EMPOWER NATIONAL REPORT ON THE USE OF MODELING-BASED LEARNING IN CURRICULA

THE NETHERLANDS

2026

EMPOWER

Empowering Teachers for Science Learning Through Modelling-Based Approaches

IPN | European University Cyprus | SOSCIEATH | University of Cyprus | Radboud Universiteit | Utrecht University | UAB Universitat Autònoma de Barcelona | Co-funded by the European Union | Erasmus+ Enriching lives, opening minds.

Erasmus+ Project EMPOWER

EMPOWERING TEACHERS FOR SCIENCE LEARNING THROUGH MODELLING-BASED APPROACHES

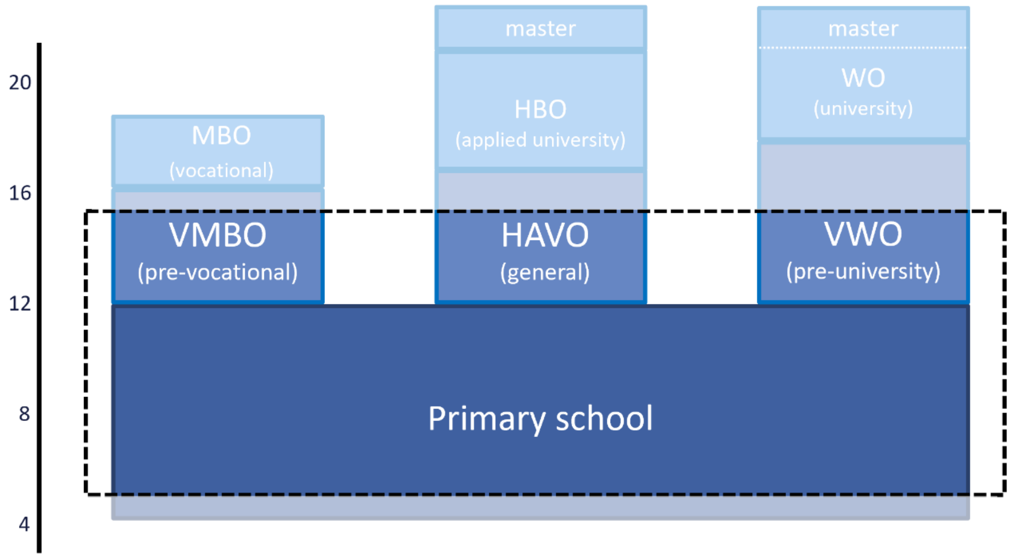
Project-Team of the Workpackage (alphabetical order)
Tom Bielik (SRU), Wouter van Joolingen (UU), Kim Krijtenburg-Lewerissa (UU)

Contents

1 Introduction

The Dutch education system is organised into several stages that together form a continuous educational pathway. It begins with primary education, which includes preschool and covers ages 4 to 12, followed by secondary education from around ages 12 to 18. Within secondary education, students are placed into different tracks—VMBO, HAVO, or VWO—based on their abilities, preparing them for vocational training, higher professional education, or university (see Figure 1). The present report focuses exclusively on primary and lower-secondary education, as this corresponds to the age range (5-15) targeted in the implementation of EMPOWER project in the Netherlands.

Figure 1 *The Dutch educational system*



2 Background

In primary education and lower-secondary the Dutch curriculum is organized into *Kerndoelen* (Core Objectives). The Dutch core objectives describe what students should be exposed to, the efforts expected of them, and what they are expected to master, thereby providing direction and a common foundation for all learners. These Core Objectives are legally defined as an assignment for schools—requiring them to design education so students can achieve them—while still allowing professional freedom in implementation (about 70% prescribed, 30% flexible); the goals analysed here (2026) are newly developed and are in the process of being formally embedded in legislation and regulations.

Currently, nine domains have been developed: *Dutch language, mathematics, citizenship, digital literacy, humans and society, humans and nature, modern foreign languages, arts and culture, and physical education and sport*. These Core Objectives resulted from a carefully structured and collaborative development process involving teachers, subject experts, and curriculum experts, while also incorporating input from relevant stakeholders.

