ASTEP project (Assistance in Science and Technology at Primary School) at the the Maison pour la science en Lorraine online synchronous and asynchronous contributions

14 **School development projects** are projects that are set up within a school within the framework of the school's educational project and which are aimed at improving or optimising specific components of education together with the entire school community. The incentive may also originate from the government (in this case the Ministry of Education) that invites schools to present a project that contributes to the development of a new approach within the school at disciplinary or transdisciplinary level (like for STEM subjects) or to other more general topics like bullying at school, health, inclusion, etc. A school development project is thus on the one hand embedded in the school's strategy, but can on the other hand also contribute to a systemic policy pursued by the government. Sometimes the government invites schools to submit projects which allow them to support or develop a new policy. This is perfectly illustrated by the living labs organised within the framework of the Flemish initiative Focus on Talent. In most cases, the government financially supports such projects for several years.

15 "M@gistère" is the national professional development and training platform of the French Ministry of Education. More information is available at https://magistere.education.fr/

from engineering and master's students to support STEM teachers during their lessons are used.

The professional development courses largely focus on interdisciplinarity and cooperation between teachers in the last years of primary school and the first years of lower secondary education (formations inter-degrés).

Each of the Maisons annually publishes a brochure containing the provision of professional development courses.

A complete overview of all the professional development courses on offer is available online or in the brochures (http://www.maisons-pour-la-science.org/formations/toutes).

Some of the MPLS's, like Alsace, organise a special professional development course to train teachers with STEM experience into teachers who can organise professional development initiatives themselves. At the same time an experienced teacher trainer (who is usually someone who still teaches part-time at a school) may also opt to obtain a master's degree MEEF (métiers de l'enseignement, de l'éducation et de la formation) which is taken at the ESPEs (école supérieures du professorat et de l'éducation). The ESPEs have replaced the former IUFMs (instituts universitaires de formation des maîtres) which offered pre-service teacher training until 2014. The professional development courses which he or she gives will then become part of these new master's programmes for which credits are awarded, since it concerns a course "en alternance" (sandwich course).

The 9 regional MPLS's also respond to regional economic development and regional research by offering professional development courses that are closely associated with these topics. The activities of the MPLS Auvergne are related to the company Michelin, among other things. The MPLS Centre Val-de Loire is engaged in the perfume and cosmetics industry. The MPLS Alsace works together a lot with EDF[16], amongst others, given the dams and power stations on the Rhine. The MPLS Nord-Pas-de-Calais works around textiles. The MPLS Brittany is engaged in alternative energy. The MPLS Midi-Pyrénées works on aeronautics and space travel, etc.

Together with the 9 MPLS's and with researchers and teacher trainers the National Coordination designs educational materials and promotes distance learning. In this context it is currently preparing a MOOC (Massive Open Online Course) on the subject of IBSE. It is also in charge of the support to the administration and the finances (funds) of the project.

5. **Link with research and innovation**

The 9 regional MPLS's must be embedded in and cooperate with the university and have a close partnership with the (regional and local) education sector, the inspectorate and the research and business communities. Important elements in these professional development courses are the visits to laboratories and the organisation of professional development courses in laboratories during which teachers are actively put to work (hands-on) and collaborate with researchers. A contribution by researchers is provided for in each professional development course. It is in fact tried to inform teachers about the latest scientific innovations and to anchor these innovations in the professional development course.

16 Electricité de France

6. **Network structure / management structure and personnel**

Although the 9 MPLS's are more or less independent (in terms of finances and administration), they still work closely together within the MPLS network (as well as with the 10th national MPLS) to offer a high-quality professional development provision. At least twice a year a joint three-day seminar is organised bringing together all the MPLS's. Apart from that, specific study days are also organised on specific topics: cooperation with the business community, pre-service teacher training providers, etc.

Each separate MPLS has a scientific committee and a steering committee, which are sometimes also assisted by a small executive committee. All regional stakeholders are represented in these regional committees: the university (in particular pre-service teacher training - ESPE), the regional education authorities (Rectorat), the inspectorate, the research and business communities, civil society and informal and non-formal STEM actors. This allows each Maison to avail itself of the network of expertise and knowledge available in the region. In many cases they can also call on the support of the Fondation Universitaire which collects funds from potential sponsors for each university.

Across the Maisons a national Scientific Committee lead by the French Académie des sciences members has been put in place to guarantee the quality of professional development initiatives. This committee also expresses its opinion on the quality of professional development courses that are offered by the MPLS's every year.

The 9 regional MPLS's each have a core team of 4 to 10 people. Their number amounts to 45 FTEs in total. The core team is mostly composed of a director (sometimes assisted by a deputy) and an ingénieur de formation who is responsible for organising all the approved professional development courses. Sometimes this task is divided between 2 or more persons. The latter are all teachers with great experience in STEM education and/or teacher training. This group is supported by a secretariat.

The professional development courses are created by working groups in which education, research, innovation and business leaders meet to specifically determine the needs and content of the courses. The National Coordination (also called 10th MPLS) in Paris has a team of 6 FTEs to coordinate the project of the MPLS's. They also use trainers and researchers for the professional development courses.

7. **Finances and reach**

In 2011 the Fondation Lamap submitted a project to the French Government within the framework of the Programme d'investissements d'avenir (PIA) or Investment Programme for the Future. An amount of €12 million was allocated for the establishment of the MPLS's over a five-year period. During these five years the first five Maisons had to contribute at least as much as the national government. This contribution could originate from the regional authorities, the university or businesses. After five years the MPLS's should be self-sustaining, which is difficult for some[17]. The five Maisons which were set up two years after the first even had to contribute €50,000 per year from the business community or civil society in order to be allowed to submit their application to become an MPLS. . Each year the 10 MPLS's together must train 5,000 teachers. Last year the programme reached 10.000 teachers. The total budget is €24 million (including €12 million from the PIA): €16 million for the 9 regional Maisons and €8 million for the National Coordination, to be spread over five years. As a result, the invested cost per professional development participant amounted to approximately €690 in the past but less than € 400 the previous year. This sum includes the cost for the replacement of the primary school teachers.

17 There is everything to indicate that most Maisons will succeed in becoming self-sustaining, which is primarily thanks to the support from regional stakeholders and partners. The universities play a key role in this respect, since promoting STEM and popularising science and research are part of their key remit. MPLS's which are not self-sustaining are likely to be closed.

The funds (for the first 5 years) originate from the government: on the one hand through the PIA, but on the other hand also from the Ministry of Education through the rectorat or the regional education structure which can put teachers or teacher trainers at the disposal of an MPLS, or from the local authorities. The local university also contributes by making rooms, researchers and administrative and technical staff available and by paying the maintenance, heating, electricity, etc. of the local Maison in its buildings. All in all the business community currently only makes a limited contribution. For instance, for the MPLS Centre-Val de Loire this amounts to €50,000 per year on an annual budget of €450,000. For the other MPLS's the contribution from the business community is even lower.

In a number of rare cases a Maison carries out assignments for the local authorities, like training communicators who motivate children for STEM in STEM clubs or workshops during leisure time. Teachers from publicly funded, privately run education have to pay for the professional development courses, whereas they are free of charge for teachers in public education.

The total budget per Maison averages between €300,000 and €600,000 a year. This includes everything, even the personnel. Primary school teachers are replaced and their transport is paid from the budget of the MPLS.

8. **QA evaluation / research**

The evaluation of the activities of the 10 MPLS's (mainly professional development courses) is coordinated by an external partner. This partner sets up a formative and summative assessment of the MPLS's and their professional development courses on the basis of quantitative and qualitative data. The evaluation tools used include questionnaires, interviews, focus groups and participation in all the activities. These data are used by the MPLS's in their individual annual reports. The evaluations of the first three years show a very high degree of satisfaction in more than 90% of the teachers and 98% of the participants would recommend the courses to their colleagues.

Some MPLS's work together with the ESPE, so that master's students can also make their dissertation or thesis on the subject of STEM. As mentioned earlier, master's or PhD students are also involved in the ASTEP project.

9. **Strengths**

- The importance which the government attaches to the development of a systemic STEM policy.
- The support from universities and research centres, the people in charge of education (nationally and regionally), the business community and the Académie des sciences.
- The co-creation and co-implementation of professional development courses by trainers, researchers and participants from the business community (engineers, technicians, etc.).
- The great importance attached to the professional development of teachers in pre-primary and primary education.
- The emphasis placed on socio-economically disadvantaged young people.
- The thorough formative and summative assessment of the development of the network and the professional development courses.

- The assurance by the Académie des sciences of the quality of professional development courses.
- The efforts to reinforce cooperation between the 10 network partners and to become a close knowledge network by describing and documenting the ins and outs of the network as a whole.

Special characteristics:

- Intense cooperation between researchers and teacher trainers and the active involvement in research of teachers to be trained during activities in laboratories and other research centres. 99% of the teachers want to recommend the professional development to colleagues for these reasons.
- The supervision (national and regional) by the Académie des sciences.
- Cross-fertilisation and intense cooperation between the 10 Maisons pour la science.

2.2 Regionale vo-ho netwerken, formerly Regionale Bèta Steunpunten, the Netherlands

Introduction

The Regionale Bèta Steunpunten (Regional Science Support Centres - http://www.betasteunpunten.nl/steunpunten), have recently (March 2016) broadened their activities and have been changed into Regionale vo-ho-netwerken (Regional networks secondary and higher education) in order to enable adding activities for Humanities and Social sciences. As the focus of this study is on STEM, we shall however mainly refer to the activities of the Regionale Bèta Steunpunten (RSP) as their activities were linked specifically to STEM subjects and as the Regional networks secondary and higher education have only come into existence very recently.

The emergence of the RSP cannot be seen separately from important developments in the field of STEM that took place in the Netherlands following the publication in 2003 of the national action plan "Delta Plan voor Bèta / Techniek" (Delta Plan for Science / Technology). This Action Plan aimed to give a necessary impulse to the Dutch knowledge economy in the area of science and technology. During six and a half years the Platform Bèta Techniek (National Platform Science & Technology) committed itself to realising the goals of the Deltaplan Beta / Techniek, in collaboration with the education sector, the business community and intermediary organisations. In the context of the programme Verbreding Techniek Basisonderwijs (Extension of Technology in Primary Education) support centres were also established between 2004 and 2010. For primary education a separate network of Wetenschapsknooppunten (Science Hubs) has been created besides the network of Regional Science Support Centres. These science hubs are based on teaching inquiry and design based learning. Pupils are encouraged to actively gather knowledge by asking questions, conducting research and finding solutions. Apart from acquiring knowledge, the focus is thus on learning inquiry based skills and developing an inquisitive attitude.

1. **Goals of the network**

The Regional Science Support Centres (Regionale Bèta SteunPunten/ RSP), is a very recent initiative that was launched around 2012-2013. There is no formal overarching national organisation, but the support centres for science subjects do cooperate at a national scale.

Their mission is to strengthen regional cooperation between schools, university of applied sciences and universities in science and technology education for the following purposes:

- to contribute to the continuing professional development (CPD) of teachers in secondary[18] and higher education;
- to strengthen the connection between secondary and higher education and subsequently increase student success in higher education;
- to realise continuing subject innovations in science subjects, in terms of both content and teaching methodologies;
- to improve the science/technology connection between secondary and higher education;
- to promote (science) talent development in secondary education pupils;
- to establish a link with other secondary and higher education networks, as well as with external partners, including the business community.

The underlying motive behind these goals is to attract more young people to the world of science and technology, in education and on the labour market, and reinforce the Dutch knowledge economy.

2. **Initiator / geographical spread of the network**

The Regional Science Support Centres for secondary and higher education originated roughly in three steps. The first step was the establishment of regional support centres for a new, cross-cutting subject: Nature, Life and Technology. These centres combined the development of materials with teacher professional development. As a second step, promoted by the associations of chemists and of physicists, regional support centres for chemistry and for physics were promoted, responding to the curriculum innovations for the STEM subjects. In the same step, centres for biology, for mathematics and for information sciences followed. The third step, completed around 2012-2013, was to group the regional centres for different STEM subject into (broad) regional centres. Thus, establishing (Broad) Regional Science Support Centres supported the introduction of the new curricula.

Regional support centres are teacher networks in universities and university of applied sciencess in the Netherlands. Within these networks secondary and higher education teachers collaborate intensively in teams to develop and implement new science education, and to further train teachers.

18 Secondary education ("Voortgezet onderwijs"): After primary school pupils in the Netherlands move on to secondary education: voorbereidend middelbaar beroepsonderwijs/vmbo (pre-vocational secondary education), hoger algemeen voortgezet onderwijs/havo (senior general secondary education), voorbereidend wetenschappelijk onderwijs/vwo (pre-university education) or employment-oriented training. Secondary education prepares pupils for middelbaar beroepsonderwijs/mbo (senior secondary vocational education), hoger (beroeps)onderwijs/hbo (higher (professional) education) or wetenschappelijk onderwijs/wo (university education). Employment-oriented training prepares pupils for the labour market.


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The Regional Science Support Centres are spread throughout the Netherlands, and operate under different names:

- Amsterdam: Bèta Steunpunt Amsterdam (ITS Academy)
- Eindhoven: Bèta Steunpunt Brabant - Leiden: Regionaal steunpunt Leiden
- Limburg: Bèta Steunpunt Zuid-Limburg
- Arnhem-Nijmegen: Breed Regionaal Steunpunt Arnhem-Nijmegen
- Groningen-Leeuwarden: Breed Regionaal Steunpunt Noord
- Twente: Bèta Steunpunt Oost
- Utrecht: Bèta Steunpunt Utrecht
- Wageningen: Bèta Steunpunt Wageningen
- Zeeland: Bèta Plaza Zeeland
- Delft: Bèta Steunpunt Zuid-Holland
- Leiden: Regionaal Steunpunt Leiden.

Recently, the centres in Delft and Leiden combined many of their activities in a Regionaal Steunpunt Zuid-Holland.

3. **Target groups and stakeholders**

The target groups of the activities of the Science Support Centres are clear:

- teachers of science subjects in secondary education
- school management teams and other school leaders

The Science Support Centres have many stakeholders which interact in several ways. At the level of each separate Regional Science Support Centre there are regional stakeholders:

- university[19], university teacher training, university of applied sciences(s), hbo teacher training programme(s)
- science focal points
- regional secondary education schools, including subject teachers and pupils
- mbo schools in the region
- Junior colleges[20]
- the local business community

19 In Amsterdam, two universities participate, the Free University Amsterdam and the University of Amsterdam.
20 "Junior colleges" refers to a partnership between pre-university education and higher education, which allows students in the last two years to already take university courses.

- other actors from informal and non-formal STEM education. For instance, one of the RSPs works together with NEMO[21], the Science Centre in Amsterdam.

In addition, there are national stakeholder organisations that also operate regionally:

- the business community (JetNet, ...)
- (semi) public services (Ministry of Education, National Platform Science & Technology, National Institute for Curriculum Development)
- professional organisations (NNV, KNCV, NiBi, PWN, KIVI NIRIA, NVON ...)
- science education innovation organisations (IOBT), and
- publishers of course books, secondary education content, etc.

4. **Link with research and innovation**

There is a clear link with research and innovation because of sound cooperation with the research at universities and research institutes and the business community. This collaboration between schools and businesses was one of the spearheads developed within the framework of the Delta Plan Bèta / Techniek which had been implemented for 6.5 years from 2003 onwards. The best example of this collaboration was the development of the JETNET network, which was initially carried by a small group of businesses, but was later on extended to a close and important partnership. Within the framework of JETNET very valuable initiatives were set up, like masterclasses for teachers on new developments in research, a course on science professions in the classroom, placements in businesses, etc.

