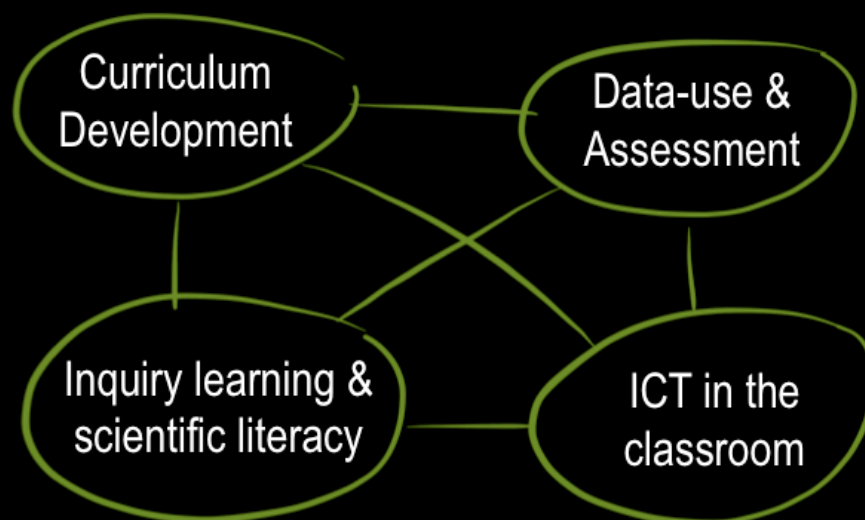


Advances in Theory and Practice of Teacher Professional Development

Research Program of ELAN Institute for Teacher Training and Professional Development

ADVANCES IN THEORY AND PRACTICE OF TEACHER PROFESSIONAL DEVELOPMENT



Team approach | (Pedagogical) Content Knowledge | Science education

Summary of ELAN Research Program

ELAN is the University of Twente Institute for Teacher Training and Professional Development. Its main mission is to empower and equip teachers for continuous learning, both in formal and informal learning settings.

The research program of ELAN is based on the premise that the quality of the teacher is one of the most important influences of student achievement (Hattie, 2009). Therefore, to improve education, it is essential to focus on the role of the teacher as learning professional. The focus of our research is predominantly (but not exclusively) on equipping and empowering teachers with the knowledge, skills, attitudes, and motivation needed to provide innovative and engaging education for their students in a wide context, ranging from primary education to higher education. ELAN's research focuses on both science education and science-related societal issues.

ELAN's overarching research theme may be summarized as follows:

How can teachers and other professionals be equipped to teach science and science-related societal issues in inspiring and innovative ways?

This leads to research that focuses on:

- Teachers' knowledge of, skills in, and attitudes towards formal and informal collaborative, inquiry-based, and contextualized (science) education;
- The development and evaluation of programs, interventions, and tools that foster collaborative, inquiry-based, and contextualized (science) learning, with a specific focus on teacher performance and the effects of this performance on students' learning.

We pursue methods of professional development that can make a difference. These methods build on the assumptions that collaboration among professionals and active creation or redesign of educational materials and lesson scenarios do not only lead to new ways of teaching, but also to teacher professional development (Clarke & Hollingworth, 2002). The conditions and results of these new approaches towards professional development are assessed using both qualitative and quantitative methods. Validated instruments are used, or developed when needed. Our research leads to a more thorough understanding of implementing teacher professional development (Desimone, 2009). Through collaboration with (teams of) practitioners we bridge the gap between theory and practice in a natural way.

This document outlines ELAN's research program. The different sections provide some background on the needs and methods of the research as well as the research questions underlying the program and the manner in which the program is divided into different sub-parts.

Advances in Theory and Practice of Teacher Professional Development

Background and Rationale for the ELAN Research Program

Being a teacher means lifelong learning, both formally and informally. Our society is constantly changing and therefore also the educational context of schools and the student and teacher population. Professionals need to be equipped with the knowledge, skills, and attitudes needed to enhance student learning in this constantly changing environment. Therefore, the focus of both our teacher education program and our research is on equipping and empowering teachers with the knowledge, skills, attitudes (mindset), and motivation needed to provide innovative and engaging education for all students in a wide context.

ELAN's teacher education and research program focuses on those more fundamental issues that contribute to our theoretical understanding of what constitutes effective and sustainable learning for the 21st century among teachers and students. Moreover, the research program aims to bridge the gap between educational theory and educational practice. Advances in both theory and practice lead to the coverage of several issues that are relevant both from a scientific and societal angle, such as the need for contextualized learning and scientific literacy or the need for more collaborative learning of both students and teachers.