Science education is described in the domain *Humans and Nature*. This domain consists of 4 subdomains for primary, and 5 lower secondary education (see Table 1) and focuses on understanding nature, science, and technology, and how they interact with humans, enabling students to explore phenomena, think scientifically, and develop critical, responsible perspectives on real-world challenges.

Table 1 *The content of the domain Humans and Nature in the Dutch curriculum*

Sub domain	***Core objectives***	***Topics primary education***	***Topics upper secondary education***
Natural sciences and technology	The pupil explores and explains the world from a natural science and technological perspective	A Issues B Ways of thinking C Methods D Nature of natural sciences and technology	A Issues B Ways of thinking C Methods D Nature of natural sciences and technology E Safety
Physical phenomena and technical systems	The pupil demonstrates an understanding of and experiments with physical phenomena and technical systems	A Technical systems B Matter and its properties C Light, sound, energy and forces	A Technical systems B Forces C Energy D Light (HAVO-VWO)
Chemical phenomena	The pupil demonstrates an understanding of and experiments with matter, processes and circular production		A Particles B Processes

Organisms and health	The pupil demonstrates an understanding of organisms and their health	A Organisms B Healthy living	A Organisms B The survival of life on Earth C Healthy living D Relationship and sexual health
Earth system	The pupil demonstrates an understanding of and explores the Earth system	A Earth B Weather, climate and water C Ecosystems	A Earth B Weather, climate and water C Ecosystems

3 Methodology

This report is based on a qualitative content analysis of the newly developed Core Objectives for primary and lower secondary education (grade 1 to 9). The analysis was conducted using the new *Kerndoelen* published by Netherlands Institute for Curriculum Development (SLO) who developed these core objectives for the Dutch Ministry of Education, Culture and Science. The objectives analysed in this report (2026) are newly developed and are currently in the process of being formally incorporated into legislation and regulations. Two documents were examined: one for primary education (grade 1-6) and one for lower secondary education (grade 7-9). The analysis focused on the *Humans and Nature* domain, which outlines the science content of the Dutch curriculum, including the accompanying glossary of key concepts.

The analysis focused on identifying all references to modelling (such as models, modelling competence, modelling processes, or other model-related practices) within the curriculum texts. To ensure consistency, a common coding scheme, developed and agreed upon within the consortium, was used to categorize the identified instances. In addition to the predefined codes, supplemental codes were introduced under the category “other” to capture cases that were not fully captured by the initial framework. A summary of the coding scheme and the identified instances is presented in Table 2 below.

The coding scheme was designed to capture the multidimensional representation of modelling within the curricular texts through a comprehensive set of interrelated categories and subcategories. Initially, the framework identifies (1) the definitions of modelling competence, distinguishing between specified and not specified instances. The second component of the scheme involves (2) the significance of models, which categorizes whether the text mentions the importance of models in the natural sciences, the educational process, or the modelling process in science, thereby capturing their conceptual role within the curriculum. Furthermore, (3) the scheme identifies various types of models, such as mental, conceptual maps, physical, 3D models, diagrams, drawings, and models available in the school science labs, while a fourth component records (4) the contextual area that models are used in. MbL practices are also examined by (5) coding the actions required from students during teaching and learning with models – specifically model creation, use/selection, evaluation, and revision – whereas (6) meta-modelling knowledge codes distinguish between knowledge about the properties and functions of models and knowledge of the modelling process itself. Supplemental categories were introduced under "other" (7) to capture instances such as the discussion of the significance of modelling-based reasoning or the use of models to understand physical systems. Finally, the framework records (8) the