The following groups are involved in this partnership: researchers at all levels, PhD students, assistants, professors and master's and bachelor's students, in collaboration with teachers.

5. **Focus / activities**

The organisation and activities differ from support centre to support centre, but share a common core. The following elements in any case belong to their regular activities:

- regional and in-service training of secondary education teachers in STEM disciplines, co-creation of professional development, coordination and evaluation
- regional training for other groups like school management team members and/or technical assistants
- the organisation of events, like a regional conference for all parties involved
- development of teaching materials

21 https://www.e-nemo.nl/en/

- maintenance of contacts with practising teachers in secondary education
- collaboration with science centres and museums, including NEMO Science Centre in Amsterdam

The regional subject-specific centres, e.g. all biology centres, cooperate nationally in matters like course development and quality improvement. The overarching regional centres have their national co-operation too, on strategic and practical matters like fund raising, quality improvement and communication.

Professional development courses include the following subjects: Biology, Chemistry, Physics, Nature, Life and Technology, IT and R&D.

The RSP calls on the expertise of the university or university of applied sciences for training or professional development courses. The services of the university and research institutes, and sometimes the business community, are mostly used for anything relating to Biology, Chemistry, Natural Science, Physics and IT. Universities of applied sciences are used for anything that has to do with technology, and sometimes also IT. If no university is located in the region of the RSP (like in Zeeland where the HS Zeeland coordinates the RSP), a connection with a university outside the region is made.

Professional development courses are usually embedded in professionalization pathways or form part of the establishment of school development projects. In this case the professional development is quite substantial. It is not just one course lasting one afternoon, but a professional learning community working over a longer period of time with regular meetings of one day or half a day, implementation of what has been learned at school and preparations for the next meeting. Sometimes, follow-up is provided by the supervisors in charge.

Several RSPs insist that at least two teachers or groups of teachers (possibly including the school management team) should participate in the training initiatives in order to promote a systemic approach (and a school strategy) throughout the school.

6. **Network structure / management structure and personnel**

These RSPs are generally partnerships between universities and universities of applied sciences and can therefore be regarded as “broad” in that sense. They are also “broad”, because they all encompass different subject support centres, which in turn cooperate at a national level per subject (in LVOs). Each RSP has a coordinator who represents it in the Steunpuntenraad/SPR (Support Centre Council), which is described in the following section. RSPs have a large degree of autonomy in defining the needs of the RSP and the strategy to achieve these goals. The following tasks in any case belong to the activities of a RSP: providing regional (coordination of) training and in-service training of secondary education teachers in several school subjects, maintaining contacts with regional stakeholders and holding national consultations with other BRSPs in the Support Centre Council.

At national level, the cooperation in the Steunpuntenraad/SPR (Support Centre Council) and the subjects’ cooperation (LVOs) is completed by the Steunpuntenadviesraad/SPAR (Support Centre Advisory Council), in which a variety of stakeholders are represented. The SPR is the national consultative body of the broad regional support centres. Its members include representatives of the BRSPs and their main external financiers. Its chairperson is elected from the BRSP representatives in the SPR for one year. The National Platform Science & Technology (PBT) and the National Institute for Curriculum Development (SLO) supports the SPR in its secretariat, in the development of a quality system and in communication.

The SPR meets several times a year. Its most important tasks include:

- facilitating the exchange of information between RSPs in all possible areas;
- coordinating the in-service training agenda and events, like a regional conference;
- coordinating national subsidy applications;
- facilitating the exchange of information between RSP coordinators and LVO chairpersons (through regular contact between SPR chairperson and LVO chairpersons);
- coordinating the quality control of RSPs;
- exchanging information with national stakeholders;
- jointly enhancing the profile of the RSPs;
- making policy, for instance in the field of quality assurance, on the basis of personal experiences of the RSPs and input from stakeholders through the SPAR.

The SPAR advises the SPR on anything it considers important. The annual SPAR has evolved into a conference where the SPR-members meet with representatives of the national stakeholders and the chairpersons of the LVOs. These are all people who can give advice regarding the content of the final goals of the RSPs. The SPAR may also be consulted via e-mail. The SPAR as a team and its individual members can advise the SPR via an e-mail to the SPR secretary, even if this advice was not requested. Quite some changes have occurred since the SPAR was designed.

7. **Finances and reach**

The Ministry of Education allocated €3 million to the RSPs over the period from mid-2013 to mid-2016. Follow-up of this nationally sourced funding is being discussed.

Three to four people are available (although not always full-time) for the national coordination of the regional science support centres, whereas 2 to 6 people (mostly part-time) are available for the coordination at regional level. The Regionaal Bèta Steunpunt Zeeland employs one part-time coordinator, who combines the coordination duties with teaching, and one part-time secretarial assistant. Apart from that, 5 to 15 people have been appointed for each regional science support centre (at least 1 person per regional support centre usually works part-time). For each STEM subject area (Biology, Chemistry, Physics, Natural Science, IT, etc.) one person (usually an experienced teacher) can be exempted for content-related work for each subject area. Sometimes this person combines two or more subject areas. This distribution varies by RSP.

On average, each BRPS is granted a national subsidy amounting to between €150,000 and €300,000 per three years. The university and higher education institutes which accommodate the RSP must together contribute at least the same amount in time or buildings, in kind (heating, electricity, maintenance) or in cash. For this purpose the universities can use part of the funds they receive within the framework of communication and science valorisation. The remaining funds stem from schools in the region that are members of the RSP and pay a membership fee. This fee differs from RSP to RSP. In some cases secondary education schools can avail themselves of the RSP's services free of charge. In other cases they pay up to €5,000 a year, depending on the services and assistance they receive from the RSP. Per RSP, approximately half of the local schools are

affiliated today. The government allocates funds to schools to purchase professional development courses. Usually a school is granted a professional development budget of €600 per teacher/per year. In concrete terms, this means that the RSP Zeeland has a total annual budget of €310,000.

The funds awarded to each RSP are made available through the Platform Bèta Techniek.

The Support Centre Council and the Support Centre Advisory Council receive administrative support for their activities from the Stichting Leerplan Ontwikkeling/SLO (Curriculum Development Foundation) in Utrecht, funded from the national subsidy by the Platform Bèta Techniek. This foundation also makes its meeting rooms freely available.

For the moment the larger RSPs reach around 150 to 300 teachers each year. For the smaller support centres this number will vary around 15 to 50 teachers. To give a concrete example: for the Regional Support Centre in Utrecht it concerns 259 teachers, technical education assistants and school heads participating in a professional development course and 200 participants in the regional teachers' conference. It is therefore likely that all RSPs together have approximately 1,000 to 1,200 participants/year in the professional development courses plus 1,500 to 1,800 participants in the conferences. This estimate is based on elements communicated by the national coordinator of the RSP network, since concrete figures were not available for each separate RSP.

8. **QA evaluation / research**

The participants in the professional development courses are invited to complete a questionnaire. A final interview often also takes place, since many of these courses are spread over several days and activities. Because the participants are often groups of teachers from one and the same school, these group interviews also measure the impact of professional development within the school. In some cases action research is set up as well, albeit not on a systematic basis.

Each RSP must draw up an annual report. These reports are to be sent to the national coordination to be bundled together into a coordinating report of all the RSPs.

An internal national audit of the networks will be carried out by means of a peer review and a monitoring system, including on-site visits.

9. **Strengths**

- The importance which the government has attached for almost two decades to the development of a systemic policy for STEM, first with the Axis programme and then with the Delta Plan Bèta Techniek and its follow-up.
- The support from universities and research centres, national and regional education leaders and other stakeholders, with a focus on the business community[22].
- The connection in curriculum development between national programmes and regional and local practices.
- The connection between curriculum development and teachers' professional development.
- The connection between secondary and higher education, and between education and the world of companies.
- The great emphasis on the start-up and assistance of school development projects by involving teacher teams in in-service training.
- The quality assurance (evaluation) of the organised professional development courses.
- The efforts to reinforce cooperation between the network partners.

22 Currently, these contacts are rare. However, each BRSP must build contacts of its own with the business community. The fact that these contacts are quite limited for the moment has to do with the BRSPs having been established only very recently.

Special characteristics

- The significance attached to school development projects.
- The regional structure and the significance of the regional support centres.
- The reinforcement and continuation of the achievements made in the past ten years within the framework of the Deltaplan Bèta Techniek.


Ontwerpen

2.3 National STEM Learning Network (NSLN), UK

The National STEM Learning Network consists of:

- the National STEM Learning Centre, York, which provides intensive, residential professional development alongside a library of STEM teaching resources, both on- and off-line
- the Network of around 50 Science Learning Partnerships in England, which provides locally available science focussed professional development
- partners in Scotland, Wales and Northern Ireland which provide locally available professional development through the partner organisations SSERC, Techniquest and Education Authority Northern Ireland

Since 2004 the NSLN has provided teachers, technicians and other educators with high impact, subject-specific professional development and support in STEM subjects.

1. **Vision of NSLN**

- The vision is that all young people, across the UK should receiving a world-leading STEM education.

2. **Basic principles of the NSLN**

- Teachers and others involved in STEM education have the right to access subject-specific, high impact professional development and quality-assured resources, so that they can teach effectively and inspire the young people with whom they work.
- Every young person has the right to a broad and balanced education that includes, but is not limited to, STEM subjects.
- STEM subjects are valuable not only because they can lead to exciting, rewarding career options, but also because they enable individuals to be active citizens in an increasingly technological society.
- STEM subjects open doors, provide options and are vital to the modern age - however, they are part of a young person's development, not all of it.

- STEM subjects should be taught by teachers who regularly update their subject-specific knowledge and skills through appropriate professional development, and are given the time, resources and support to do so.
- Schools should be incentivised to enable young people to progress to STEM study and career pathways post-16 (end of compulsory schooling) to all students, regardless of entry route.
- Careers advice and guidance can be supported by subject teachers spending time with STEM employers, as well as students having a variety of opportunities to engage with employers through visits, talks, webinars and other means.
- School and college leaders and governors should recognise the unique demands on STEM teachers in terms of updating subject knowledge and skills, and support them in this throughout their careers.
- Government, policymakers and others should support this through appropriate incentives and resources.

3 Initiator and geographical spread

The National STEM Learning Network (NSLN) was established following the publication of the reports of the House of Lords Science and Technology Select Committee (2001) and of the Council for Science and Technology (2000). These bodies clearly identified the need for subject-specific continuing professional development (CPD) for science and technology teachers. The Wellcome Trust invested £25 million to fund the National Science Learning Centre and the Department for Education and Skills (DfES), now Department for Education (DfE)[23] allocated £26 million to the then nine regional centres. The NSLN was opened in March 2006 by the then Prime Minister Tony Blair.

The non-profitmaking organisation STEM Learning Ltd (formerly Myscience.co Ltd) manages the NSLN, including the National STEM Learning Centre, 50 Science Learning Partnerships and other STEM programmes. STEM Learning is an independent company owned by the universities of Leeds, Sheffield, and York which are part of the White Rose University Consortium and Sheffield Hallam.

The NSLN is clearly part of a long-term STEM strategy that was outlined in the Science & Innovation Investment Framework 2004-2014 (http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/spending_sr04_science.htm).

This strategy was to make sure that a sufficient number of young people would study to become an engineer, scientist, technology specialist, researcher or mathematician. The new strategy for the period 2014-2024 is available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/387780/PU1719_HMT_Science_.pdf.

Until March 2013, the NSLN works consisted of nine regional Science Learning Centres (until 2013 spread over England, and with partners in Scotland, Wales and Northern Ireland. Since September 13, there has been the establishment of a Network of up to 50 school-centred Science Learning Partnerships across the whole of England, which enable quality professional development to be delivered locally, often using the latest online technologies. One of the key elements is to establish networks of collaborating schools to create or improve STEM strategies.

23 DfE: Department for Education They published a report on STEM in 2011. The STEM cohesion programme: final report: https://www.gov.uk/government/publications/the-stem-cohesion-programme-final-report

Sustained STEM subject-specific and leadership professional development for teachers, technicians, school and college leaders, STEM coordinators and other senior staff is organised at the central NSLC in York to promote the development of learning communities between these leaders in the field of STEM. The Science Learning Partnerships provide local subject-specific support and networking as part of the government approach of school-led self-sustaining approach to school improvement.

4. Target groups

The target groups are two clearly distinct groups. First of all the teachers (primary and secondary and post-16) and classroom-based support staff, such as teaching assistants and technicians (who assist science teachers). NSLN provides a UK STEM teacher with professional development at all levels of their career - from a developing teacher to an effective teacher, an established teacher, an inspirational teacher and, finally, a national expert teacher.

Secondly, the professional development is also intended for experienced leaders, i.e. the heads of department or subject leaders who can play a specific and prominent role within the school in designing a STEM strategy. To support the development of such strategies, there is some professional development organised occasionally for senior leaders or other policy managers within the school.

The professional development supported through the National STEM Learning Centre and through the Science Learning Partnerships provide opportunities for individuals for online and face to face scheduled courses locally and nationally, face to face and online networking, opportunities for groups of schools to work together on STEM strategies and interventions, and some CPD for an entire school. In this way all the teachers of that school become part of the STEM innovation initiative.

5. Link with research and innovation

The NSLN works very closely together with the researchers, universities and STEM employers and employer groups. All formal scheduled professional development attempts to embed the use of STEM in real life to support careers education and links with the latest research and innovations in the field of professional STEM and STEM education.

Moreover, the NSLN provides a Cutting Edge Science programme (https://www.stem.org.uk/research-councils-uk) in partnership with leading scientists to support the teaching of STEM subjects at the GCSE (at the age of 16) and A levels(age of 16-18) , which give access to higher education. In each of the subjects, a scientist will provide input for teachers to learn about the recent advances in the field and provide an insight into his or her own current research.

These Cutting Edge Science courses are delivered at venues across the UK and are designed to introduce the latest knowledge, new contexts and new stimulating, practical (hands-on) STEM activities to teachers.

6. Focus and activities

The NSLN offers a wide range of professional development courses to the aforementioned target groups, through sustained residential professional development courses in York and shorter CPD through the Science Learning Partnerships. Professional development is also provided by the partners including SSERC in Scotland, Education Authority Northern Ireland (EANI) and Techniquest in Wales.

ENTHUSE[24] Awards contribute towards the costs of attending world-class professional development provided by the National STEM Learning Centre for all UK state funded schools and colleges. All eligible schools are able to apply and will receive the Award on completion of CPD activities.

The NSLN also supports groups of schools, mainly primary schools, to work together to address STEM teaching and learning locally. This is supported by a small number of ENTHUSE Partnership Awards of £12,000 (over two years) for groups of between four and eight primary schools located in England, wishing to work together to address local issues of underachievement in science/STEM subjects. More information is available at https://www.stem.org.uk/bursaries

Impact Awards, on the other hand, are available on specific targeted CPD activities through the Science Learning Partnerships to enable participants to deliver high levels of impact on their pupils' attainment and engagement. Impact awards cover CPD fees, supply cover, travel and accommodation. For more information, visit https://www.stem.org.uk/bursaries.