Our research is based on the contention that teachers have the responsibility of acquainting their students not only with the content of their scientific disciplines, but also with the way the world is explored in those disciplines, the way that knowledge is constructed, and why building such knowledge is important. In order to achieve these goals, teachers should be equipped with the appropriate knowledge, skills, and attitudes. Examples with regard to knowledge concern Pedagogical Content Knowledge (PCK/Vakdidaktiek) and data literacy. With regard to skills, our research focuses on teaching how to work with standard teaching methods in a more flexible and creative way. As for attitude, we focus on teachers' awareness of the importance of and self-efficacy in, for example, inquiry learning, data based decision-making, and the use of ICT in the classroom. This often requires that teachers not only become aware of their own preferred teaching styles, but also that they expand their repertoire in response to learners' needs and new educational challenges.

Outline of the Research Program

ELAN's overarching research theme may be summarized as follows:

How can teachers and other professionals be equipped to teach science and science-related societal issues in inspiring and innovative ways?

We pursue methods of professional development that can make a difference. These methods build on the assumption that collaboration among professionals and active creation or redesign of educational materials and lesson scenarios do not only lead to new

ways of teaching but also to teacher professional development (Clarke & Hollingworth, 2002). The conditions and results of these new approaches towards professional development are assessed using both qualitative and quantitative methods. Validated instruments are used, or developed when needed. In sum, our research should lead to a more thorough understanding of the factors that contribute to effective teacher professional development (Desimone, 2009) and effective (science) education:

- Research on teachers' knowledge of, skills in, and attitudes towards formal and informal collaborative, inquiry-based, and contextualized (science) education;
- Development and evaluation of programs, interventions, and tools that foster collaborative, inquiry-based, and contextualized (science) learning, with a specific focus on teacher performance and the effects of this performance on students' learning.

Research at ELAN is conducted from two, partly related, research perspectives: from a broader perspective rooted in educational research and educational psychology and from a perspective that focuses on the development of subject specific content knowledge and pedagogies (CK and PCK).

From the broader perspective that is rooted in educational research and educational psychology, we aim to develop and investigate processes and professional development interventions that may lead to more active and engaging formal and informal learning. We draw on insights into the processes of creating and building scientific knowledge and scientific reasoning, the societal roles of science and mathematics, attitudes towards and images of science and mathematics, and an understanding of the (historical) development of scientific knowledge. This approach incorporates theories and methods that are based on both literacy and engagement, education and communication, and formal and informal learning. Examples are data literacy, the effectiveness of teaching with standard methods in a more flexible and creative way, teachers' awareness of the importance of and self-efficacy in, for example, teaching science as a practice, data-based decision making, and use of ICT.

This view also constitutes ELAN's research from the perspective of development of subject specific pedagogies. Teachers are often required to expand their Pedagogical Content Knowledge (PCK) as well as their Content Knowledge (CK) repertoire in response to societal changes, learners' needs, new educational challenges, or government policies. The focus in this research perspective is on teachers' knowledge and beliefs about orientations toward science and mathematics teaching, the science and mathematics curriculum, instructional strategies, students' understanding of specific topics, assessment, and on teachers' content knowledge.

In the next sections, the research program is elaborated on. Based on our overarching research question, the different research projects that are conducted at ELAN are all driven by the need to tackle several important challenges that we face in current scientific and societal thinking about teacher professional development and science education and science-related societal issues. We focus specifically on curriculum development, ICT in the classroom, inquiry learning and scientific literacy, and data use and assessment.

In addition, in order to make a true contribution to the advancement of theory and practice of teacher professional development, our research program consists of different sub-parts that represent different 'research angles':

1. Theory development (e.g., how do professionals learn, what constitutes teachers' attitudes towards science education or inquiry learning);

2. The development, implementation, and evaluation of new interventions (e.g., which interventions, methods, or tools have the desired effects on both teachers and learners);
3. The development and validation of a variety of measurement instruments and methods that assess pedagogical content knowledge, skills, and attitudes of both teachers and students.