Table 2 *Coding scheme used for the analysis of modelling references*

Definitions of modelling competence	Specified
	Not specified
Significance of models	Significance of models in the natural sciences
	Significance of models in the educational process
	Significance of models in the modelling process in Science
	Not specified
Types of models	Mental
	Conceptual map
	Physical
	Models available in the school science lab
	Simple model
	3D model
	Diagrams
	Drawing
	Other
	Not specified
Contexts of model use	
Modelling practices	Model creation
	Model use/selection of models
	Model evaluation
	Model revision
	Not specified
Meta-modelling knowledge	Knowledge about the properties and functions of models
	Knowledge of the modelling process
	Not specified
Other	Significance of Modelling-Based Reasoning
	Use of models to understand the concept of a Physical System
	Other
	Not specified
Aim of text	For the teacher
	For the student

Ways/strategies of using MbL	Ready-made models
	Ready-made models by other students
	Develop models from scratch
	Not specified

aim of the text (directed at the teacher or the student) and (9) the specific ways or strategies of using MbL, such as the use of ready-made models or developing models from scratch, while consistently coding cases lacking explicit information as “not specified” to maintain analytical transparency.

A total of 30 references to models were identified across the analyzed curricula. In the document for primary education, models were referred to five times. Four of these references are definitions of models and modelling in the glossary, the remaining one referred to the integration of models and modelling in education. In the document for lower secondary education, models are mentioned 25 times. Four of these references are definitions of models and modelling in the glossary. From the other 21 references, six apply to all tracks (*VMBO*, *HAVO* and *VWO*), while the remaining 15 are specific to the more theoretical tracks (*HAVO* and *VWO*).

4 Findings

In the domain *Humans and Nature* of the Dutch core objectives for primary education, models are mentioned only five times. Four of these references provide definitions of modelling and one focuses on the expected student skill of reasoning with models. For lower secondary education, models are mentioned 25 times, of which four times as definitions for models and modelling. For the remaining references that focus on the students skills, six of the references apply to all tracks (*VMBO*, *HAVO* and *VWO*), while the remaining 15 are specific to the more theoretical tracks (*HAVO* and *VWO*). The content of these references will be presented in the following paragraphs.

4.1 Strategies for using MbL

The Dutch curriculum does not prescribe specific didactical strategies, so no strategies for using MbL were specified. The curriculum leaves around 30% of teaching time flexible, meaning that schools and teachers can choose how to design instruction and potentially decide how to implement modelling-based learning in practice. Because of this, for most references (14 references) it is not specified if students use ready-made models. One reference states students need to create a model themselves, and six references state that students need to apply or select existing models.

4.2 Definitions of modelling competence

The Dutch core objectives do not define modelling competence, but they do explain what models and modelling are. A model is described as a simplified picture of a real-world situation that helps you solve a problem or answer a question. It includes only the parts that matter for that purpose. A model can also be a simplified representation made for a specific goal—for example, a computer program when it concerns a computational model. A mathematical model is seen as an abstract version of a situation that highlights certain features and leaves others out, such as a schematic drawing, a calculation method, or a formula. Mathematical modelling refers to using, adjusting, and creating such a mathematical model.

4.3 Significance of models in the natural sciences

The significance of models for science is not explicitly addressed in the Dutch curriculum. However, models are described as tools for understanding, explaining, predicting, and analysing phenomena and systems, and are presented as representations that can be constructed, used, evaluated, and revised.

4.4 Types of models

For all educational tracks in lower secondary education, the curriculum emphasises the ability to create functional analogue and digital 2D and 3D models within design processes. Students also have to use particle models to describe differences between pure substances and mixtures, and to explain phase transitions and chemical reactions in terms of changes at the particulate level.

For the theoretical tracks, the curriculum extends this foundation by addressing the value and limitations of historical and conceptual models of matter, including the four elements, phlogiston theory, Dalton's atomic model, and modern representations of the nucleus and electron cloud. At these levels, students also work with scientific models, such as comparing family trees constructed from phenotypic and genetic characteristics. In the earth sciences, *HAVO*/*VWO* students have to analyse climate models by examining how different assumptions lead to divergent future scenarios, and they explore explanatory models for geological processes such as the formation of relief, volcanism, and earthquakes.