The National STEM Learning Centre (https://www.stem.org.uk) houses the largest collection of teaching and educational materials that is available to STEM teachers, 26,000 physical resources and over 10,000 collated and curated online resources to support teaching and learning in STEM subjects . Teachers can search over 700 STEM careers resources, and for additional support in in embedding careers awareness as part of the curriculum, the STEM Careers Toolkit has been designed, with teachers at every step of the way, to provide:

- an accessible guide to government policy on careers education and information, advice and guidance for young people across the four countries of the UK
- evidence about the influential and key roles that teachers can have on their students' career choices across all phases of education
- good practice tips and examples of how to successfully relate subject knowledge and the curriculum to careers choice and the labour market
- links to the key in-depth sources of information, from the UK's four inspectorates' guidance for schools to the most robust sources of labour market and careers information

A key part of the NSLN is the evidence of impact of the CPD on teacher development and the subsequent impact on outcomes for young people. The NSLN has identified seven key outcomes (https://www.stem.org.uk/what-we-do) and has a systematic approach to the evaluation of the impact of CPD through an internal Impact toolkit (based on the Guskey 2000 model) and externally commissioned evaluation which provides evidence against these outcomes. This evidence of impact of the evaluation for programmes and CPD is available on https://www.stem.org.uk/impact

Finally, the network also organises a programme called STEM Insight which is a unique opportunity for teachers to experience the world of industry or university deepening their knowledge of STEM-related careers. These unique placements in industry or university are underpinned with tailored CPD from the National STEM Learning Centre and Network, and a bespoke package of online support. For more information, see https://www.stem.org.uk/stem-insight

24 ENTHUSE Awards are provided by Project ENTHUSE – see below .

7. Network structure / management structure and personnel

The non-profitmaking organisation STEM Learning (formerly Myscience.co Ltd) operates the National STEM Learning Centre and Network and runs other STEM programmes. STEM Learning comes under the White Rose University Consortium (comprised of the universities of Leeds, Sheffield, and York) and Sheffield Hallam University. It also has strategic partners in other parts of the UK.

STEM Learning has a board of directors of 10 members and a national steering committee of 23 educational experts (volunteers).

The activities are all coordinated from York, involving around 85 staff members. They are also in charge of monitoring the scientific quality of the training courses.

STEM Learning now manages the whole Network of up to 50 partner Science Learning Partnerships. There are five regional managers working with educational experts called Regional Development Leaders (2 or 3 per region) and some central administration staff. Each Science Learning Partnership has a part time educational leader and some part time administrative staff. Throughout England some 200 people are engaged part-time in the network of school partnerships.

8. Finances and reach

The NSLN and its partners have a total budget of £11 million. The NSLC in York has a budget of

£4,816,000 (originating from the Wellcome Trust + revenues from residential courses, amongst others).

The financial support is a unique partnership between charitable trusts including the Wellcome Trust and the Gatsby Foundation, from the government via the Department for Education and from employer and employer organisations who have formed a charity Project ENTHUSE[25] to support bursaries for teachers of STEM subjects to access CPD.

The NSLN and its partners annually work with around 15,000 teachers across the UK. Over a ten-year period they have reached 95% of the secondary and 18% of the primary schools. In the past decade they provided approximately 230,000 days of CPD which greatly varied in nature: face to face CPD including residential CPD lasting several days, local whole and half day courses or evening sessions; online CPD and online networking; bespoke school-based CPD; action research projects; scientific visits and placements for teachers.

The 50 Science Learning Partnerships have worked with 14,500 teachers and technicians in 6,721 schools since 2013. During the past ten years the NSLN and its partners have had an impact on more than 7,000,000 young people through CPD courses for teachers and other groups at their school.

25 Project ENTHUSE which is a unique partnership of government, charities and employers that have come together to bring about inspired STEM teaching through the professional development of teachers, technicians and support staff across the UK. Current ENTHUSE the Department for Education, Wellcome Trust, BAE Systems, Biochemical Society, BP, Institution of Engineering and Technology, Institution of Mechanical Engineers, Rolls-Royce, and the Royal Society of Chemistry.

9. QA evaluation and research

Evaluation and research, particularly of the impact of CPD, takes centre stage in the activities of the NSLN. The impact of CPD is evaluated through externally commissioned evaluation reports and triangulated through data amassed through an Impact toolkit which is used across the National STEM Learning Centre https://www.stem.org.uk/impact

Recently, after 10 years of operation of the Science Learning Centres, a report was published on the impact of their activities. This report is entitled "10 Years of Impact on Teachers, Pupils and Schools. Lessons in Excellent Science Education".

https://www.stem.org.uk/impact

The National Science Learning Centre in York has also developed a self-evaluation tool for teachers and schools which can be used to develop a STEM strategy for the school. More information is available at https://set.stem.org.uk/

10. Strengths

- A National STEM Learning Centre and Network with a broad and far-reaching network that contributes to the implementation of a clear STEM policy of the English government.
- A large variety of CPD opportunities for teachers, experienced teachers and school management teams that want to help develop a STEM strategy at school.
- The great emphasis on cooperation with scientists.
- A prominent place for school partnerships to develop a sound STEM strategy (school development projects).
- Strong cooperation with the employers and employer organisations.
- Ample funds for collaborating with the school and its teachers.
- The focus on collaborative work between teachers and/or schools. Strong STEM schools help weaker ones.
- All activities are clearly underpinned by research and impact evaluation.
- Clear communication of results to all stakeholders.

Special characteristics

- The emphasis is on learning partnerships between schools. UP to 50 schools (which each offer assistance to a number of additional schools) even form an integrated part of the knowledge network.
- CPD is not just intended for teachers, but also for policymakers within schools.
- The substantial funds that are made available by the Wellcome Trust, the Department for Education, BAE Systems, Biochemical Society, BP, Institution of Engineering and Technology, Institution of Mechanical Engineers, Rolls-Royce, and the Royal Society of Chemistry. By pooling the funds, they can be used more efficiently.
- Thorough impact evaluation based on a clear theory of change.

2.4 Network : LUMA Centre, Finland

1. **Goals of the network**

LUMA Centre Finland was established 8 November 2013 as the umbrella organization for 13 LUMA Centres in Finnish Universities and Universities of Applied Sciences to strengthen and promote their collaboration on national and international level. The LUMA Centre Finland network is directed and coordinated by the University of Helsinki.

The aim of LUMA Centre Finland is to inspire and motivate children and youth into mathematics, natural sciences and technology through the latest methods and activities of science and technology education. The aim is also to support the life-long learning of teachers working on levels of education from early childhood to universities, and strengthen the development of research-based teaching.

The **general goals** of all the activities of the Network of LUMA Centres are:

- to promote the scientific literacy of all people (at each age) and
- to make sure that a sufficient number of skilled scientists, researchers, technicians and mathematicians are available who can contribute in the large range of STEM professions

The specific goals are:

- to inspire and encourage 3–19-year-old children and youths to pick up STEM as a hobby, in their studies and also as a career;
- to support and encourage both current and future teachers and instructors at all levels from kindergarten to university in teaching STEM subjects and in the development and upkeep of their expertise and ability to inspire students throughout their careers;
- to increase awareness among the general population about the significance of STEM subjects to the well-being of the individual, the society and the environment;
- to closely collaborate with informal and non-formal STEM education.

2. **Initiator / geographical spread**

STEM education has been promoted in Finland since 1996 through various activities. The LUMA[26] Programme was a development programme for STEM in education[27] for the period 1996-2002. It was set up by the Finnish National Board of Education. The final report of this programme is available at http://www.oph.fi/download/48078_LUMA_final_report.pdf.

To continue to work on the achievements from the period 1966-2002, the first Finnish Science Education Centre was established in 2003 at the University of Helsinki, with the aim of promoting STEM education. To also realise this goal throughout Finland, support was given to the creation of such centres all over the country. Since 2007, regional LUMA centres have been established around Finland. Their number amounted to 13 in 2016[28].

The LUMA Centre Finland network was established in November 2013 as an umbrella organisation of all LUMA regional centres engaged in STEM on the basis of collaboration between schools, universities and the business sector, with the aim of promoting and supporting life-long learning, studying and teaching of STEM subjects on all levels of education.

> One of the goals of LUMA Centre Finland is to strengthen and stimulate LUMA activities around Finland. To meet this goal, LUMA Centre Finland has supported the establishment and activities of the 13 regional LUMA Centres operating within universities and higher education institutes all over the country. The regional LUMA centres help promote STEM education throughout Finland and provide equal access to sound STEM education.
>
> The geographical spread of the 13 centres came about gradually in the years 2000.

3. **Target groups**

The target groups of the LUMA Centre Finland network are:

- children and young people aged 3 to 19
- university students in STEM disciplines
- pre-service teacher training
- schools and their head teachers
- people in charge of teacher training at universities
- the professional development of working teachers
- parents and all adults
- informal and non-formal STEM education
- policymakers at all levels: national, regional and local (per municipality)
- the business sector and civil society

26 LUMA: (LU stands for 'luonnontieteet', natural sciences in Finnish, MA for mathematics.)
27 Interview Professor, Dr. Maija Aksela
28 http://www.luma.fi/centre/

4. **Link with research and innovation**

The LUMA activities are designed based on the latest research, and the activities themselves are studied to obtain data for developing them. There is a clear link with research and innovation in the broad sense of the word, since all industries (and especially the core industries of business life in Finland) like IT, chemistry and forestry, in collaboration with the economic services, are closely involved in the set-up and implementation of all LUMA activities. Finnish education also has a strong link at the local level with the business community and civil society, since the municipalities are in charge of education.

5. **Focus / activities**

The activities of the different LUMA centres usually relate to all components and sub-areas of STEM education. This is illustrated by the activities of the LUMA Centre at Helsinki University (which is the coordinator for the national LUMA Centre Finland network).

It includes 7 specialised resource centres: BioPoP (biology), Geopiste (geoscience), F2k (physics), Kemma (chemistry), Linkki (computer science), LumO[29] (pedagogy) and Summamutikka (mathematics). The following URL gives access to the in-service training provision offered by each of these resource centres. Unfortunately, the sites are in Finnish and Swedish: http://luma.fi/helsinki-en/

All LUMA centres belonging to the national network believe that the general and specific goals can be achieved through a wide range of STEM activities:

- STEM clubs, STEM camps, special STEM events, webzines and other activities for children and youth
- pre- and in-service training for teachers and interactive online web portals including videos and other materials
- STEM classes and laboratories that support teachers in their work at school and in the classroom
- research on the teaching of mathematics and (natural) science
- research on the effectiveness of LUMA's own activities
- research into how activities are best developed based on previous research results
- collaboration with policymakers and the media, and especially with all other stakeholders (like companies) who are active in the field of STEM

All LUMA centres organise in-service training for teachers (mostly online), and develop teaching materials, and most of them work together with providers of pre-service teacher training. They also work together with science centres like the Heureka Science Centre which offers high-quality support to teachers and pupils. These centres are also involved in pre-service teacher training.

The national LUMA Centre Finland puts the majority of in-service training courses online and invests in online learning communities. In addition teachers can attend parts of a training course as in-service training at the university in pre-service teacher training.

29 http://www.luma.fi/helsinki-en/

At the LUMA Centre Finland, prospective teachers are trained for collaboration with science and technology centres, science museums and other organisations that organise extra-curricular or out-of-school STEM activities. Prospective teachers can thus take a placement at these scientific institutes as part of their training. The centre also helps them, for instance, to organise summer camps or summer schools for STEM teachers or other STEM entertainers during the summer months. This greatly strengthens and reinforces the link between formal STEM education and the scientific community. The student in training will be awarded ECTS credits for this.

Since the idea is for the LUMA Centre Finland network to highlight the activities and cooperation of these 13 centres - in Finland and on an international level - on the basis of a single, shared strategy, the LUMA Centre Finland annually organises an international symposium on STEM education in English, in parallel to its "teachers' days". More information about the 2016 symposium is available at http://luma.fi/isse-2016/.

STEM teachers from all levels of education, prospective teachers, teacher educators and researchers in STEM education from any country can participate in this symposium. Again, the aim is to share ideas and experiences on STEM education. The fact that this international symposium is organised at the same time as the National LUMA days for Finnish teachers offers foreign teachers the opportunity to meet potential Finnish partners for European projects. Foreign participants may apply for Erasmus+ Key Action 1 mobility scholarships to participate in this international event.

6. **Network structure / management structure and personnel**

LUMA Centre Finland is managed by a Board chaired by Senior Lecturer Pekka Hirvonen from the LUMA Centre of University of Eastern Finland . Professor Maija Aksela from the University of Helsinki was appointed first Director of LUMA Centre Finland.

Currently a joint working strategy is being drawn up for LUMA Centre Finland. It specifies focus areas and collaboration projects which will take form according to the aims of the LUMA Centre Finland (which is in fact an umbrella network).

The Board of LUMA Centre Finland works in close collaboration with new and established partners: the Finnish National Board of Education, the Chemical Industry Federation of Finland, the Finnish Forest Industries Federation, the Federation of Finnish Technology Industries, the Economic Information Office, Heureka (Finnish Science Centre in Helsinki), teachers' associations and the Association of Finnish Local and Regional Authorities.

In the Finnish model the personnel for the regional LUMA centres and the national LUMA Centre Finland is limited. For the LUMA Centre Helsinki (and LUMA Centre Finland) 1 FTE coordinator is employed who (in collaboration with the Director Prof. Maija Aksela) coordinates the activities and works together with 7 researchers who are all PhD students and therefore do not cost anything. Furthermore, secretarial support is provided to each regional LUMA centre by the university accommodating the regional LUMA centre.

7. **Finances and reach**

Finances vary from centre to centre. The LUMA Centre Finland could not provide us with an overview of the costs for each regional centre. The LUMA Centre Helsinki is financially supported by the University of Helsinki for an amount of €200,000 per year. This is also the case for the LUMA regional centre at the University of

Oulu which receives about the same amount from its university. The university also contributes by making buildings, laboratories, technical and administrative support, etc. available.

Other universities provide no or less financial support to their regional LUMA centre. All regional centres pay €10,000 per year to the LUMA Centre Finland for umbrella scientific and administrative support.

Partnership agreements are concluded with the business community for each regional LUMA centre and for the national LUMA Centre Finland. The LUMA Centre Helsinki has entered into such an agreement with a cluster of companies: each company contributes €20,000 per year, each time for a three-year period. At the end of this period an evaluation is carried out and the collaboration and support may be extended. In Finland each company has the legal responsibility to organise "outreach" activities for education.

The Finnish National Board of Education, i.e. the national agency working on the authority of the Ministry of Education and Culture, (sometimes) finances the salaries or fees of in-service trainers. In-service teacher training courses (usually online) and materials are free of charge.

Apart from that additional funds are appropriated for the new national STEM education development programme 2014-2019 (LUMA Finland programme)[30] of the Finnish Ministry of Education and Culture. Thirty pilot projects were launched, half of which encompass design-based research. On the basis of an annual evaluation by a steering committee and of research the best pilot projects will be upscaled (implemented on a larger scale) in the period 2017-2019.

The new programme (drawn up following consultation of all the stakeholders, including teachers) uses the results of current education research to design and implement new teaching methods, learning environments and materials for schools. The programme develops new methods and tools for inspiring children and young people into STEM and for increasing their skills and knowledge. For this purpose, teachers, pupils, families, schools and policymakers are collaborated with in the context of the programme.

8. **QA evaluation / research**

LUMA Centre Finland attaches great importance to underpinning STEM activities with research. Prof. Maija Aksela leads the LUMA Centre Finland, as well as the LUMA Centre of the University of Helsinki. She strongly emphasises the importance of research and action research as key elements for the sustainability of innovation and for reinforcing the basis on which innovative projects can be upscaled to involve more STEM actors (possibly together) in formal, informal and non-formal STEM education.

This research takes different forms. On the one hand, research is conducted by the researchers at the distinct universities. On the other hand, action research activities are set up by the teachers themselves with support from universities. As far as research at the University of Helsinki is concerned, it is found that master's and PhD students are closely involved in this research and carry out research into pilot projects.

