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Policy envisions and requirements for STEM teachers' competence development: State of affairs in the NETHERLANDS

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Recent changes in the Netherlands in terms of policy envisions for STEM teachers competence development

Teacher professional development in the Netherlands is anchored in the Law. The Education Professions Act 2006 (Wet Bio, n.d.) states that continuous professional learning and development as a compulsory part of the teacher profession. In conformity with the Law the national Education Professional Cooperation Board developed a general teacher competence framework as a 7 competence areas structure (Onderwijscoöperatie, n.d.). This framework had functioned as a backbone for curriculum development in pre-service teacher education and in-service teacher professional learning activities in the school from 2006 till July 2017. In 2011 the Minister of Education entrusted the Onderwijscoöperatie with gauging the teacher competence framework so that it could function as a professional standard for the teaching profession in the future. Amendment to the Law was signed in April 2017 (Wet Bio, n.d.). The framework has been updated, and formulated as three generic competence areas in subject matter, teaching and pedagogical expertise. An overview of the updated framework is provided in p. 2 of this document.

The *National Teacher Register* forms an important provision of the Education Professions Act for embedding continuous professional development in the teaching profession. It is an instrument through which teachers can keep record of their professional learning activities and thus make their competence development explicit. Operational as from 2012, the Teacher Register functioned till August 2017 on a voluntary basis. Teachers could collect and keep record of professional experiences and learning activities in order to demonstrate the realized professional learning and competence growth. From September 2018 collecting and providing evidence of participating in professional learning activities through the National Teacher Register becomes compulsory. All teachers are expected to engage in professional learning and use the Register for validation purposes (Lerarenregister, n.d., Rinnooy Kan, e.a., 2007).

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While professional bachelor level is the basic requirement of teacher education in all educational sectors in the Netherlands, the Dutch Ministry of Education provides financial resources and pre-requisites for further professional learning and competence development of teachers up to professional and academic masters' and Ph.D. level. In 2008 the *National Teacher scholarship* (Actieplan Leraar 2020; 2011; Regeling Lerarenbeurs, n.d.) was introduced as a system of national bursaries that individual teachers can apply for to follow a professional or an academic bachelor or masters' program or shorter educational programs in specific professional domains. Schools are additionally financed so that teachers can be replaced for the duration of their study (Rinnooy Kan, e.a., 2007). Between 2008 and 2012 ca 19000 scholarships were granted for bachelor and masters' programs and for shorter programs. From 2012 onwards the scholarship can only be granted for an accredited professional of an academic masters'program and a restriction was introduced in the duration of the grant. A recently formulated target for teacher graduates with a professional bachelor diploma is to receive a masters' diploma within 5 years after graduation (Lerarenagenda 2013-2020, n.d.)

The national agenda on teacher professional development in the Netherlands is strongly influenced by policy envisions and discourse on new educational priorities such as development of 21st century skills, citizenship and civil society, inclusive education, education and training for yet non-existent professions (Gravemeijer, 2017; Onderwijs2032, n.d.; Thijs., 2014; Walma van de Molen & Kirschner, 2017).

Specific developments in STEM domains have been driven by the necessity to enhance and further improve education in science and technology, better equip students for further studies in highly demanding technology enhanced domains, improve the image and stop falling numbers in science and technology in higher and further professional education in the country (Nationaal Techniekpact2020, n.d.).

In 2013, The National Technology Pact 2020 and a Platform Bèta Techniek were established as joint initiative of governmental institutions and industry. Among the objectives updated in 2016, are increasing the number of students with a STEM profile in general secondary education; provision of in-depth innovative advanced level education in Science and Technology through the increase of students choosing Science specialization in upper secondary schools and the introduction of *Technasium* as a new type of secondary school. Technasium offers in-depth curricula in STEM with a particular focus on Research and Development (R&D) as a core school subject and participates in developing regional networks involving Technasia, local industry, research centres and business (Van Diggelen & van de Brok, 2013). The introduction of Technasia and new subjects in all STEM curricula stimulated professional learning initiatives at national, regional and grass roots levels such as development of shared Open Resource databases with teaching materials in a variety of subjects, including STEM, joint development of curricula for the new subject of Nature, Life and Technology in upper secondary schools, development of regional and national networks like Opeduca or Jet-Net (www.opeduca.eu; http://www.jet-net.nl/english).