4.5 Contexts of model use

Models appear within eight themes in the Dutch core objectives for lower secondary education. At all tracks, modelling is introduced as part of scientific and technological ways of thinking used to explore and explain the world. Students investigate the nature of science and technology and learn how models support the development of scientific understanding. They work with objects and technical systems, using models to make sense of how these systems function. They also study particles, phase transitions, separation methods, and chemical reactions—contexts in which models help visualise invisible processes and interpret experimental results.

For the theoretical tracks, the curriculum builds on this foundation by extending modelling to broader and more complex systems. Students develop insight into the persistence of life on Earth and use models to explore weather, climate, and water systems and their changes. They also investigate how physical conditions on Earth vary across different timescales, using models to interpret long-term processes and dynamic natural environments.

4.6 Modelling practices

The modelling practices described in the Dutch core objectives span the four main subthemes: model creation, model use, model evaluation, and model revision. Model creation and model use are part of all educational tracks. Model creation is mentioned once, and involves constructing functional analogue and digital 2D and 3D models within a design process.

Model use is mentioned eleven times. Students reason with systems and models, use models to describe phenomena and systems, and apply particle models to explain differences between pure substances and mixtures, as well as phase transitions and chemical reactions. For the theoretical tracks, model use extends into more complex analytical and predictive applications. Students analyse aspects of systems using models, predict situations and system behaviour, and relate variables within a model. They also work with biological models by comparing family trees based on phenotypic and genetic characteristics. In the earth sciences, they examine how assumptions in climate models lead to different scenarios and explore explanatory models for geological processes such as relief formation, volcanism, and earthquakes.

Model evaluation is explicitly part of the *HAVO*/*VWO* curriculum and mentioned twice. Students have to identify similarities and differences between models and reality and assess whether model outcomes are plausible, thereby developing a more reflective understanding of the epistemic status of models.

Model revision is mentioned once for *HAVO*/*VWO*, and involves adjusting parameters within existing models to improve their accuracy or fit.

4.7 Meta-modelling knowledge

Both knowledge about the properties and functions of models and knowledge about the modelling process are explicitly addressed in the Dutch curriculum. Across all educational tracks, students learn what it means that scientific knowledge consists of models and where the boundaries of those models lie.

For the theoretical tracks, this foundational understanding is further elaborated and mentioned 5 times. Students learn that the choices made when constructing a model determine what the model can and cannot say about a situation. They also learn that models can be used to predict the behaviour of systems, while recognising that assumptions and boundary conditions limit the validity of these predictions. In addition, they explore how a single model can be viewed and interpreted from different perspectives, and learn to describe the value and usefulness of successive models of matter.

Meta-modelling knowledge regarding the modelling process is not mentioned in the *VMBO* core objectives. *HAVO*/*VWO* students explore how new technologies and scientific insights can lead to the development of new models that offer different or improved explanations of phenomena.

4.8 Aim of the text

The Dutch core objectives are written from the perspective of what students should learn, experience, or be able to do. Accordingly, all references in the text concern intended student learning outcomes.