Master's students at the university are invited to make their dissertation or thesis on a subject relating to STEM education. Within the LUMA Centre of the University of Helsinki, the PhD students are put in charge of an innovative STEM activity or a STEM pilot project on which they build their PhD research during three to four years.

30 http://www.luma.fi/isse-2015/3682

The LUMA Centre Finland publishes the scientific Journal "LUMAT: Research and Practice in Math, Science and Technology Education"[31]. The aim of all LUMA activities is to promote learning, studying and teaching of natural sciences, mathematics, computer science and technology. (LU stands for 'luonnontieteet', natural sciences in Finnish, MA for mathematics, and T for technology.) The latest issue of October 2015 was specifically dedicated to STEM education. It was entitled "Special Issue: An Overview of the Current State and Future of Mathematics, Science and Technology Education in Finland". It is available at http://www.luma.fi/lumat-en/4127.

9. **Strengths**

- The importance which the government attaches to the development of a systemic STEM policy with the LUMA programmes and projects.
- The support from universities and research centres and from education and business leaders (national, regional and local).
- The great focus on the start-up and supervision of school development projects[32].
- The large emphasis on in-service training for teachers from pre-primary to secondary education.
- The strong collaboration between pre- and in-service teacher training.
- The explicitly strong collaboration with informal and non-formal STEM education.
- The very strong focus on research regarding the teaching of STEM subjects, action research by and with teachers and research into these types of research, like the LUMAT Journal.
- The assurance of the quality of the organised in-service teacher training courses.
- The efforts made to reinforce cooperation between the 13 network partners.
- The efforts made to give an international dimension to LUMA Centre Finland.
- The integration of scientific research and educational innovation in the field of STEM.

31 http://www.luma.fi/lumat-en/1642:

Special characteristics

- The focus on both specialised STEM education and STEM literacy and life-long learning.
- The focus on learning communities and school development projects.
- The cooperation between pre- and in-service teacher training.
- The strong collaboration with informal and non-formal STEM education.
- The efficient application of resources by using PhD students for impact research.
- The strong focus on evaluation and research of STEM activities.

2.5 IMST Innovations Make Schools Top, Austria

IMST is a national wide support system and network to provide quality based innovations in STEM and German education. For this purpose, teachers and teacher educators implement innovative school projects and exchange their experiences through networks. IMST does not only affect the individual instruction, but also the school development and the structures of the educational system itself. Colleges of teacher education and universities as well as schools collaborate within the so-called "thematic programmes", one of the two main-strands of IMST. Furthermore, the Regional Education Boards are involved in the "regional networks" – the second strand of IMST. These measures foster sustainable cooperation, which supports synergies in the educational systems (see e.g., Krainer & Zehetmeier, 2013).

IMST includes two main strands:

- Thematic programmes
- Regional networks

Furthermore, the Gender and diversity network fosters the gender and diversity competences of teachers, which is regarded as an important criteria of teaching quality.

Thematic programmes

The Thematic Programmes (TP) represent a new and innovative support structure for teachers and schools. Their design is based on the idea of a fund with an application process, including a scientific reviewing system with its sophisticated quality assurance plan adopted for schools and teachers as well as by experts' support teams which accompany the project work. Each Thematic Programme is hosted by a cooperation of Universities and colleges of education. These hosts have been selected by a jury after an application procedure.

Actually, there are four national Thematic Programmes focused on CBL and IBL to stimulate innovative projects in STEM. Each programme supports about 20 school projects a year which were selected by an annual call (application process: application, reviewing, jury). After the projects were granted, the teachers are supported by the TP-Teams. The support is focused on accompanying teachers and school teams in their working process to enable good practice of the projects initiated by the teachers themselves. Some principles like evaluation and documentation including dissemination are fundamental and compulsory for the projects.

Concerning the future there are plans to expand the idea of the Thematic Programmes by a sustainable anchorage through a national Austrian Educational Fund.

IMST Network-Programme

The IMST programme 'Regional and Thematic Networks' supports regional networks in all nine Austrian provinces, and three thematic networks which operate on the national level. Within the IMST thematic programmes, teachers put into practice innovative instructional projects and receive support in terms of content, organisation and finance.

The goals of the networks are threefold:

- Raising the attractiveness and quality of lessons in mathematics, biology and ecology, chemistry, physics, information technology, geography, descriptive geometry and related subjects, as well as promoting cross-curriculum initiatives and school development in grammar, vocational and secondary modern schools, primary schools and kindergarten
- Professional development of teachers
- Involving as many schools as possible

The formation of regional networks is based on two principles:

- Use of existing personnel, institutional and material resources in the federal provinces
- The persons and organizations and school development act autonomously and take over responsibility for the development of regional networks (Rauch, 2013; Benke, Kittner, & Krainer, 2014).

Furthermore, 20 Regional Educational Competence Centers (RECCs) in STEM subjects and German were implemented all over Austria to act as a cooperative structure between universities and teacher education colleges. They partly fill the gap of a lack of subject didactic centres in higher education throughout Austria which can provide research-based didactical professional development for teachers. These centers were also awarded with the IMST-RECC-label by the federal ministry of education.

Gender_Diversity Network

The IMST Gender_Diversity Network is based on two important principles: gender sensitivity and gender mainstreaming. Gender and diversity sensitivity is regarded as a major criterion for the quality of teaching. Teachers who gained these competences make better use of potentials and resources of their students and are enabled to better understand individualities.

Thus, gender mainstreaming and gender sensitivity are principles that aim at broadening educational opportunities, life plans and opportunities for all individuals, regardless of their gender. Working against discrimination and exclusion, the focus on diversity within the IMST Gender_Diversity network also considers categories like social background, sex, ethnic and social origin, culture, education, different abilities or religion.

1. **Goals of IMST**

IMST has following goals[33]:

- Overall goal: Contribution to establish a culture of innovative quality development to foster the STEM education at Austrian schools
- improving instruction in Mathematics, Science, IT, German and related subjects34;
- raising the attractiveness and quality of lessons in Mathematics, Biology and Ecology, Chemistry, Physics, Information Technology, Geography, Descriptive Geometry and related subjects;
- promoting cross-curricular initiatives and school development in grammar, vocational and secondary modern schools, primary schools and kindergarten;
- professional development of teachers;
- involving as many schools as possible in educational innovation.

2. **Initiator / geographical spread**

The initiative was taken in 1998 by the Alpen-Adria-University of Klagenfurt to set up STEM as a cooperative structure between schools, school administration, universities/teacher training colleges and businesses. From the beginning the initiative received support from one or two ministries. Initially, the initiative was limited to secondary education. However, gradually, kindergarten and primary education (and the professional development of their teachers) and pre-service teacher training were involved as well. The IMST initiative is coordinated by the Institut für Unterrichts- und Schulentwicklung/IUS (Institute of Instructional and School Development) at the Alpen-Adria-University of Klagenfurt[35].

The IMST developed in three phases:

- research project: analysis of the disappointing TIMSS results for Austria (1998-99)
- school development project (2000-2004)
- build-up of a school support system since 2004

33 https://www.imst.ac.at/app/webroot/files/netzwerkprogramm/Rauch_Benke_Operating%20and%20evaluating%20regional%20networks.pdf
34 The Austrian Ministry of Education wanted not only work to be done on STEM subjects, but also explicit attention to be devoted primarily to the German language, as well as to other related subjects to promote interdisciplinarity.
35 https://www.imst.ac.at/app/webroot/files/netzwerkprogramm/Rauch_Benke_Operating%20and%20evaluating%20regional%20networks.pdf

3. **Target groups**

The activities of IMST are targeted on the following groups:

- STEM and German language (mother tongue) teachers at all levels of education
- schools and members of the school management teams
- pupils
- prospective teachers who are also involved in IMST initiatives
- universities and teacher training colleges
- regional education leaders
- businesses and civil organisations, NGOs
- research institutes and science centres
- actors in informal and non-formal education
- other education projects at national, European and international level

4. **Link with research and innovation**

The IMST programme has a strong link with research institutes and centres at the universities and in some cases, especially in relation with the regional networks, also with the business community. However, innovative initiatives in the business community are not really collaborated with and businesses are therefore hardly involved in the development of continuing professional development (CPD) courses for teachers. Nevertheless, reference is sometimes made to projects for which such cooperation is essential. The financial support from businesses is extremely modest as well. All IMST activities are based on a clear strategy to promote innovation in education through school development projects which in their turn lead to evaluation and research.

5. **Focus / activities**

Activities of thematic programmes

Currently the STEM teachers participate in four thematic programmes[36] which are exclusively focused on competency-oriented teaching and learning in e-learning, competences in STEM education, German and laboratory work. Since 2000, some 100 such innovation projects have been started and assisted (20 per year and per programme following a call for innovation projects). This joint planning, assistance and evaluation in their turn lay the foundations for research. Teachers develop (during their professional development) innovative materials and teaching competences for their lessons and are supported by professionals in using these materials in the classroom. Participants may be individual teachers, but also groups of teachers, entire schools or even local school networks. They commit to reporting on their activities by means of action research reports.

36 Id.

The outcome of the project work is presented at an annual conference and an annual innovation day, several network meetings and on the internet IMST-Wiki (http://www.imst.ac.at/wiki). Therefore, a well-coordinated collaboration between the IMST Network Programmes and the Thematic Programmes is essential.

Activities of the regional networks

The activities of each regional network within IMST differ according to the needs of regional schools and the types of assistance and support already available. The basic philosophy of all the IMST activities and projects is that learning and teaching innovations are most efficient when developed in close connection with teaching practice and when teachers are investigating their own work and networking with each other and with the academic community. This allows teachers to further develop their teaching knowledge and competences as well as their theoretical understanding[37].

The activities of the regional networks are determined by the regional steering committee, but usually include:

- establishing a platform for teachers, schools and other stakeholders;
- organising opportunities for the exchange of experiences and professional development initiatives;
- supporting synergies to promote development in schools;
- creating a pool of experts to advise on matters relating to professional and school development;
- drawing up an annual report and interim reports on the activities of the regional network;
- drawing up and implementing an evaluation of the regional networks.

Activities of the Gender_Diversity Network

The aim of the G_D network is to describe and to highlight unequal opportunities, power relations and different forms of discrimination within rooms for learning. IMST initiates a reflection of norms, values and hierarchies at play to then deconstruct these through gender_diversity sensitive actions.

Areas of activities are:

- counseling of all IMST programmes
- designing of advanced learning programmes for members, regional didactic centers, networks and thematic networks
- supplying service and coordination through knowledge transfer and support
- networking within IMST and with relevant stakeholders in the educational system
- communicating and disseminating our goals, principles and measures through our website, newsletter or specific events.

37 https://www.imst.ac.at/app/webroot/files/netzwerkprogramm/Rauch_Benke_Operating%20and%20evaluating%20regional%20networks.pdf

The expertise of the IMST national coordinating body

This expertise can best be summarised as follows:

- acting as consultant and adviser for all IMST programmes and activities;
- designing CPD courses in collaboration with and for regional networks, regional teacher training centres and thematic networks;
- providing support and coordination for pooling and disseminating expertise and support;
- reinforcing networking within IMST with other stakeholders and the education system itself at national and regional levels;
- communicating on the activities and disseminating information about the life and activity of the networks by means of the website, newsletters, conferences, etc.

The IMST programme itself organises the following activities:

- annual IMST innovation day for teachers
- annual IMST conference for teachers and STEM subject experts
- half-yearly IMST newsletter
- half-yearly network meeting for all the representatives of the regional networks, regional didactic centres and thematic programmes
- self-evaluation activities for all these groups
- the compilation of their reports
- the IMST-Wiki of best practices[38]

All reports and practices developed within the projects of the thematic programmes, are made available to all teachers through IMST-Wiki on the website of the IMST programme. This is an excellent example of a database containing interesting practices. The emphasis is on descriptions drawn up by teachers who are involved in STEM initiatives in the classroom and have produced relevant reflective papers. These teachers were and are assisted by academic collaborators of the IMST programme which is headed by Prof. Konrad Krainer at the IUS of Klagenfurt University. Teachers who conduct a project and file report receive a financial compensation. The IMST-Wiki of Best Practices can be viewed at www.imst.ac.at/imst-wiki/index.php/Hauptseite.

38 https://www.imst.ac.at/imst-wiki/index.php/Hauptseite

International activities

IMST is very strongly involved in several important projects of DG R&I, such as the FP7 PROFILES project on IBSE, the FP7 PARRISE (RRI) project, the FP7 Fibonnaci project on IBSE involving 60 universities, the DG EAC LLL KeyCoMath project and a Horizon 2020 project "European Network for STEM".

6. **IMST structure / management structure and personnel**

The network structure has been gradually built since 1998. In 2015 it consisted of a national coordination-centre, regional networks, regional didactic centres, 4 thematic programmes and a gender and diversity network. From 2005-2006 onwards 6 Austrian Educational Competence Centres (for biology, chemistry, physics at the university of Vienna, mathematics, German and the IUS at the Alpen-Adria-University of Klagenfurt) were established.

In 2015, there are 27 regional didactic centres in the federal states established by universities, teacher education colleges and frequently with state education authorities 20 of them were awarded with the RECC-quality label, which was established for the development and advancement of didactic centres. The regional networks in every federal state cooperate with the didactic centres within joint projects and teacher training courses.

The IMST programme thus encompasses a national network (with some type of national coordination and support) with independent regional networks in each of the Austrian federal state, the regional didactic centres which support the professional development of teachers and research, plus four thematic programmes at national level in which teachers can set up innovative instructional projects and receive support from IMST in terms of content, organisation and financing. A gender and diversity network was also launched to call attention to the strategies of gender mainstreaming, gender sensitivity and managing diversityto facilitate a variety of education supply, perspectives and equity of chances for pupils.

Teachers with great STEM experience can be trained to become regional coordinators (multipliers) who help school clusters at the regional level to develop and implement a STEM strategy and STEM education in order to bring school development projects to a successful conclusion. The IMST programme has - in line with its goals - done research into the role and impact of these multipliers in the upscale and multiplication of STEM initiatives to more schools.

At the same time the University of Klagenfurt coordinates three of the six National Competence Centres, more specifically the centres on mathematics and German education and the department for education and school development (IUS) which is the head office of the IMST programme.

7. **Management structure and personnel**

The national IMST programme has supported steering committees[39] in each of the regional networks. These steering committees coordinate the generation of content for activities and professional development courses. The steering committee also involves the regional education authorities and pre-service teacher education at teacher education colleges and universities.

One of the two basic principles to be respected in the formation of regional networks and regional didactic centres is that the new structures should build upon already existing personnel and institutional and material facilities in the federal states.

The nine regional networks choose their aims autonomously and anchor them in the collaboration contract with the IUS. In biannual reports, they document and evaluate their activities. The network coordination team at the IUS monitors the reports, offers support where needed, and organizes biannual network meetings with representatives of the regional networks, the regional competence centres as well as the thematic programmes.

8. **Finances and reach**

IMST has communicated the financial data in the strictest confidence for the sole use of the Flemish Department of Education and Training. The authors do not want to betray this confidence and therefore only give some general information.

The IMST programme receives the following funding from the Ministry of Education for the phase 2013-2015 (full three years):

- €2 million
- €0.6 million for partially exempted teachers (coordinators/multipliers) who assist and support school development projects at their school or within school clusters. The 'ordinary' teachers within the school are not exempted.

These resources are approximately doubled by the partner organizations in the IMST-network.

These financial data do not pertain to spin-offs of the IMST programme like the national and regional competence centres which themselves receive limited financial support from the Ministry of Education.