Introduction of Science and Technology in primary education curricula is another important consequence of the National Technology Pact2020 with direct implications for teacher competence development and in-service teacher education for primary schools (Nationaal Techniekpact2020, n.d.)

Among other initiatives, Ministry of Education and the Platform Bèta Techniek has introduced a programme supporting several STEM teachers a year in doing fundamental research in their discipline through the system of internships. By doing research teachers get new sources of inspiration for their teaching practice and can make link between science and practice.

Dimensions and aspects of STEM teachers' competences that are evident in policy documents in the Netherlands

The recently renewed teacher competence framework is the core document that defines teacher competences through three pillars: subject matter, teaching and pedagogical expertise (Onderwijscooperatie, n.d.). In specific:

Subject matter: the teacher has and continuously updates disciplinary knowledge to stay above the school subject content and is able to design and compile learning arrangements, select and adjust material to make it learnable. Based on disciplinary knowledge, the teacher can contextualize and link the school knowledge to daily and work-related contexts, scientific knowledge and contribute to general academic forming of learners.

Teaching: the ability to make domain specific knowledge learnable to students in conformity with pedagogical standpoints and vision of the school, the ability to translate domain specific knowledge in school curricula and lesson plans and carry out instruction, taking into consideration the learning objectives, the level and individual learner characteristics, domain specific aspects, available methods and tools and the ability to evaluate the progress and results and introduce improvements based on evaluation.

Pedagogical expertise: the ability to create a safe, supportive and stimulating climate for learners, their cognitive and socio-emotional development, so that the learners are enabled to develop into independent and responsible adults and citizens and realize their potential to the full.

For each pillar relevant knowledge and skills areas are defined, as summarized in table 1.

Table 1: *Knowledge and skills in the teacher competence framework*

Pillar	Knowledge	Skills
Subject matter (discipline) specific	Up-to date domain knowledge, both at the basics as advanced level, theory and application Knowledge is above the content: Is well versed in the state of the art in the domain of teaching and relations with adjacent areas	Can explain, give an overview, demonstrate and present both the theoretical frameworks as practical applications Can position and relate to other disciplines within the curriculum Can make links to daily practice and possible further educational trajectories

Instructional	Learning and instructional theories	Can give feedback Can explain content Can stimulate learners to learn actively Can realize outcome-based learning Personalized learning
Pedagogical	Developmental and behavioral sciences Instructional psychology Learning sciences, Pedagogical science Inclusive education Personalised learning	Can lead, monitor, steer group processes Can win trust Can create a safe pedagogical climate Can create a climate that stimulates learning, including making mistakes

As for ***dispositions***, the framework sums them up as follows: "*the professional attitude involves the ability and disposition to reflect on one's own knowledge, effectiveness of knowledge transfer and skills for personal development. It is important that teacher learn from each other in the school and outside, individually and in teams*".

Specifically for ***secondary education in STEM disciplines*** the teacher competence framework lays emphasis on design and development perspective including the ability to effectively utilize existing curricular resources to design instruction and to interact with tools and resources; making sense of and using tools/resources to design and enact instruction and to adapt curricula, resources, and learning environments to new insights and new teacher roles as coaches and facilitators of learning (Eindhoven School of Education, 2016).

As an illustration of ***the required teacher graduate level competence level***, a quote. Technical University Eindhoven formulates its vision on professional STEM teachers as "*innovative experts in their subject domain who design and develop (technologically) rich contexts for learning. They evaluate their education, including their own role, and demonstrate an inquiry and learning attitude towards their subject and work as teachers. As such they are a role model for their students. In innovative contexts they act as agents of change together with colleagues inside and outside their schools and demonstrate professional leadership needed for this. ESoE educates these academic professionals in close cooperation with schools*" (Eindhoven School of Education, 2016).