Based on the combination of thematic challenges and research angles, examples of research questions that underlie the research at ELAN fit into the following schematic overview:

Table 1. Examples of research questions in the ELAN program

	Theory development	Interventions	Measurement development
Curriculum development	<p>How can we prepare teachers and schools for life-long professional development?</p> <p>How can we best define the learning goals of collaborative curriculum design in teacher design teams at school, teacher, and student level?</p>	<p>How can teachers design education with inspiring activities for learners?</p> <p>How can teachers use resources and expertise to optimize the learning settings that they are responsible for and maximize their PCK?</p>	<p>How can we measure the effectiveness of curriculum designs?</p> <p>How can we measure pedagogical content knowledge?</p>
Inquiry learning and scientific literacy	<p>What constitutes teachers' attitudes and skills towards teaching science and inquiry learning?</p> <p>What approaches and skills do we need for the shifting focus towards a more generic scientific literacy with cross cutting science concepts and core ideas in science?</p>	<p>How can we coach teachers to foster learners' inquiry skills?</p> <p>How can we best arrange for learners to design and execute experiments or design solutions for authentic problems?</p>	<p>How can we measure teachers' and students' attitudes towards science and inquiry learning?</p> <p>How can we measure progress in inquiry learning, creativity, curious attitude, etc.?</p>
ICT in the classroom	<p>What frameworks and approaches do we need for modern ICT use in the classroom?</p>	<p>How can teachers design effective education with inspiring ICT-enhanced activities for learners?</p>	<p>How can we measure the ICT skills of teachers and students?</p>
Data use and assessment	<p>How do teachers and school leaders use data in decision-making processes?</p> <p>How can we best define the goals of data use at the school, teacher, and student level?</p>	<p>What are characteristics of effective and sustainable professional development with regard to data use?</p> <p>How can teachers use formative assessment in their classroom in such a way that it results in progress in both teacher and student learning?</p>	<p>How can we measure teacher's attitudes knowledge and skills with regard to data use?</p> <p>How can we measure social networks of teachers and school leaders with regard to data use?</p>

In the following sections, we provide more background information and a short description of our different research topics.

Theory Development

Building new theoretical frameworks

One of the main reasons why educational development programs or interventions often do not generate the desired results is that the underlying concepts are often ill defined. Thus, in order to stimulate and assess effective professional development (in terms of knowledge, skills, and attitudes) and its impact on for instance, students' knowledge acquisition, creative or inquiry thinking, or attitudes and motivations, these concepts first need to be well defined and elaborated on. Part of our research therefore focuses on extensive studies of the multidisciplinary literature and on interviews with experts in the field, in order to build new conceptual frameworks (e.g., to describe the underlying dimensions of teachers' attitudes towards science education or the components that constitute students' skills and motivations for inquiry learning).

Modern approaches to teaching science

Research in science teaching has come a long way in studying the way scientific concepts are learned and can be taught. Many instructional approaches, such as using instructional devices such as concept maps and ICT-tools such as simulations attempt to provide a basis for building conceptual understanding of the various scientific disciplines and their topics. Currently, however, attention is shifting to a more generic view of science, stressing the importance of students reaching an acceptable level of *scientific literacy* (National Research Council, 2012), meaning that they obtain insight in the processes of science and the nature of scientific knowledge, rather than only its results. This requires new frameworks for and approaches to teaching that illustrate the way scientific knowledge grows, and it also implies that we should relate our teaching to current developments in science itself. Open questions are how to shape such teaching methods and how these new learning goals can be defined and evaluated.

Inquiry learning

Inquiry learning requires ways of teaching that engage students in scientific experiences. As said above, it is not enough to learn science only by its results, such as Newton's laws or the structure of DNA. Instead, students should be engaged in the main driving forces of scientific endeavor: curiosity, wonder and persistence to build understanding and explanation of scientific phenomena. A possible means to bring such practice to the classrooms is by inquiry learning, a form of learning in which students are placed in the driving seat as scientists and where they discover new knowledge, determine cross cutting concepts, and construct models of phenomena. Open questions are how to best implement such teaching practices and what specific skills and attitudes we need to develop to establish effective inquiry learning.

Pedagogical Content Knowledge

PCK is strongly rooted in classroom practices. Development of (student) teachers' PCK requires opportunities to enact newly learned content knowledge and pedagogies, including ICT and assessment strategies and instruments. Although there is consensus with respect to the importance of PCK, the nature of PCK is still under discussion: does PCK constitute a separate knowledge base or is it an amalgam of content knowledge with pedagogies to foster student learning? Our research into PCK development of teachers ultimately seeks to answer this aspect.

Science learning in informal contexts

Schools are not the only place where people learn. Informal learning often takes place in contexts purposely designed for learning, such as science museums, science cafés and scientific press. In science education it is important to study these situations, as they are designed for and often successful in drawing people's interest in science. Theoretical questions of interest are the relation between the design of informal learning situations, the motivation of participants to get involved in it, the effects on participants' knowledge of and attitudes toward science, and how such desired effects may be best defined and studied.