Teachers or schools do NOT pay to take part in professional development courses within the framework of IMST. The IMST programme covers their expenses, including the transport of teachers and educators.

IMST activities reach around 4,000 teachers on an annual basis. However, an overall figure was not given. In total, in the period 2013-2015 about 250 innovative school development projects were started (at a rate of approximately 20 a year per thematic programme). They were used as the basis for developing the IMST-Wiki action research database which contains around 1,000 action research reports drawn up by teachers.

39 https://www.imst.ac.at/app/webroot/files/netzwerkprogramm/Rauch_Benke_Operating%20and%20evaluating%20regional%20networks.pdf

9. **QA evaluation / research**

The IMST programme attaches great importance to underpinning STEM activities by evaluation and research. Prof. Konrad Krainer who runs the IMST initiative has conducted a great deal of research into the impact of IMST activities, in collaboration with colleagues. He strongly emphasises the importance of research and action research as key elements for the sustainability of innovation and for the reinforcement of the basis used to upscale innovative projects in order to involve more STEM actors.

This research takes different forms. On the one hand, research is conducted by the researchers at the distinct universities. On the other hand, action research activities are set up by the teachers themselves with support from universities and teacher training colleges. Master's and PhD students are closely involved in research at universities and conduct research into school development projects.

A lot of results on the research and evaluation of IMST activities are available in international Journals, but also in several Austrian scientific journals:

Biology (BIOSKOP): http://www.austrianbiologist.at/bioskop/

Chemistry (Chemie und Schule): http://vcoe.or.at/cs/index.php

Physics and Chemistry (Plus Lucis): http://www.univie.ac.at/pluslucis/PlusLucis/index_pl.html

In 2013 an issue of the IMST Newsletter was entirely dedicated to the evaluation and research of IMST activities:

https://www.imst.ac.at/files/ueber_imst/oeffentlichkeitsarbeit/imst_newsletter_40.pdf.

All the IMST newsletters can be found at https://www.imst.ac.at/eintraege/newsletterarchiv/bereich_id:50.

10. **Strengths of IMST**

- The importance which the government has attached to the development of a systemic STEM policy through the IMST programme since the late 90s.
- The support from universities and research centres, national and regional education leaders and other stakeholders.
- The great emphasis on the start-up and assistance of school development projects.
- The great importance of professional development training for teachers from kindergarten to secondary education.
- The strong collaboration between pre- and in-service teacher education.
- The very strong focus on research regarding the teaching of STEM subjects, action research by and with teachers and research into these types of research.
- The quality assurance (evaluation) of the organised CPD courses and other IMST activities.
- The efforts to reinforce collaboration between the network partners.
- The efforts to give an international dimension to the IMST programme.

Special characteristics

- The attention that is devoted to researching the effectiveness of specific projects and teaching methodologies through action research by the teachers involved and through research at the universities.
- The importance of school development projects which not only focus on STEM subjects, but also on the German language.
- The strong link between pre- and in-service teacher training.
- The great emphasis on evaluation.

2.6 Scientiam Inquirendo Discere: SID project, Italy

1. **Goals**

- To set up and implement a systemic STEM programme at local, national and international level for the development of pilot centres in accordance with the model designed within the framework of the FP7 Fibonacci project.
- To disseminate IBSE in schools by organising professional development for science teachers at several levels of pre-primary, primary and secondary education.
- To translate and adjust pedagogical materials on IBSE developed by successful networks.
- To develop new modules (teaching packages) or adjust existing modules to the national curriculum (20 different modules with over 300 activities).
- To design kits - boxes with experiments and manuals - (more than 500 so far) which are made available free of charge to teachers and schools that participated in the professional development and want to apply the IBSE approach in their classroom and school.
- To set up long-term learning communities.
- To promote the participation of scientists in the co-creation and co-implementation of professional development courses in accordance with the French MPLS model.
- To design development strategies for schools and teachers with an approach that is adjusted to each specific level.

2. **Initiator / geographical spread**

In the period from 2009 to 2012 ANISN, i.e. the national Italian association of STEM teachers, participated in the FP7 Fibonacci project for IBSE dissemination (http://www.fibonacci-project.eu/). This project used a model in which universities, university colleges or other organisers of professional development training for STEM teachers with a lot of experience in inquiry based science education (IBSE Reference centres) tutor other organisations in progress to also become STEM and IBSE reference centres. In 2010, SID started with one IBSE pilot centre in Naples. The SID programme was officially launched in 2011 with 3 pilot centres (Naples, Pisa and Venice). Currently, 10 centres are spread throughout Italy: Naples, Venice, Rome, Pisa, Milan, Bari, Turin, Potenza and Sardinia.

3. Target groups

The following target groups are involved in the activities of the SID network:

- Trainers or teacher trainers
- Pre-primary and primary school teachers
- Secondary education teachers
- Schools with pre-primary, primary and lower secondary education

4. Link with research and innovation

Since the network of pilot projects is usually embedded in universities or research institutes, there is a very strong link with science and technology research and with innovation. These institutes clearly contribute to the co-creation of the professional development provision. Moreover, they are closely involved in the implementation of this provision. For a large number of these initiatives, teachers and/or pupils work in the available laboratories or become acquainted with the innovative scientific activities which universities or research institutes participate in. This is highly appreciated by teachers and pupils.

Researchers and scientists are also invited to give guest lectures organised by SID. In addition, they help develop pedagogical modules within a working group. Sometimes researchers or scientists work together with pupils at the school. However, this is rather exceptional.

5. Focus / activities

The main activity of the 10 pilot centres is organising professional development for primary or secondary education teachers. The teachers to be trained are divided into three levels: beginning teachers, teachers with some experience and advanced teachers. Teachers can register for professional development courses lasting one year. After that they can continue in the second and third year. If after having finished the professional development training for advanced learners (third year) they also meet certain criteria such as having developed resources, becoming referent teachers in their school, participating in national and international training courses, etc. they can become professional development educators or trainers. .

In addition to the professional development courses, summer courses are also organised for larger groups of teachers during the summer holidays. Usually these are mixed groups of teachers who are only beginning to use IBSE in the classroom and teachers who already have experience in this respect. This combination of beginning and experienced teachers is welcomed by all the participants. Since the exchange to a large extent promotes the collaborative work between teachers, this substantially increases the professionalisation of each reflective teacher. Some professional development courses are also organised in a number of partner schools for all the teachers of those schools in order to promote collaborative learning and increase the impact of the professional development courses.

The pilot centres also take part in various European projects (like the LLP Comenius Network SUSTAIN[40]). This offers teachers a unique opportunity to become acquainted with other STEM activities and approaches in other European countries. SID is also closely involved in the activities of the SCIENTIX [41] programme of DG R&I[42] and in the activities set up by European Schoolnet. Within this framework they annually organise professional development courses for Amgen Teach[43] of the American Amgen Foundation which seeks to promote IBSE in education.

Furthermore, a working group is organised to develop teaching materials for teachers in the classroom, and guest lectures are given by researchers or scientists.

Finally, the SID programme is also a member of the UTRECHT STEM Think Tank which encompasses a group of 6 networks which include all the aforementioned networks plus one of the partners of the German MINT Forum, i.e. the Stiftung Haus der kleinen Forscher[44]. This group aims, among other things, to improve the quality of the professional development of STEM teachers and to examine how school development projects can be set up for STEM with a systemic approach.

6. Network structure / management structure and personnel

The network is composed of 10 pilot centres. The pilot centres are affiliated with a number of schools (5-15) where 20 to 60 experimenting teachers[45] teach 600 to 2,000 pupils.

Each of the 10 pilot centres is housed in a university, research institute or (science) museum. In some cases a contract is signed between ANISN and the host institution.

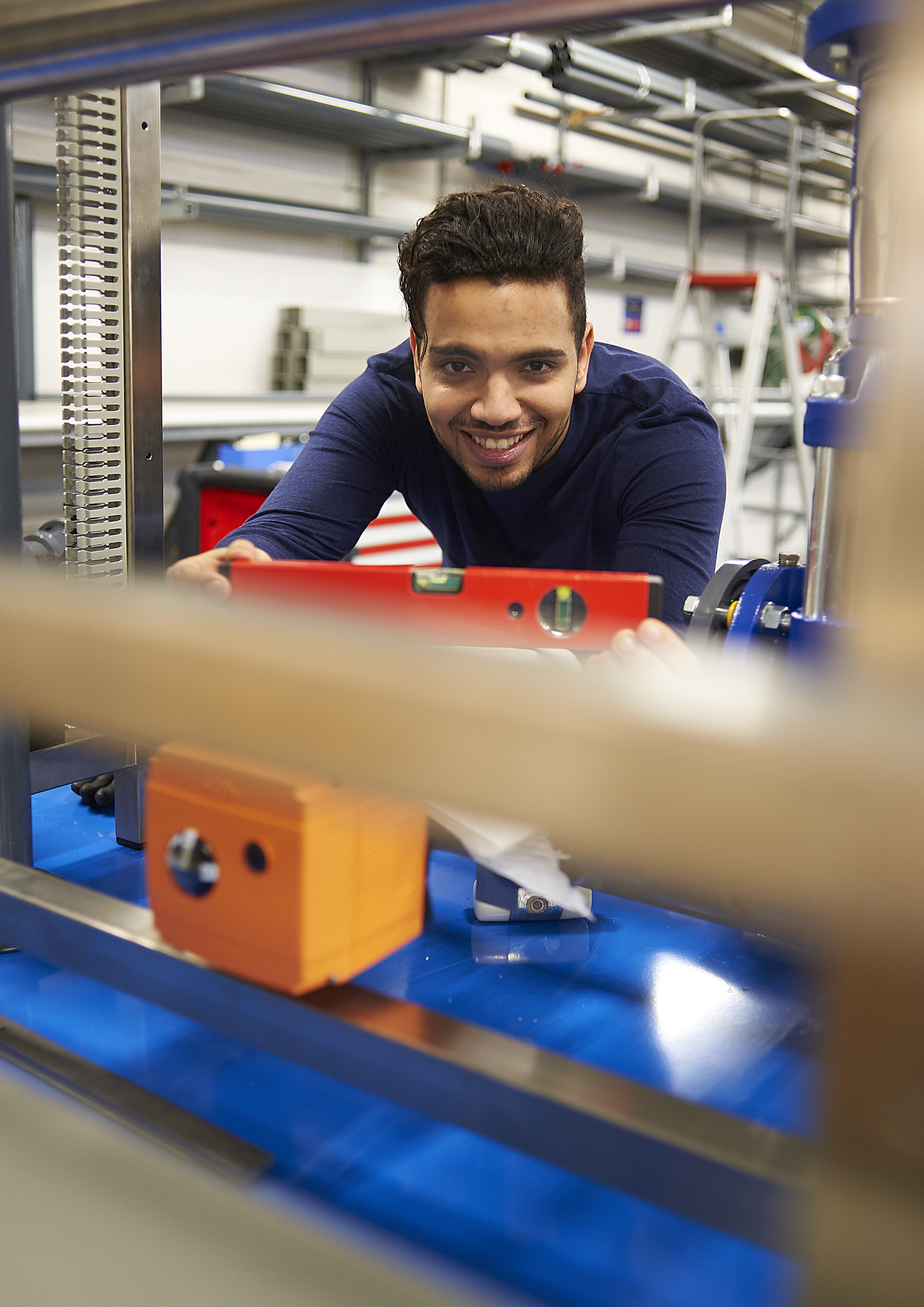
The cooperation with the university or research institute is not just limited to accommodating the SID pilot centre. The university or research institute and the SID are involved in joint working groups, in organising professional development courses, seminars and hands-on activities in the laboratories or in fundraising projects.

The collaboration with the local education authorities varies by pilot centre. Sometimes a local committee is in place to determine the training provision. This committee also tries to obtain support from the local authorities in disseminating the training provision. In other cases partnership agreements are concluded between local authorities, school networks, ANISN, the Accademia dei Lincei[46], the scientific host organisation or the museum.

Cooperation with the local education authorities is generally good. Sometimes they even offer support to the local pilot centre. The Ministry of Education supports the SID programme in several ways: with a financial contribution or through communication and certificates for the participants, schools and trainers. A cooperation agreement was signed by the Ministry of Education and the Accademia dei Lincei which specifically mentions the SID project. However, no contract was signed between the Ministry and ANISN.

As of 2012 a larger scale project was set up called “I Lincei e l’istruzione” (The Academy and Education) on instruction of the Italian language, science and mathematics. Although SID is responsible for “science” within this new framework, the Ministry reduced its financial support. The Ministry’s role is limited to a “political” role for the broader project of the Accademia dei Lincei. The financial contribution for SID is small and is not at all in line with the network’s growth.

40 More information about SUSTAIN is available at http://www.fondation-lamap.org/en/sustain/project.
41 More information about the SCIENTIX programme is available at http://www.scientix.eu/web/guest;jsessionid=F2957C15500EFB89DA7C-808020C8CEBD.
42 DG Research and Innovation
43 More information about Amgen Teach is available at http://www.amgenteach.eu/.
44 More information about the Stiftung der kleinen Forscher is available at http://www.haus-der-kleinen-forscher.de/de/
45 Teachers attending professional development courses
46 Italian Academy of Science



Personnel

The SID project is mainly driven by voluntary and highly motivated STEM teachers who have been committed for years to keeping the centres going. This is both the strength and weakness of the project.

At national level, one person is in charge of the SID project within ANISN. This person is exempted part-time by the Ministry of Education. The national coordination of ANISN thus consists of 8 people, including 7 volunteers.

The ANISN working group which designs teaching aids is composed of 15 members (all volunteers).

One or two people are in charge of each local pilot centre (volunteers!): 13 in total.

Each pilot centre has 5 to 10 trainers or educators (70 in total). The volunteers receive only a small compensation to cover their travel expenses.

7. Finances and reach

Since 2012, initially 3 and now 10 centres have reached approximately 1,200 teachers and around 50,000 pupils. In total, some 70 educators or teacher trainers are actively involved in the professional development courses.

Financial sustainability is a complicated and rather weak aspect of the SID project because the revenues strongly fluctuate each year and it is the Academy that decides on the allocation of the Ministry's funds. Overall it must be stressed, however, that many great things have been achieved with few financial resources.

Financial characteristics of the SID project:

- The personnel of ANISN does not receive any payment, but they can recover their expenses (in most cases). They are often retired STEM teachers or teachers who teach on a full-time basis and in addition invest time in the SID project.
- Trainers or educators are paid an annual sum ranging between €250 and €1,000.
- The host organisation of the pilot centres (university, research centre, etc.) makes the rooms, heating, electricity and local personnel available free of charge.
- Participating researchers are NOT paid at all.
- The Ministry of Education allocates funds to the Accademia dei Lincei, which passed on €67,000 to the SID project in 2011/2012. However, this amount has been reduced to €30,000 since 2014-2015.
- Sometimes the local pilot centres receive(d) some financial support from a Foundation (like a bank). This support amounts to between €3,000 and €10,000 per year or every two years. However, this support is not provided on a structural basis and must each time be re-approved. In some centres this support was a one-off.
- Each local pilot centre tries to canvass additional support in several ways, with varying success.

- The Amgen Teach project in which SID participates contributes €36,750. However, this sum is used entirely for organising the Amgen Teach professional development courses. This project lasts three years.
- The total operating budget of the SID project is estimated at an average of €40,000 per year. Moreover, the person running the SID project is exempted from teaching duties on a part-time basis by the Ministry of Education, which is a contribution of €20,000. However, this decision needs to be renewed each year.
- In fact, 2 to 3 teachers who are exempted on a full-time basis should be put at the disposal of the SID project, but no funds are available for this.