Dimensions and aspects of STEM teachers' competences that are evident in teacher training curricula in the Netherlands

Teacher education curricula in the Netherlands can be clustered in four categories. Table 2 below provides an overview of the curricula by category describing dimensions and aspects of teacher competences in general and specifically, issues related to teaching STEM disciplines.

Table 2: *An overview of curricula in teacher education in the Netherlands (from primary school teacher to teachers of upper secondary schools)*

Type:	***Teacher education for primary school teachers at applied universities (hogescholen /PABO). 4 year non-university teacher education***
Specific STEM-domain related issues:	From 2014 onwards Science and Technology is included in core curricula so that to prepare teachers for the inquiry projects with Science and Technology
Teacher competences (knowledge, skills and dispositions): developments and challenges	**Knowledge**: there is renewed focus on knowledge base. Aspirant students have to pass basic knowledge exams in core subjects (language, mathematics) All curricula include developmental psychology, general pedagogy, specializations in young children. From 2014 onwards Science and Technology (Wetenschap en Techniek) has been included in core curricula. **Skills** development constitutes a large component in the curricula and is implemented through in-service training and internships at schools (workplace learning) **Dispositions**: a recent focus on the development of the inquiry habit of mind (in particular in academic tracks teacher training schools)

Type:	***Teacher education at applied universities (hogescholen) (secondary school teachers) – 2nd degree [bachelor, for middle school]*** ***(secondary school teachers) – 1nd degree [professional master, high school)***
Specific STEM-domain related issues:	Diverse programs at applied universities, such as [the 2nd degree] Teacher of Physics, Biology, Chemistry, Mathematics of Teacher of Science and Technology (Exact & Techniek) with Physics & Chemistry as core disciplines
Teacher competences (knowledge, skills and dispositions): developments and challenges	**Knowledge** discipline specific subjects, educational science and pedagogy, pedagogical content knowledge **Skills** (a large component of all curricula) – in-service or internship at schools, **Dispositions**: development of reflective and inquiry habit of mind (a new emphasis)

Type:	***University teacher education and training (secondary school teachers) – 1st degree, high school [upper level]***
Specific STEM-domain related issues:	Discipline specific Master of Education programs with specialization in Biology, Physics, Chemistry and Mathematics (University of Leiden, University of Groningen) Masters programs in Science Education and Communication (TUEindhoven, TUDelft, University Twente). Graduates hold a master of science degree. 5 discipline specific specialisations: Computer Science/Informatics, Physics, Chemistry, Mathematics and a combined domain specialization in Nature, Life and Technology together with Reseach and Development A Master of Science and Education
Teacher competences (knowledge, skills and dispositions): developments and challenges	**Knowledge:** Curricula integrate two lines – a discipline related line related to the subjects the student will teach and profession related line - directed at general professional and pedagogical teacher competencies. In-depth domain specific knowledge, knowledge of educational science; pedagogical content knowledge; design aspects for STEM-subjects. **Skills:** profession related skills are trained during internships in schools. *Education design skills* – develop, apply and evaluate. *Research skills*: developed and demonstrated through a Master thesis, an independent research project conducted in the educational practice. f.e., University of Groningen requires 840 hours [half the study time] in in-service TUE program sees inquiry, doing research as part of the professional teacher development and a contribution to teacher competence as to supervising students doing inquiries. Research is practice oriented (evaluate and improve deep learning in STEM learning) **Dispositions**: professional dispositions (functioning in a team, in the school as a professional organization and acting as an academically trained professional. Reflective and Inquiry habit of mind f.e., University of Leiden (ICLON School of Education) offers master specializations in mathematics, physics, chemistry and biology for students of master programs in the respective disciplines, with 1 year in discipline and 1 year in teacher training including educational science, adolescent psychology, pedagogical content knowledge and skills (through internships at schools) and an independent research project. University of Groningen offers a Master of Education in combination with a disciplinary masters in Computer Science, Biology, Physics and Chemistry and the Education and Communication in Mathematics and Sciences. The curriculum includes teaching and instruction in a discipline, pedagogical knowledge and training of skills in practice, educational science and learning theories, professional dispositions (reflective and inquiry set of mind) as well as research skills