Bringing education closer to scientific practice

School science almost necessarily lags behind the frontiers of modern science. New developments in the natural sciences take time to be adopted, first in university teaching, followed by secondary education. In times, such as the current, in which scientific developments happen very fast, the gap between school science and scientific practice may become unacceptably high. In such a case, the teaching of science at school no longer provides an adequate image of the way science progresses in practice. Within the research program, we seek for means of relating teachers and students to the world of contemporary science. Questions to be asked relate to the level of scientific knowledge and skills that are within reach of students (at different levels) and how they relate to the way modern developments in science are made a part of the curriculum.

Making sense of mathematics

The primary task of secondary education is preparing students for the choices that lay ahead of them and stimulating them to optimally contribute to society. From this perspective, it is essential to raise the academic level of teachers and to forge closer links between secondary education and academia. For mathematics teachers, it is essential to give attention to problem solving as well as abstract ideas, logical constructions, and symbolic language in order to be able to work efficiently with abstractions, to express ideas precisely and succinctly, and to perform formal calculations with confidence in the results. By means of a Lesson Study approach we are developing and assessing math curricula combining problem solving, abstract ideas, logical constructions, and symbolic language.

Development, Implementation, and Evaluation of Interventions

Promoting the professional development of teachers

Teaching and learning of Math, Science and Social Science is at the heart of ELAN's tasks. Improving the practice of teaching these topics therefore also is core to this research

program. Focus in this line of research is on methods for improving a broader scientific literacy, attitudes toward science, as well as pedagogical content knowledge, both at pre-service and in-service level for primary and secondary education. Examples of these types of projects include the development, implementation and evaluation of Teacher Design Teams, Data Teams, Lesson Study Teams, and Professional Learning Communities within and across schools. The focus in these projects is on professional development in teams. These teams work on, for example, curriculum development, the use of ICT in the classroom, the use of data (e.g., formative assessment), co-creation of innovative learning scenarios (lesson study approach), and inquiry-based teaching, with the ultimate goal of enhancing student learning. Ownership is crucial in all of our projects, and therefore several of our interventions are developed bottom-up, in close cooperation with teachers and experts in the field.

Our research aims at: (a) identifying the main factors that determine teacher development and (b) the design and evaluation of interventions aimed at improving such development. Although our interventions are often initially developed on a smaller scale, through a bottom-up approach with relatively small numbers of teachers, this does not prevent using and testing them with larger samples of teachers. This means that our interventions can be and often are generalized and replicated on a larger scale and in other educational contexts than initially developed. This 'upscaling' makes it possible to conduct large-scale studies into the effectiveness of these interventions, such as research on data teams, lesson study teams, and teacher design teams, both nationally and internationally.

Several of our studies are longitudinal studies that make it possible to study both the short and long-term effects of the implementation of our professional development interventions, as well the sustainability of these interventions, using a variety of research designs and methods (qualitative, quantitative as well as mixed methods, in which we also engage in developing and validating new measurement instruments).

Furthermore, in our research we acknowledge that our interventions are set in a wider educational context, which may influence the implementation as well as the effectiveness of our interventions. For example, a school's organizational context, student characteristics, and teacher characteristics may influence the effectiveness of interventions, and several of our studies therefore also focus on the enablers and barriers of effective professional development. Questions to be asked relate to: in what context, under which circumstances is professional development with certain characteristics most effective in enhancing both teacher and student learning?

The teachers' ICT toolbox

Teachers in general and science teachers in particular are confronted with rapid developments in ICT-tools that can be used to support their teaching. Such tools include smartboards, portable, networked devices, computer simulations, modeling tools, collaborative tools, tools for visualization etc. For science teaching, such tools offer new possibilities to enhance the repertoire of teaching methods to foster the development of scientific knowledge, skills, and attitudes. For instance, networked tools may be used to stimulate scientific discourse in the classroom, managed by teachers using argumentation diagrams built in real time on a smartboard based on students' contribution. Similar tools can be used to support an inquiry-based lesson based on student-collected data. The range of possibilities has no limits, and in order to support teachers in using these possibilities typical example applications and scenarios of use need to be developed and evaluated. Together, these typical examples can form a toolbox for teachers that can be utilized in

education. In pursuit of this research line, ELAN will, in collaboration with partners, arrange elements of the toolbox and evaluate them in realistic educational settings. This will result in interventions, products, and knowledge on how ICT can be used in science education in a responsible and effective way.

Students' conceptual development of quantum mechanical concepts

Quantum mechanics is the foundation of all research in modern physics. Therefore it will be implemented in the Dutch physics curriculum. Quantum mechanics is hard to understand and hence it's important to investigate how this subject should be taught in order to make it successful. This research aims to determine which concepts of quantum mechanics are important for scientific literacy, what problems students have during the learning process, and what didactical approach results in good understanding.