8. **QA evaluation / research**

Professional development courses are evaluated by means of online questionnaires completed by teachers attending the courses. Some of the pilot centres have designed evaluation tools to evaluate the project as a whole, at the level of both teachers and pupils. It is each time evaluated how satisfied the teachers who attend professional development courses are, but also how satisfied the pupils are with the fact that the teachers use different teaching methods. It is also tried to evaluate how the parents feel about the changed teaching methods.

Work is currently done to establish an evaluation council of teachers and an evaluation council of educators, trainers and other experts who have participated in organising professional development courses.

The teaching modules are also evaluated by teachers and pupils. All the data are collected on a regular basis and processed in an internal evaluation report.

In 2014 an external evaluation was carried out by an external agency of all the activities of the SID project and of the different pilot centres. The very positive results represented a strong motivation to continue.

9. **Strengths**

- The quality of the professional development courses.
- The motivation and unrelenting commitment of the ANISN leaders and the experienced STEM teachers (active and retired teachers) who collaborate with them.
- The cooperation with the French Fondation La main à la pâte which gives them material and expert support. French retired IBSE expert teachers participate as volunteers in professional development courses in Italy.
- The support which the network receives from the Accademia dei Lincei, i.e. the Italian Academy of Science.
- The participation of ANISN in numerous European and international projects to continue to inspire and innovate themselves.

Special characteristics

- The bottom-up approach to the organisation of professional development courses.
- The clear progress in the professional development from beginners to advanced.
- The participation of ANISN in European projects, which resulted in cross-fertilisation.
- The strong link with schools and school development projects.
- The commitment of dozens of volunteers.
- The permanent evaluation by teachers who took a professional development course, as well as their pupils.

2.7 MINT FORUM, Germany

Introduction

Apart from the six networks described earlier the national MINT Forum in Germany is also briefly discussed here. The nature and structure of the MINT Forum are different from the other networks because each member of the MINT Forum organises activities which are not necessarily endorsed by all the members of the Forum. Nevertheless, this type of cooperation also seems extremely useful in terms of information, because some 35 (often highly diverse) institutions and organisations have joined forces in the German National MINT Forum to promote education in the fields of mathematics, IT, natural science and technology (STEM education). Since its creation in 2012 the National MINT Forum has been recognised as the focal point for the promotion of STEM education in the Federal Republic of Germany.

1. Initiator(s)

In 2012 the initiative was taken to establish the MINT Forum. The founding members include many foundations, academic institutions, professional associations, academic alliances and businesses.

The National MINT Forum regards itself as a supporting communication and multiplier platform of its members with the common purpose of reinforcing the effect of STEM initiatives by individual actors through stronger networking and collaboration, creating synergies between initiatives and contributing to the continuous improvement of STEM education and training.

2. Target groups

The partners of the MINT Forum agree on the fact that STEM education must be an essential component of each type of fully-fledged education and training. They endorse the idea that STEM should be embedded in a continuum from pre-primary, primary and secondary education (general, technical and vocational education) to higher and adult education.

They emphasise that account should also be taken of extra-curricular STEM activities which young people participate in within and outside school. The link with informal and non-formal STEM education is therefore also important for the MINT Forum.

The partners focus on the continuum of both formal and informal education.

3. **Link with research and innovation**

There is a link with research and innovation through the research institutes that are members of the Forum, like the Max Planck Institute, and via the industrial members (see footnote 25).

4. **Structure of the Forum**

Within its partnership[47] the MINT[48] Forum strictly complies with the principle of subsidiarity: each member's identity, visibility and autonomy are fully respected.

The National MINT Forum tries to formulate joint 'political' proposals in the field of STEM which are beneficial to all the members. It is therefore a strategically and politically oriented partnership (some kind of lobby group) which is not operationally oriented. It is an exchange platform that facilitates synergy and coordinated actions. The members inform each other about current and planned activities and share their networks and experiences with each other.

5. **Activities**

The National MINT Forum supports the initiatives of individual members and promotes joint activities via working groups on specific STEM subjects.

The Forum also wants to formulate recommendations for educational policymakers at national level and in each of the federated states. It also wants to reach agreements on shared quality standards for STEM or launch joint projects regarding STEM in general or specific sub-areas in particular.

The National MINT Forum organises the annual National STEM Summit where key 'political' messages and the most important themes of their work are explained and discussed with representatives from the political and economic world, the education and training sector and civil society. This summit offers a unique opportunity to meet all the major STEM stakeholders.

At the 2nd STEM Summit of MINT (2014) the latest proposals and demands of the National MINT Forum were discussed.

The 3rd National STEM Summit took place on 25 June 2015 and featured the theme Berufliche Bildung: Ein deutsches Erfolgsmodell in Gefahr?[49] (Vocational Education: A German Success Story in Danger?).

47 The members of the MINT Forum are: ING - Fakultätentage der Ingenieurwissenschaften und der Informatik an Universitäten e.V., Acatech - Deutsche Akademie der Technikwissenschaften e.V., BDA | Bundesvereinigung der Deutschen Arbeitgeberverbände, Berlin-Brandenburgische Akademie der Wissenschaften, Bundesagentur für Arbeit, Deutsche Telekom Stiftung, Deutscher Industrie- und Handelskammertag e.V., Fraunhofer-Gesellschaft, Gemeinnützige Hertie-Stiftung, GESAMTMETALL - Gesamtverband der Arbeitgeberverbände der Metall- und Elektroindustrie e.V., Hans-Böckler-Stiftung, HAWtech - HochschulAllianz für Angewandte Wissenschaften, Heinz Nixdorf Stiftung, HRK Hochschulrektorenkonferenz, Jacobs Foundation, Joachim Herz Stiftung, Körber-Stiftung, Kompetenzzentrum, Technik-Diversity-Chancengleichheit e.V., Lehrer Forum MINT, Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V., MINT Zukunft schaffen, MNU - Deutscher Verein zur Förderung des mathematischen und naturwissenschaftlichen Unterrichts e.V., Nationale Akademie der Wissenschaften Leopoldina , sdw - Stiftung der Deutschen Wirtschaft gGmbH, Siemens Stiftung, Stifterverband für die Deutsche Wissenschaft e.V., Stiftung Haus der kleinen Forscher, TU9 German Institutes of Technology e.V., VDI - Verein Deutscher Ingenieure e.V., Wilhelm und Else Heraeus-Stiftung, Wissensfabrik - Unternehmen für Deutschland e.V..

48 MINT stands for Mathematik, Informatik, Naturwissenschaft und Technik or Mathematics, IT, Natural Science and Technology, which is the equivalent of the English STEM.

49 http://www.nationalesmintforum.de/658.html

The fourth National STEM Summit will be organised on 2 June 2016.

Working groups

The following working groups have been established to identify similarities in the activities and joint challenges and to possibly address them together, as well as to avoid double work:

- STEM education as part of a holistic/systemic educational concept
- Promoting the skills and interests of talented STEM young people, in particular of children and young people from socio-economically disadvantaged backgrounds
- Internationalisation of STEM education
- Development of quality standards and criteria for STEM initiatives
- Teacher training in STEM subjects
- Development of STEM activities in the different regions

Publications

In a separate working group the German National MINT Forum has developed a guide for evaluating MINT initiatives: "Leitfaden 1.0 für die Qualitätssicherung von MINT-Initiativen". More information is available at http://www.nationalesmintforum.de/fileadmin/user_upload/gerke/NMF/Leitfaden_1.0_Webversion.pdf.

Recommendations

The MINT Forum has also made 10 recommendations for improving the training of STEM teachers: "Zehn Thesen und Forderungen zur MINT-Lehramtsausbildung: Empfehlungen des Nationalen MINT Forums". More information is available at

http://www.nationalesmintforum.de/fileadmin/user_upload/gerke/NMF/Empfehlungspapier_final_Webversion.pdf.

6. Finances

- The activities of the MINT Forum are administratively and financially supported thanks to the help and participation of several members. No figures were made available, except the total budget for the Haus der kleinen Forscher (Little Scientists' House): €8,980,384.56, of which 50.2% is spent on personnel costs.

2.7.1. Some elements on the Stiftung Haus der kleinen Forscher (Foundation Little Scientists' House)

The Stiftung Haus der kleinen Forscher is one of the members of the MINT Forum.

It was established in 2006 with the aim of raising interest in STEM in children aged 3 to 10 years.

The main emphasis is on organising professional development for teachers, kindergarten teachers, educators and entertainers.

Some figures regarding the STEM programme of the Haus der kleinen Forscher which is directed at pre-primary and primary education and STEM academies (extra-curricular STEM activities):

The Stiftung Haus der kleinen Forscher collaborates with several partners: other foundations that are members of the MINT Forum, the federal government or regional authorities in the federated states (Länder), local authorities, businesses or sector organisations, science museums, NGOs, etc.

Professional development activities are based on three pillars: collaborative, dialogic and inquiry-based learning (IBSE).

Pre-primary and primary schools, childcare centres or STEM academies that collaborate with them can, upon their request and following an evaluation of their activities, be certified as "Haus der kleinen Forscher".

Their activities are also strongly underpinned by evaluation and scientific research of their own activities. They regard themselves as learning organisations that constantly work to improve themselves.

Some figures:

- Total budget of the Foundation: €8,980,384.56, of which 50.2% is spent on personnel costs.
- The 230 network partners reach 26,500 pre-primary and primary schools or childcare facilities.
- They reach 43% of the pre-primary schools or childcare facilities, 31% of the STEM academies and 19% of the primary schools.
- 147 staff members are employed at the head office in Berlin and 314 with local partners.
- Participation in professional development courses: Teachers and educators of 20,600 pre-primary schools and childcare centres, 2,900 primary school teachers and 1,100 educators/entertainers of STEM academies took part in the professional development courses.

Special characteristics of the MINT Forum

- Not a real network structure, but rather a forum where members meet to pursue shared goals.
- No additional cost because each member finances its own activities. Coordination is organised by two of the founding members.
- Possibility to promote cooperation between different members.
- The MINT Forum is a strong lobby group vis-à-vis policymakers.

2.8 Main characteristics of the described networks

Organisation	Starting year	Initiative	Key focus	Budget/year	Reach
1. **FRANCE** Les Maisons pour la science (FR) Coordination of Lamap in cooperation with 9 universities	2012	Lamap and Académie des sciences	**STEM professional development** of teachers of pre-primary, primary and lower secondary education by teams of **researchers** and trainers during activities in laboratories	€1.7 million per year (average over 7 years) from PIA (government) €1.7 million per year (average over 7 years) at the local level from local authorities and the businesses community	Network of 10 Maisons 10,000 teachers per year
2. **THE NETHERLANDS** Science support centres at 11 universities	2004	Ministry of Education and regional authorities	**Regional training** and professional development of **secondary education teachers** in STEM disciplines and training of school management team members with focus on school development projects	Between €100,000 and €300,000 per year per regional network	Network of 11 support centres 1,000-1,200 teachers per year for all the support centres together
3. **UK** NSLN network Coordination by non-profitmaking organisation Myscience.co Ltd Part of the White Rose University Consortium	2006	Wellcome Trust - Department for Education and Skills	**Improvement of STEM education in UK through 52 learning partnerships with schools from which further dissemination takes place** **STEM professional development** for teachers and technicians of pre-primary, primary and secondary education and training for policy makers in schools	£11 million per year made available by the Wellcome Trust, the Department for Education and industrial partners, amongst others	Network from 52 schools 15,000 teachers and policymakers (per year?)

4. **FINLAND** LUMA Network of 13 LUMA centres Coordination: LUMA Centre Helsinki, University of Helsinki	2003	Finnish National Board of Education	Improvement of both **STEM specialisation and general STEM literacy** through online support for STEM teachers and collaboration with pre-service teacher training	€200,000 per year for coordination Funds for other centres vary by centre Also support from businesses	Network of 13 centres 1,000 to 1,500 teachers per year + 600 - 1,000 students in pre-service teacher training
5. AUSTRIA IMST Innovationen Machen Schulen Top, (AT) Coordination: IUS Univ. Klagenfurt	1998	Federal Ministry of Education and Women & Alpen-Adria-Universität Klagenfurt, in collaboration with partners	Research into effectiveness of specific projects and teaching methods **through action research** by teachers involved in professional development	€1.5 million per year from Ministry of Education and regional authorities	Network of 9 centres 4,000 teachers a year
6. ITALY SID Scientiam Inquirendo Discere (IT) Coordination: ANISN	2010	ANISN + Accademia dei Lincei	Bottom-up approach and progress in the organisation of professional development courses with **participation of ANISN in European projects**, which resulted in cross-fertilisation Commitment of dozens of volunteers	Between €67,000 and €30,000 per year (amount is being reduced)	Network of 10 centres Average of 400 teachers per year
7. GERMANY: Haus der kleinen Forscher/ HdkF Stiftung2	2006	Ministry of Education + private foundations	STEM qualification programme (professional development) for teachers and educators in 24,000 **pre-primary schools and child-care centres** in collaboration with **researchers**	€9 million per year (80% from Ministry of Education and 20% from private partners) + regional funds (unknown)	229 local networks 4,300 certified local institutions (schools, day care centres, after-school care, etc.).

3. Conclusions: Critical Success Factors for Successful STEM Networks

Below, a series of critical success factors are given which can be deduced from the 7 examples of STEM networks described in the present report. These success factors also serve as recommendations which can be taken into account when starting up a STEM knowledge network in Flanders. In addition, they are key elements in the sustainability of a STEM knowledge network.

Before focussing on these success factors, it may be interesting to briefly list the characteristics and formulate a number of comments:

- None of the countries use the term "knowledge centre" (which could give the impression that the knowledge is attracted, even invented and then disseminated by that centre).
- All the networks are set up on a structural basis and greatly focus on knowledge sharing and, by consequence, on knowledge reinforcement and deepening and the transfer of this knowledge to the classroom/school.
- There is much room and respect for bottom-up approaches (peer-to-peer education often takes centre stage).
- A strong emphasis is placed on continuous professional development (CPD) in collaboration with universities and STEM professionals in laboratories and businesses.
- The 7 described networks focus strongly on the professional development of teachers. Naturally, this is essential in promoting STEM. However, the question is whether this also has to be the case in Flanders.
- Only a limited financial contribution is made by businesses and sectors.
- A fundamental contribution from the government in the long term is essential to achieve a strong effect.
- It goes without saying that an existing knowledge network cannot be "copied" just like that, since the national or regional context (especially of the education system) differs strongly by country.

3.1 A clear STEM policy and long-term vision of the government

The analysis from the networks concerned clearly shows that all the networks (except for the Italian SID) draw their strength from the systemic policy pursued by the government in the field of STEM. As a result, most networks have been created to support and implement this policy. This is also the reason why the government (co-) finances most of these networks.

In several of the described networks there is great involvement from the government through various ministries (education, training, employment, science innovation, etc.) which combine their efforts to promote education and science innovation. This is the case in Finland, Austria, the Netherlands, France, Germany and the UK. Some of the networks also involve the national, regional and local (education or other) authorities in their STEM activities and funding.

As far as this factor is concerned, the chances of success of a STEM network that is yet to be established in Flanders are extremely high, since the STEM Action Plan is endorsed by the Department of Education and Training, the Department of Economy, Science and Innovation and the Department of Work and Social Economy, and because Flanders has made a clear choice to invest in STEM. It is extremely important that the leaders of the different departments are involved from the beginning to join forces in terms of content and finances, to opt for a long-term approach and to increase the final impact.