Type:	***University master of Science programs in Educational Science, Pedagogy – 1 year full time programs for candidates with a background in Education (teachers). National bursary applicable ; OU NL (distance education); University of Groningen; Utrecht University; UvA VU; University of Twente***
Specific STEM-domain related issues:	While STEM is not a specific profile, however, STEM domains can form the field of knowledge application
Teacher competences (knowledge, skills and dispositions): developments and challenges	**Knowledge:** Research methodologies, instructional design, developmental psychology, theories of learning and instruction, technology for learning, use of technology and tools in design of curricula and **Skills**: instructional design, research methods, academic writing, development of learning environment, **Dispositions** academic habitus, reflective and inquiry habit of mind, critical thinking

Some relevant facts and figures

a. Teacher training for primary education (PABO's)

A total of 27 teacher training schools for primary education (PABO) with 54 programs. Relevant developments: a focus on basic knowledge, compulsory tests in the Netherlands and arithmetics. Another important trend – introduction of Science and Technology in primary education curricula with a focus on inquiry and design based learning.

b. Teacher education at applied universities (hogescholen) (secondary school teachers)

There are 44 teacher education programs at applied universities for the 1st degree with 12 in STEM domains (around 30% of all programs).

At bachelor level there are 190 programs with 383 variants of full time and part time programs. STEM disciplines represent a third large category of HBO TT curricula and have around 500 graduates per year, see figure 3. All programs have implemented a knowledge base requirement and take part in national tests of disciplinary knowledge. Dropout rates (up to 49%) and the quality of education are seen as challenges. An important new trend is according to the Inspection, the "in-service training".

c. University teacher education and training (secondary school teachers)

There are 140 1 or 2 year full time or part time university teacher programs, in 273 variants. These programs combine teaching discipline related subjects in discipline-based groups and theories of teaching and instruction, pedagogical aspects in inter-disciplinary groups. Yearly around 1850 students enroll in these programs, 1/5 of them part time. STEM domains have stable a third place in overall enrolments and diploma's (see Figures 1 & 2).

The compulsory research component presents a challenge since the requirements are in conformity with the research requirements in other masters' programs while the teacher profession demands development of professional skills through extensive practice making one year academic masters programs a challenge. Universities are developing 2 year master of Education programs to tackle this problem.

Next to offering Master of Education programs, universities contribute to further professional development of teachers through projects and participation in regional centres of teacher professional development.

Dimensions and aspects of (STEM) teachers' competences that are implicitly evident from students STEM curricula in the country

Starting from late nineties of the last century, curricula of pre-university 6 year study tracks VWO) and general secondary 5 year study tracks (HAVO) in secondary school in the Netherlands have undergone major changes. In the context of teacher competence development the following developments are relevant: The introduction of "Studiehuis", guided and independent (project based) learning in the lower secondary school with the teacher positioned as a coach instead of the exclusive source of knowledge and "a sage on the stage". "Tweede fase", or the second (upper) school phase curriculum innovation with a focus on development of generic skills, cross-disciplinary and higher order skills like information problem solving and research skills in secondary school curricula and examination & assessment programs. As a consequence, a mayor applied task of conducting an independent inquiry or design project has become a constituent part of the final examination program and school curriculum.

Both developments implied mayor shifts in the organization of the teaching process from instruction and knowledge transmission to guidance of independent and group work and monitoring student learning within school disciplines and in cross-discipline learning activities, including stimulating independent learning (inquiry) skills in children. Conducting an independent domain-specific or cross-disciplinary research project in the last school year culminates this trajectory. A pre-vocation schools the projects of 20 study hours are conducted, the minimal volume of independent projects in pre-university education is 80 hours (source).

A STEM-specific development concerns the curriculum of Technasium with high requirements for both domain knowledge and pedagogical and didactical skills of the teachers. Thus, the core subject of Technasia, R & D, requires besides in-depth discipline related knowledge, the ability to design project-based activities and design skills and organization of curriculum. Functioning in regional networks requires social networking skills.