Development and Validation of Measurement Instruments and Methods

Apart from a lack of theoretical underpinning in a number of educational development or teacher-training programs, many studies also suffer from a lack of reliable and valid measuring instruments that accommodate to necessary theoretical and statistical standards (e.g., Gardner, 1995). For example, a recent review of the attitude literature that was conducted at our department points at important flaws in the methodology of a majority of attitude instruments, such as weak psychometric properties and failure to pilot-test, validate, and evaluate the instrument according to current psychometric standards.

At ELAN, we believe that a sound theoretical and practical underpinning, implementation, and short-term and long-term evaluation of development programs should go hand in hand with the development of theoretically and psychometrically valid measurement instruments and other evaluation methods, whether quantitative or qualitative. In several of our research projects, we therefore conduct part-projects that focus specifically on the development of new instruments and other evaluation methods, such as survey instruments, observation schedules, and social network analysis instrument.

Outline of projects

Projects carried out within the research program are aimed at improving the practice of education. Therefore, many projects have a clear relation to practice. Various research methods may be appropriate, ranging from qualitative research based on observations and interviews, through development research, in which research and development go hand in hand, to quantitative, (quasi-) experimental studies. Choice and elaboration of methods depend strongly on the specific research question and context.

The list below presents examples of ongoing ELAN research projects. They represent the scope and focus of the research work that is outlined above.

Theory Development

Primary teachers' attitudes towards science and technology: The development of a new theoretical framework

Juliette Walma van der Molen, Sandra van Aalderen-Smeets

A theoretical and practical foundation for Teacher Development Teams

Floor Binkhorst, Adam Handelzalts, Wouter van Joolingen

A systematic review of conditions fostering the use of formative assessment in the classroom

Kim Schildkamp, Bernard Veldkamp, Anne Dijkstra, Maaïke Heitink

Making sense of mathematics

Nellie Verhoef

Instructional video guidelines

Jan van der Meij

Development, Implementation, and Evaluation of Interventions

The effects of inquiry-based teaching on primary children's scientific talents and attitudes, their images of science, and their choice for further education

Juliette Walma van der Molen, Tim Post, Sandra van Aalderen-Smeets

The effects of company visits on primary school children's attitudes towards technical professions

Tim Post, Juliette Walma van der Molen

The effects of knowledge about neuroscience on primary teachers' attitudes towards learning, teaching, and talent development

Sandra van Aalderen-Smeets, Juliette Walma van der Molen

Computer simulations in physics education

Nico Rutten, Jan van der Veen, Wouter van Joolingen

Professionalizing chemistry high school teachers in Teacher Development Teams: what do participant learn and how?

Fer Coenders

What PCK do student teachers acquire during their initial training program and how does PCK development take place?

Fer Coenders

Improving secondary school students' inquiry skills

Henk Pol

Student learning and teacher professional development within the context of Lesson Study

Nellie Verhoef, Fer Coenders, Cindy Poortman

Dynamic representations on the interactive whiteboard

Jan van der Meij

ICT use of science teachers

Jan van der Meij

Videoconferencing and video instruction in science education

Jan van der Meij

Professional development of university teachers during the introduction of a new educational model

Inken Gast, Jan van der Veen, Wouter van Joolingen

Datateams: using data for improving school and student performance.

Kim Schildkamp, Adam Handelzalts, Cindy Poortman., Mireille Hubers, Johanna Ebbeler, Hanadie Leusink, Marije Meerdink, Maaïke Smit.

Teacher professional development in Professional Learning Communities

Adam Handelzalts, Cindy Poortman, Anne Dijkstra

Students' conceptual development of quantum mechanical concepts

Kim Krijtenburg, Henk Pol, Alexander Brinkman, Wouter van Joolingen

Development and Validation of Measurement Instruments and Methods

Developing a new survey instrument to measure primary teachers' professional and personal attitudes towards science

Sandra van Aalderen-Smeets, Juliette Walma van der Molen

Development of a semi-structured interview to measure curious attitude among primary school children

Tim Post, Juliette Walma van der Molen

Developing a survey to measure data-based decision making in schools

Kim Schildkamp, Cindy Poortman, Johanna Ebbeler, Hans Luyten

Development of a mixed-methods approach for measuring the effects of professional learning communities on teacher professional development and school improvement

Cindy Poortman, Adam Handelzalts, Kim Schildkamp, Johanna Ebbeler, Mireille Hubers

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