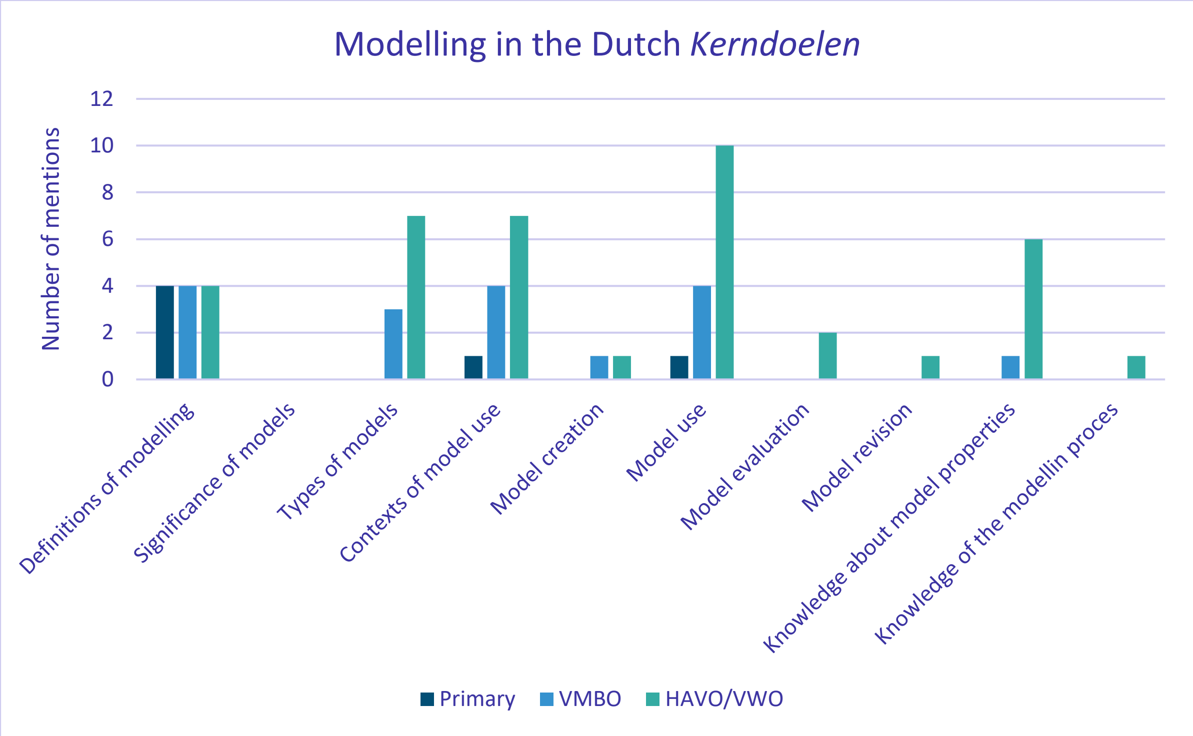
5 Conclusions

Modelling is present throughout the Dutch curriculum, but its emphasis differs across educational levels. Across all levels, primary and lower-secondary, the curriculum specifies that students be able to reason with models, while leaving the how—the didactical approach—open to schools and teachers.

In primary education, modelling is introduced only briefly and mainly through basic definitions.

In *VMBO*, modelling receives more attention but remains largely practical in nature. Students construct and use models—particularly particle models and functional analogue or digital models—but the curriculum does not extend this towards meta-modelling knowledge or more advanced analytical uses. As a result, modelling forms part of scientific and technological thinking, but its epistemic dimension remains limited at this level.

In *HAVO* and *VWO*, the curriculum presents a more extensive modelling trajectory. Students work with a broader range of model types, including historical, conceptual, biological, and Earth-science models, and engage in more advanced practices such as prediction, evaluation, and revision. Meta-modelling knowledge is also explicitly developed, including understanding assumptions, interpreting models from different perspectives, and recognising how scientific and technological developments lead to new or revised models.


Modelling in the Dutch *Kerndoelen*
Number of mentions
0
2
4
6
8
10
12
Definitions of modelling
Significance of models
Types of models
Contexts of model use
Model creation
Model use
Model evaluation
Model revision
Knowledge about model properties
Knowledge of the modellin proces
Primary
VMBO
HAVO/VWO

6 References

SLO. (2026). Kerndoelen voortgezet onderwijs (3e druk). Stichting Leerplanontwikkeling. https://www.slo.nl/thema/meer/actualisatie-kerndoelen-examenprogramma/actualisatie-kerndoelen/@25214/kerndoelen-voortgezet-onderwijs/

SLO. (2026). Kerndoelen primair onderwijs (3e druk). Stichting Leerplanontwikkeling. https://www.slo.nl/thema/meer/actualisatie-kerndoelen-examenprogramma/actualisatie-kerndoelen/@25212/kerndoelen-primair-onderwijs/

Co-funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the National Agency. Neither the European Union nor the granting authority can be held responsible for them.

EMPOWER

Empowering Teachers for Science Learning
Through Modelling-Based Approaches