Introduction of context-based curricula in Science subjects like Physics or Chemistry is an important trend initiated in 2003 (https://www.leraar24.nl/vak-scheikunde-chemie). The most important characteristic in context-based curricula is that appealing contexts for students are used as a starting point for learning (Coenders & Terlouw, 2015). The Dutch National Steering Committee, responsible for the development of context-based curricula in Science disciplines involves teachers in the design of student learning material through participation in teacher development networks. Participation in these networks is seen as a way of increasing teacher ownership of the context-based curricula that would lead to changes in knowledge and beliefs of these teachers, stimulating teacher professional development (Driessen & Meinema, 2003).

Another relatively recent development that is worth mentioning is the application of an innovative teaching method known as the *Lesson Study* approach, a method of teacher led curriculum and lesson design and research which originated in Japan and involves team work in design activities, thorough evaluation and explicit reflection on the outcomes (De Vries, Roorda & Van Veen, 2007). In the last decade Lesson Study method has been actively applied in Dutch primary education, in particularly for design of new Science and Technology lessons (Schot & van Vugt, 2016) and in secondary education, in STEM subjects in particular (School-aan-zet.nl).

Major issues for consideration: Proposed issues for discussion about STEM teachers' professional development in the Netherlands

Teacher professional development is part of the national agenda in the Netherlands as a warrant of the quality of Dutch education. The Ministry of Education and Culture and national teacher agency (Onderwijscoöperatie) take care of the pre-requisites and the general framework by formulating the general quality standards and by financing teachers' professional development. At meso level school boards facilitate teacher professional development by allocating time and facilities for learning activities, intervision and network learning and support of innovation at grass-roots level. Support of participation in regional, national and international networks of schools contributes to teacher learning as well. Pre-service teacher education, publishing houses, non-governmental educational agencies and university research centers contribute to teacher learning by offering live, online and blended courses and programs and conducting research of teacher professionalization. It is however, the teachers themselves who retain responsibility for and who have the lead in making continuous professional development an integral part of the teacher profession in the ever changing and increasingly demanding world of education.

Proposed issues for discussion on STEM teachers' professional development in the country –identified via the exploration of the Dutch context at policy, policy mediation and practice levels as presented in this document – are:

At macro level, relating to policy envisions on STEM teachers' competence development: Balance between societal demands of innovation, the national core curriculum requirements and the organization of pre-service and in-service teacher learning and permanent competence development [in STEM domains]. The trigger for discussion [can be]: the pre-requisites for sustainable teacher learning and competence development against the newly defined teacher competence quality standards and beyond them.

At meso level, relating to the mediation mechanisms from policy to practice (teacher training): Transition from pioneer work, experiments, projects and lessons learned from them to integration of innovative approaches at schools into mainstream school daily practice against the background of the current practices of teacher learning facilitation by school boards. "From sowing to harvesting". The trigger for discussion [can be] the question of how school boards ensure that innovation and teacher professional learning innovate and transform the current school practice and vice a versa how innovative practice insures sustainable teacher learning.

At micro level, relating to teacher/learning practice: Integration of 21st century skills with (STEM) domain knowledge and skills, connecting learning in and out of school with ubiquitous ICT (seamless learning idea), integration of subjects, learner directed curricula - numerous trends meet in the school of today and make active teacher involvement in designing and shaping his/her lessons, courses and curricula for and with learners a necessity. Insights in what works and why are needed to underpin design decisions, therefore the inquiring mind as an attitude comes into picture. Teacher as designer and teacher as inquirer /researcher of his/her own practice are two important trends in the teacher profession nowadays. The trigger questions for discussion could be on the impact these two new trends implicate for teacher professional learning and competence development and the implications they have on the school practice.

Given that in the Dutch context the regulatory framework for teachers' competence development has already been in place and implemented by mediating mechanisms, the main issue identified for further exploration and discussion is on the impact of teacher learning for competence development on the school practice.

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