The most successful and strongest networks are the ones that have, from the start, envisaged a model for growth which ties in with the STEM policies of the government and the Ministry of Education (and other ministries). The partners (government + networks) jointly developed a long-term vision. This is clearly illustrated by the Finnish LUMA Centre, the IMST network in Austria, the National Science Learning Centre York network in the United Kingdom and the MINT Forum in Germany. They were created within the framework of the government's systemic policy and have grown along with the development and implementation of that policy.

The Netherlands as well have had a tight systemic approach since the late nineties and especially since 2004 as a result of the Deltaplan Bèta Techniek. In France the organisation in charge of the network's coordination has been engaged in STEM for a longer period of time (since 1996) and has gradually developed several activities to promote STEM.

The networks with a long-term vision have in most cases also defined quantitative and qualitative goals or indicators or were subject to such indicators in exchange for financial support from the government or other stakeholders. This also generates data that are made available. Success indicators are set in the long and short term to examine whether the knowledge network has the intended impact. A comparison can be made with the objectives specified in the STEM Action Plan and with the STEM barometer.

3,.2 Embedding in universities in collaboration with university colleges and research institutes

All the analysed networks are embedded in and/or carried by a university or a consortium of universities and university colleges. The only network whose pilot centres are not really carried by a university (although the universities are involved) is the Italian SID network. It is also the most vulnerable network, because the embedding in the university is not optimal.

The collaboration with universities/university colleges is crucial in all the networks, not only because the former accommodate the teacher training programmes, but (important!) also because the researchers of research centres within the universities/university colleges invariably play an important role in the STEM training and professional development of teachers. The connection with research centres allows STEM teachers to familiarise themselves with the latest research, as is done, for instance, through the cutting edge science initiatives in England. PhD and engineering students (role models!) are also involved in school projects or activities. Responsibility is often shared: science for the university; technology for the university colleges (the Netherlands, Finland). Businesses sometimes also contribute in this model through their laboratories and innovation centres.

Teachers are trained in the laboratories, can do a placement there or pay a visit there with their pupils. Researchers are often partially exempted to assist in the professional development of teachers or support school projects. Germany even has a whole network of university laboratories[50] - GenaU[51] - that collaborate with schools (pupils and/or teachers).

50 GenaU (Gemeinsam für naturwissenschaftlich-technischen Unterricht): within this network the laboratories of universities and university of applied sciencess in Berlin and Brandenburg offer young people (of each age category) the opportunity to conduct experiments for each STEM discipline as a class. They also organise working groups and professional development courses for teachers.
51 http://www.form-it.eu/goodpractice/projects/learning_labs.shtml

In other words, within a STEM knowledge network close interaction should take place between education and top researchers and the latest innovations in science, technology and engineering.

3.3 Synergy between all STEM actors and stakeholders

In order to be successful, STEM knowledge networks should create synergy between all the actors from formal, informal and non-formal STEM education, as well as with the business community and civil society. The knowledge network should focus on both general STEM literacy and STEM specialisations. That is why collaboration exists with science museums, botanical gardens, zoos, observatories, etc. in each of the countries described, why most countries have a link with the business community (UK, Finland, the Netherlands, Germany, France), why two networks have a strong link with the Academy of Sciences (France, Italy) or why they work together with institutions like the Foundation against Cancer, hospitals, etc.

In addition, most networks have established a clear link between pre- and in-service teacher training[52]. This link is very strong in Finland, Austria and the Netherlands. In France it varies by Maison. Currently, this link is further extended, however, since the renewed pre-service teacher training only entered into effect in the period 2014-2015[53]. In Finland students in pre-service training do placements in informal and non-formal STEM education. Finnish teachers too can follow professional development courses in pre-service training. In England the link with pre-service teacher training is weaker, because this training for the largest part takes place within the school itself.

In addition, all the networks work together with the business community[54], either with individual companies or with sectors or federations. The collaboration is laid down in a contract for one or several years, including an evaluation to be carried out in view of an extension. The collaboration can take different forms: either companies financially support the activities of STEM networks or company employees or researchers are involved in the co-creation and co-implementation of professional development for teachers and other groups, like school management teams, science coordinators, etc.

Sometimes, funds from the business community are pooled to increase efficiency. The Wellcome Trust UK and some activities of the MINT Forum work from this perspective. Priorities for the application of shared funds are jointly established on the basis of needs and impact studies, among other things.

The Flemish STEM policy represents all these levels, which is why it can support the knowledge network in achieving this synergy. The synergy between the actors may also encourage companies or company clusters to establish a fund for the co-financing of STEM in Flanders (and its activities), since this facilitates and guarantees a systemic approach and subsequently the necessary impact.

52 Teacher training still differs strongly between the European countries offering bachelor's and master's courses and the European countries which only offer master's courses. More information is available in the following publications: The Teaching Profession in Europe: Practices, Perceptions, and Policies, Eurydice 2015: file:///C:/Users/Educonsult/Downloads/EC0115389ENN_002.pdf

53 Until 2013, pre-service teacher training was organised within the IUFM (Instituts Universitaires de la Formation des Maîtres). In 2014-2015, they were replaced with the ESPE (Ecoles Supérieures du Professorat et de l'Education) which were integrated more strongly into the universities and are in charge of pre-service training for all teaching professions and of professional development.

54 Publication by King Baudouin Foundation: Leren van elkaar. Samenwerking tussen scholen en bedrijven Een oriënterende verkenning over de argumentatie rond samenwerking en de mogelijke samenwerkingsgebieden tussen scholen en bedrijven (2006); zie: http://www.prouv.net/publication.aspx?id=294889&langtype=2067

3.4 No exclusive top-down model

Most networks have clearly emerged from a top-down/bottom-up model. This means that the government has implemented a specific STEM policy after which certain groups have proposed to develop a knowledge network to meet a specified need. This happened gradually: for instance by initially working for certain target groups (like secondary education or pre-primary and primary education) and subsequently extending the operation to other target groups.

Only the Italian network SID was entirely created from the bottom up thanks to the participation in a European network by ANISN.

It goes without saying that knowledge and expertise should be exchanged within the knowledge network. It can never be the intention for the knowledge network to ignore the richness of existing initiatives and the professional knowledge in the field of STEM. This includes teaching knowledge, as well as knowledge of professional STEM. Cross-fertilisation is facilitated by bringing the available expertise together. In addition, use can be made of the specialist knowledge of some partners in the network. The fact that some partners feel their expertise is unappreciated has in some cases led to a crisis in the analysed networks which could only be solved by devoting more attention to the knowledge of all the partners in the network.

3.5 Priority to STEM education and the professional development of teachers

All the studied STEM knowledge networks prioritise formal STEM education, mostly from pre-primary and primary school until the end of compulsory education, but often also after that. Moreover, all the studied European STEM networks primarily focus on the activities relating to the professional development of teachers and of other groups like school management teams and people in charge of STEM at school (Finland, the Netherlands, UK), STEM coordinators (UK), facilitators for extra-curricular activities (Finland, some *Maisons* in France) or teacher trainers themselves (Finland, France, the Netherlands). In some countries like Finland and Austria there is a very close and clearly structured link between the professional development of teachers and pre-service teacher training.

In nearly each of the networks primary school (but partially also pre-primary school) teachers are found to be most in need of STEM professional development. The reason is that they often teach all subjects and have not been specifically trained to teach STEM.

Professional development can be provided to teachers through face-to-face instruction or distance education, or a combination of both (blended learning). Teaching materials are developed, adjusted or pooled as well, which may help improve STEM education. Large focus is always placed on the use of quality materials which have been produced and upscaled by the teachers themselves. As a result, the ownership of and experience with the provision grows. Professional development courses may lead to the acquisition of ECTS credits or even a master's degree (France, UK, Austria). Apart from training the teacher trainers of professional development courses, professional development courses are also offered for researchers or students in STEM disciplines (engineering students or students taking a master's degree in science and third-year professional bachelors in technology) who participate in professional development or who assist primary education teachers in the classroom for STEM subjects (France). The latter may also serve as role models for school projects (ASTEP initiative in France).

3.6 Importance of school development projects and cooperation with schools

It is striking that most STEM networks currently attach great importance to collaboration with schools. In some countries like the United Kingdom these schools are even structural partners within the STEM network. It is therefore no surprise that most described STEM networks also organise professional development within the framework of school development projects or with an eye to establishing such projects. This is the case in Finland, Austria, the Netherlands, Italy, the UK and Germany. This is not yet the case for the activities of the French network of the *Maisons pour la science*. However, they are planning to work on this in the future.

The LUMA Centre Finland is responsible for the management of the new national STEM education development programme 2014-2019 (LUMA Finland programme) of the Ministry of Education and Culture[55] to strengthen STEM skills in children and youth aged 6 to 16 years old. For this purpose some thirty school development projects were launched, as has happened in the past. In the UK the 52 Science Learning Partnerships (schools) try to create and assist school networks at local or regional level, among other things by offering CPD in the development of a school development project for STEM. In Austria, the Netherlands and Italy as well it is each time tried to stimulate and assist STEM school development projects with school clusters. The emphasis is always on collaborative learning and working.

Very good examples of school development projects were and are still being set up in Germany. A textbook example is the SINUS project[56] (later SINUS Transfer project) which delivered great efforts from 1996 to 2010 to reinforce the provision of mathematics education via networks of schools that were closely linked to the university at the regional level.

The support of school development projects translates in the fact that groups of teachers (not one single teacher, but several teachers) are invited to attend a professional development course, that groups of teachers from different schools are encouraged to work together and that members of school management teams and other support staff are trained in developing a school development plan or a STEM strategy. This is reflected in the organisation of guidance and follow-up for teachers and the development of a structured evaluation and research of these school development projects. Generally, the idea is to make the project results available to other schools by means of action research reports, local or regional seminars, etc. This is part of the upscaling of pilot projects, to allow a growing number of schools to benefit from the results of these school development projects. In some projects entire schools even get a STEM makeover (Italy, the Netherlands, UK).

Flanders has a great deal of experience in school development projects, both nationally (like pioneering schools and living labs, Focus on Talent) and at the European level within the framework of Comenius. In the context of the activities of the STEM Action Plan, schools were already selected which are engaged in such projects. The Flemish knowledge network will be able to clearly contribute to the assistance of such school development projects and make sure the results are disseminated on a larger scale and are made available to other schools and researchers.

However, the Flemish knowledge network will still have to do some innovative work in terms of structural cooperation between teacher training, professional development and knowledge sharing with the research community in knowledge centres and businesses.

55 http://www.luma.fi/news/2940/: STEM education development programme
56 More information about SINUS and SINUS Transfer is available at http://www.sinus-transfer.eu/.

3.7 Transparent management structures

All the described networks have transparent management structures which are still different from each other. A steering committee has always been established to monitor the organisation and (scientific and educational) quality of the activities. Sometimes two separate bodies exist, i.e. on the one hand a scientific committee and on the other hand a steering committee which is responsible for the network's organisation and operation. In most cases contractual agreements have also been concluded between the different responsible parties that are members of these structures.

Whichever structure is established, all the stakeholders that in some or other way contribute to the network are members of this management structure. All the networks also present an annual report with quantitative and qualitative information. However, these reports were not always available when this report was drafted.

3.8 Financial support, reach and personnel

As is apparent from the financial information in the descriptions of the knowledge networks the funds available to the presented networks vary greatly. Still, it can be assumed that, in addition to basic government funding, the partners can also contribute funds by making available rooms, personnel, etc. Funds can also be sought from businesses, sectors and even NGOs. The latter can provide personnel to give training or develop materials. The partners can also get funds by submitting joint research projects or European projects. However, it must be pointed out that basic funding is required as shown from the Italian network which, due to lack of basic funding, has to count on volunteers, which makes it very vulnerable. An interesting fact is that a Foundation is often used and/or that private funds are attracted.

The financial elements provided in the comparison of the 7 networks concerned clearly indicate that **substantial** financial resources should be provided over several years. All but one of the described networks receive important financial support from various sources.

When analysing the finances, some elements can be highlighted:

- In most cases the government contribution is supplemented with resources which the knowledge network - often proportionally - has to find or generate itself. In the Netherlands and France this has even been determined as such by the government. The MPLS (France), for instance, must generate half of the funds in addition to the funds that are made available by the PIA. Still, the necessary caution is to be employed here. A large portion of these funds originates from regional authorities, universities or the *Rectorat* (regional representation of the Ministry of Education), so these are still government funds. In the Netherlands schools pay the regional centres with the funds allocated to them by the Ministry of Education.
- In each of the networks the members of the network coordination team are exempted full-time or part-time from teaching and put at the disposal of the knowledge network.
- A knowledge network is often embedded in already existing structures (and buildings). As a result, personnel costs and overheads can be limited.
- Sometimes the financial support from the business community is organised in such a way (Wellcome Trust in the UK) that resources are pooled in a fund which can be drawn on to develop activities.

- The financial support from the government and/or the business community or other partners is linked to external and internal evaluation and impact results (UK, France).
- The financial support from the government is sometimes linked to quantitative results to be achieved each year (France).
- The steering committees of the networks make sure the financial contributions from the different stakeholders are mapped (France).
- Depending on the country, the activities of the networks are either free of charge (France, Italy, Finland, Austria) or not (UK, the Netherlands). It depends on the national or regional context and the awarded subsidies.
- There is only one country in which (the Netherlands) schools pay a membership fee in proportion to the services they purchase from the knowledge network.

Given the large differences in the networks' finances, it goes without saying that their reach is different as well. However, it is difficult to compare the reach, since their activities greatly vary too. The LUMA Centre Finland prefers online CPD courses, whereas other countries opt for residential CPD courses (France, UK) in addition to CPD courses at the universities (France) and support for groups of teachers at the schools (UK). The French network is the only one which clearly mentioned the average cost (€690) of a CPD course per teacher.

It is impossible to calculate the indirect reach. To what extent do teachers apply what they have learned during the CPD course and how many pupils are reached? To what extent are colleagues at school influenced by what some teachers have learned during the CPD course and to what degree does the CPD course impact on the policy of the school or school cluster? Only the CPD courses of the SLCs (UK) invite teachers to design a strategy for their school. The NSLN (UK) states that, over the years, it reached 95% of the secondary and 18% of the primary schools.

The personnel of the knowledge networks usually consists of two groups: a group engaged in thematic STEM activities and a small administrative group. The first group is composed of academics from universities or university of applied sciencess, researchers and teachers who have considerable STEM experience in general or experience in teaching CPD courses in particular. These employees are mostly exempted part-time or full-time and made available to the knowledge network for one or several years, sometimes with salary reimbursement. Since the networks are anchored in universities, they can also use and benefit from support provided by other university departments, like PR and communication, international and technical departments, etc.

3.9 A clear link with research and evaluation of the knowledge network

All the described knowledge networks have a clear link with the research community. Moreover, the evaluation of the activities of the knowledge network itself are considered important by all the networks.

It is clear that the impact of new STEM teaching methods and initiatives is first examined through pilot projects and school development projects before they are further disseminated.

The results of the evaluation and research of the activities are essential to be able to assess their impact and efficiency. On the one hand these knowledge networks organise internal evaluations of their activities, for instance by inviting participants in CPD courses to complete evaluation forms. This evaluation is often

spread over time with pre-, post- and follow-up questionnaires to check which impact the CPD courses have on participants, pupils and schools. Some networks thoroughly evaluate the impact on these groups over longer periods of time, like the report on ten years of STEM which was published by the NSLC in York (UK). Sometimes parents are asked questions as well, like in Italy.

In addition, external evaluations of the knowledge networks are carried out by external experts from home or other European countries. In some cases peer review teams also exist in which colleagues from another STEM knowledge network explore and evaluate what happens in the knowledge network. The external evaluation or audit is an important element in the decision whether or not to provide further, less or more support to a knowledge network and to continue, extend or adjust the activities. During the evaluations it is checked whether the activities meet target group needs.

Some knowledge networks like the LUMA Centre Finland and the IMST centre in Austria carry out a lot of research into their own activities. PhD students are involved in projects to monitor them and examine their impact on the target groups concerned. On the basis of this research useful knowledge is built with regard to educational innovation in the field of STEM.

These two knowledge networks have their own scientific journals in which articles are published on STEM activities and their impact.

Great focus is also placed (especially in Finland, Austria and France) on action research, sometimes through research of prospective teachers or a master's or doctoral thesis on existing initiatives.

A close link is also established with scientific STEM research at universities, in hospital laboratories or in industry, in particular to familiarise teachers with the latest available technologies in the field of STEM (France, UK, Finland, Germany).

3.10 Communication on activities and impact of knowledge networks

All the described knowledge networks have a content-rich website with ample information about their goals, STEM activities, CPD provision, publications, evaluations, etc.

Examples of good practice or action research reports can also be found on the websites, as is the case for IMST. Several networks produce a newsletter which is regularly sent to interested parties. The LUMA Centre Finland has its own scientific journal LUMAT. The other networks publish in several scientific magazines. Most knowledge networks draw up an annual review of their activities which is used both internally and externally.

Some networks organise seminars and events to which STEM teachers are invited to acquaint themselves with their activities or the school development projects they supervise and support.

4. Recommendations for Flanders

With consideration of the aforementioned conclusions we wish to make the following recommendations for the establishment of a STEM knowledge network in Flanders:

1. Continuing to work on a strong and coordinating STEM policy of the Government of Flanders on the basis of the STEM Action Plan. Within the STEM platform further consideration could be given to long-term goals for STEM and the position of a STEM knowledge network in this context. On the basis of the analysis above it can be examined which type of knowledge network would be suitable for Flanders.

2. Appropriating sufficient funds for the start-up and coordination of a STEM knowledge network. To that end use can be made of the funds available for STEM of the Department of Education and Training, the Department of Economy, Science and Innovation and the Department of Work and Social Economy which are currently already involved in the STEM Action Plan. The partners of the knowledge network can also be asked to make a substantial contribution by means of personnel, rooms, services or other resources.

   A creative and out-of-the-box approach should also be adopted to the contribution of structural funds by private partners, since they too have every interest in increasing the number of highly qualified STEM professionals. They currently already invest funds which could probably be put to more efficient and effective use if they were pooled. The creation of a foundation modelled on foreign examples may serve as a source of inspiration.

3. As far as the activities of the network are concerned, preference should be given to the professional development of teachers, head teachers and people in charge of STEM. This completely ties in with the strategic goal 2 of the Policy Memorandum of Minister Crevits: Guaranteeing sufficient, expert and motivated educational staff, among other things by realising career-long professional learning and support for teachers.

4. However, a Flemish knowledge network need not be limited to education. There is definitely room for new ideas on the approach to STEM in informal education. Everything can be done better. In the end, an overall approach and exchange of methods and knowledge sharing will benefit the STEM landscape as a whole.

5. Using the existing knowledge and expertise regarding STEM education (in the broad sense of the word). Over the past years several universities, university colleges and training institutes have built a great deal of expertise. Pooling this knowledge and expertise may result in cross-fertilisation and a larger impact of the network. For Flanders, a consortium between universities and university colleges (within the framework of existing associations) may allow for the development of a strong network. Insights into STEM pedagogy can also be found in the knowledge networks Science Communication at Universities and University Colleges, as well as in laboratories of knowledge centres of professional STEM in businesses and sectors. We believe that, if a STEM knowledge centre is created, this knowledge should be connected and therefore maximised and deepened.

6. Working together with all the STEM actors and stakeholders when setting up the activities of the network, like formal and informal education, but also the business community and civil society. Co-creation is an effective way to obtain ownership of the goals and to firmly root STEM in the minds of a growing group of stakeholders.

7. Devoting attention to both general STEM literacy and STEM specialisations. On the one hand, our society needs more STEM graduates. On the other hand, there is also a need for general STEM literacy, so that all citizens can function optimally in our society.

8. Not losing sight of the link with research. It is essential for STEM teachers and for anyone who wants to professionally disseminate STEM in a broader and deeper manner to be informed of the latest scientific developments and innovations. In this way they can clearly demonstrate the link between STEM and applications in industry, the care sector, etc. and can keep the focus on the usefulness of STEM for society up-to-date.

9. Evaluating the activities! To verify whether the funds allocated to a STEM network are used efficiently, all the activities and their impact must be evaluated through impact research among the parties involved. Thorough research can be conducted by master's and PhD students into certain (teaching) methodologies, whereas action research can be carried out by the teachers and intermediaries concerned. In addition it has to be checked which impact it has on the choice for STEM studies and STEM careers, as is currently already the case in the STEM Monitor and Barometer.

5. Organisation of Contacts with European Organisations or Other institutions

The Department of Education also asked to propose contacts with bodies in charge of STEM at the European level.

Educonsult believes it important for the department to be involved in medium and long-term activities that are set up by certain European institutions or organisations. A one-off visit or contact may be useful. However, this will not have any lasting effect on the development of the knowledge network "STEMNET Vlaanderen" (STEMNET Flanders).

- A discussion with DG R&I, in particular with Karin Slavin, Administrator, who carries responsibility within the framework of the SWAF programme (Science With and For Society) which supports science education projects within the framework of Horizon 2020.

  Initial contact was already established between Karin Slavin and the Department of Education and Training on the occasion of the Eminent conference in Barcelona on 19 and 20 November 2015. An appointment will be made with her in early 2016.

- A discussion with the people in charge at DG EAC. In the past, two working groups were established around STEM: one for the period 2005-2010 and one for the period 2012-2014. The latter worked on Early School Leavers and Science Education. Currently, no European working groups are active in the field of STEM. Educonsult has found that the chances of such a working group being created in the future are slim. Nevertheless, Educonsult will continue to monitor the situation.

- Participation in the STEM working group for leading officials at the Ministries of Education within the context of European Schoolnet. This working group will be established in the spring of 2016. Educonsult will make sure the STEM unit of the Department of Education and Training is actively involved in the activities of this working group. European Schoolnet already sent an invitation to participate in this working group in 2016, which the Department has accepted.

- Educonsult proposes to actively involve a colleague from the STEM unit of the Department of Education and Training in the recently established UTRECHT STEM Think Tank, of which all the described European networks in France, Finland, Austria, Germany, Italy, England and the Netherlands are members.

  This Think Tank organises a two-day meeting at the National Science Learning Centre in York in September 2016. Educonsult will do its utmost to make sure the civil servants of the Flemish Ministry of Education and Training who are in charge of STEM are invited to the next meetings of the Think Tank and can participate in Peer Learning Visits organised between the members of this network.

- Educonsult also proposes to organise a work visit of one day and a half to the *Maison pour la science* in Lorraine. This *Maison* has succeeded in developing close interaction between teacher professional development, pre-service teacher training and actors from informal and non-formal STEM education. In this way they have increased the sustainability of the *Maison de la science* in Lorraine.

- Finally, Educonsult proposes to organise a work visit to the University of Twente with Pieter Boerman, the coordinator of the Dutch network of regional support centres for science and technology which is being developed in the Netherlands since 2014 and also has connections with the regional focal points for science and technology for primary education. This may result in closer collaboration with these two Dutch networks.

Annexes

1. List of abbreviations used

Acatech: Deutsche Akademie der Technikwissenschaften e.V., BDA | Bundesvereinigung der Deutschen Arbeitgeberverbände,

AVOHOKS: Agentschap voor Hoger Onderwijs, Volwassenenonderwijs, Kwalificaties en Studietoelagen (Agency for Higher Education, Adult Education, Qualifications and Study Grants)

DfE: Department for Education

DG EAC: Directorate General Education and Culture

DG R&I: Directorate General Research and Innovation

EDF: Electricité de France

ESPE: Ecoles Supérieures du Professorat et de l'Education, (Higher Education Institutes for teachers and for Education)

GenaU : Gemeinsam für naturwissenschaftlich-technischen Unterricht - Together for natural science and technical education:

HO: Hoger onderwijs (higher education)

IBSE: Inquiry based Science Education

IMST: Innovations make schools top

IUFM: Instituts Universitaires de la Formation des Maîtres. (University institutes for teacher training) In 2014-2015, they were replaced with the ESPE which were integrated more strongly into the universities and are in charge of pre-service training for all teaching professions and of professional development.

LAMAP: La Main à la pâte (hands on science)

LUMA: (LU stands for 'luonnontieteet', natural sciences in Finnish, MA for mathematics.)

LVO: Landelijk vakkenoverleg (national subjects' consultation)

MINT: for Mathematik, Informatik, Naturwissenschaft und Technik or Mathematics, IT, Natural Science and Technology, which is the equivalent of the English STEM.

MPLS: Maisons pour la Science (Houses for Science)

NSLN: National STEM Learning Network

RSP: Regionale Bèta-steunpunten

SID: Scientiam Inquirendo Discere: Learning science while inquiring

SLO: Nationaal expertisecentrum voor leerplanontwikkeling (national expertise centre for curriculum development)

SPAR: Steunpunten adviesraad (Support centre advisory council)

SPR: Steunpuntenraad (Support centre council)

STEM: Science, Technology, Engineering and Mathematics

VDI: Verein Deutscher Ingenieure e.V., (German engineers Association)

VO: Voortgezet onderwijs (secondary education)

VOHO: Voortgezet onderwijs - (secondary education-higher education)

VRWI: Vlaamse Raad voor Wetenschap en Innovatie: (Flemish Council for Science and Innovation)

2. List of websites used

Next to the information gathered from interviews, some information was also retrieved from the Internet.

- http://eacea.ec.europa.eu/education/Eurydice/
- http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/132EN.pdf.
- http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133EN.pdf
- http://eacea.ec.europa.eu/LLp/events/2012/documents/comenius_thematic_cluster_meeting/new_session-3-ws4-seamus-knox.pdf

- http://www.amgenteach.eu/.
- http://www.betasteunpunten.nl/steunpunten
- http://www.fibonacci-project.eu/.
- http://www.fondation-lamap.org/en/sustain/project.
- http://www.form-it.eu/goodpractice/projects/learning_labs.shtml
- http://www.haus-der-kleinen-forscher.de/de/
- http://www.ingenious-science.eu/web/guest;jsessionid=C0139710404AECB218B5C184E58DAD94
- http://www.luma.fi/centre/
- http://www.luma.fi/helsinki-en/
- http://www.luma.fi/isse-2015/3682
- http://www.luma.fi/lumat-en/1642:
- http://www.luma.fi/news/2940/: STEM education development programme
- http://www.nationalesmintforum.de/658.html
- http://www.prouv.net/publication.aspx?id=294889&langtype=2067
- http://www.scientix.eu/web/guest;jsessionid=F2957C15500EFB89DA7C808020C8CEBD.
- http://www.sinus-transfer.eu/.
- http://www.vrwi.be/pdf/Choosing%20STEM.%20Young%20people's%20educational%20choice%20

for%20technical%20and%20scientific%20studies.pdf

- https://ec.europa.eu/research/swafs/pdf/pub_science_education/KI-NA-26-893-EN-N.pdf
- https://ec.europa.eu/research/swafs/pdf/pub_science_education/report-rocard-on-science-education_en.pdf
- https://www.e-nemo.nl/en/
- https://www.gov.uk/government/publications/the-stem-cohesion-programme-final-report
- https://www.imst.ac.at/app/webroot/files/netzwerkprogramm/Rauch_Benke_Operating%20and%20evaluating%20regional%20networks.pdf
- https://www.imst.ac.at/imst-wiki/index.php/Hauptseite
- https://www.vohonetwerken.nl/netwerken
- www.scientix.eu

3: Questionnaire used to gather information

1. Name of the organisation coordinating the Centre or network:

2. Legal status of the national centre and the regional centres or the network as a whole: public, private , mixed (quango)?

3. Date of launch of the centres or network:

4. Main Mission and Objectives: (available on the web site)

Overall plus specifically for CPD

Links with national / regional STEM strategy of government / ministry of Education

Involvement in a national platform or other consultative body to advise government of ministry of education on STEM?

Qualitative objectives agreed by the network

Quantitative objectives agreed by the network

5. Activities of the national centre and the regional centres

- Kinds of activities:

o CPD: short , long (several days), blended CPD

§ CPD leading to (ECTS) credits and possibly a degree

§ CPD co-created by trainers + researchers + industry ?

§ How and by who is the offer of CPD decided?

o Consultancy / Advice concerning the development of STEM strategies at school, local or regional level,

o Development of STEM materials, tools, games

o Organisation of STEM prizes

o Organisation of national or regional STEM days or events

o Resource centre

o Database with good / interesting practices

o Newsletters

o Lobbying

o Etc.

6. Target groups: formal, informal, non formal education

- Primary / secondary:

o teachers, trainers (training the trainers) , science technicians, heads

- Higher education: links with Pre-service teacher education

- Informal / Non formal education:

o Links with Science / technology centres, Science museums, botanical gardens , zoos etc.

o STEM mediators involved in informal / extracurricular activities

7. A Network composed of a national and regional centres

(in some cases they may not be regional networks but regional coordinators)

- Geographic scale of the network. (How many centres, their locations?
- How are regional centres selected?
- Which criteria do they have to meet when applying?
- Is there a charter the national and regional centres have to adhere to?
- Is there a contract between the National centre and the regional ones?
  - How many years does it cover?
  - Is the extension linked to an evaluation

8. Institutional frame/ partnership:

- Role of the Ministry of education, local government
- Role of universities
- Role of other stakeholders:
  - companies, foundations, civil society organisations etc.

- Links with the inspectorate ?
- Links with other organisations
  - STEM national centre, STEMNET (UK) etc.
  - Federations or confederations of industry?
  - Chambers of commerce
  - Other?
- Type of relationships with them, contracting issues, etc.

9. General organization of the network:

- Management structure : managing board, scientific committee, executive board ?
- Annual meeting(s) of the network: national centre plus regional centre
- Network activities
- Annual report of national centre and / or regional centres

10. Staff involved at the national centre and in the regional centres:

Type of staff:

admin. Staff , trainers, scientists / researchers, industry people, university students, PH.D. students?

o Seconded to the centre / centres

o Contracts with the centre or centres

11. Budget / financial aspects

How is the national centre financed?

How are the regional centres financed? Grants, income from activities / consultancy

Do they have to be financially self-supporting?

Who pays for the CPD?

Support to teachers such as grants of ministry, of foundations ?

Role of Foundations in funding national or regional centres

12. Involvement of scientists, industry or civil society

How are they involved?

Is involvement based on agreement / contract?

13. Quality Assurance: external, internal evaluation ?

- Evaluation of the network as a whole
- Evaluation of the national centre
- Evaluation of the regional centres
- Evaluation of activities (such as CPD) on national or regional level

14. Knowledge management system within the network

Do you have a knowledge management system within the STEM network which enables to gather and consolidate the expertise and knowledge generated by the national centre and the regional centres?

15. Other elements of innovation or major features of the programme to be highlighted:

16. European or international STEM projects or networks involved in so far

17. Any advice you would give to the Flemish ministry of education when setting up a national STEM network?

(Footnotes)

1 The development of the Regional Science Support Centres has only just started picking up. Therefore, it is very difficult for us to already discuss the strengths and special characteristics.

2 The Haus der kleinen Forscher is only one of the members of the MINT Forum. No overall data are available for this Forum.

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