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1. Boon, M. 2004. *Technological instruments in scientific experimentation – Review Article.* International Studies in the Philosophy of Science. **18**(2&3): 221-230.
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4. Bod, R.; Boon, M., Boumans, M. 2006. *Introduction to the Symposium 'Applying Science'*, International Studies in the Philosophy of Science. **20**(1): 1-4.
5. Boon, M. 2008. *Diagrammatic models in the engineering sciences*. Foundations of Science. **13**: 127-142.
6. Boon, M. (2011, in press). *Two Styles of Reasoning in Scientific Practices: Experimental and Mathematical Traditions*. International Studies in the Philosophy of Science. 25(3) pages
7. Boon, M. and T.T. Knuuttila (in press due date November 2011). *Breaking up with the Epochal break: The Case of Engineering Sciences*. Chapter 6 in: *Science Transformed? Debating Claims of an Epochal Break* A. Nordmann, H. Radder and G. Schiemann (eds.). Pittsburgh: Pittsburgh University Press. http://www.upress.pitt.edu/BookDetails.aspx?bookId=36252
8. Boon, M. 2009, *Instruments in Science and Technology* in: *A Companion to Philosophy of Technology*, Jan-Kyrre Berg Olsen, Stig Andur Pedersen, Vincent F. Hendricks (eds.), Blackwell Companions to Philosophy Series, Blackwell Publishers. 78-84.
9. Boon, M. 2009. *Understanding in the Engineering Sciences: Interpretative Structures*. in: *Scientific Understanding: Philosophical Perspectives*. Henk W. de Regt, Sabina Leonelli, and Kai Eigner (eds.) Pittsburgh, Pittsburgh University Press. 249-270.
10. Boon, M. and T.T. Knuuttila 2009. *Models as Epistemic Tools in Engineering Sciences: A Pragmatic Approach.* in: *Handbook of the Philosophy of Technological Sciences*, Anthonie Meijers (ed.), Amsterdam, Elsevier Science. 687-719.
11. Boon, M. (2011). *In Defence of Engineering Sciences. On the Epistemological Relations between Science and Technology*. Techné: Research in Philosophy and Technology. 15(1): 50-73.
12. Boon, M. (in press due date Jan 31, 2012). *Understanding Scientific Practices: The Role of Robustness Notions.* In: *Characterizing the Robustness of Science after the Practical Turn of the Philosophy of Science.* L. Soler, E Trizio, Th. Nickles, W. Wimsatt (eds). Springer: Boston Studies in the Philosophy of Science. http://www.springer.com/philosophy/epistemology+and+philosophy+of+science/book/978-94-007-2758-8?changeHeader
13. Knuuttila T.T. and M. Boon (2011, online Sept 2nd 2011). *How do models give us knowledge? The case of Carnot's ideal heat engine*. European Journal Philosophy of Science. http://www.springerlink.com/content/e037750q0w5100tm/fulltext.html
14. Boon, M. (2011). *Tales of Experimentation. Book Review of Rom Harré, Pavlov's Dogs and Schrödinger's Cat: Scenes from the living laboratory*". Metascience. 20: 159-163.

1. Boon, M. 2004. *Technological instruments in scientific experimentation – Review Article.* International Studies in the Philosophy of Science. **18**(2&3): 221-230.

TECHNOLOGICAL INSTRUMENTS IN SCIENTIFIC EXPERIMENTATION: REVIEW ARTICLE:

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Abstract

This article discusses *The Philosophy of Scientific Experimentation*, Hans Radder (ed.). Focus is on the role of instruments in scientific experiments. On a standard view experiments are used for testing theories, theories are about Nature, and apparatus and Nature can be clearly distinguished. From this perspective, several contributions propose classifications of scientific instruments. However, as instruments have a crucial role in scientific experimentation, one may ask what the scientific knowledge produced in these experiments actually is about? In order to deal with this problem, a distinction is proposed between different types of instruments, called *Measure*, *Model* and *Manufacture*, which each have specific characteristics and different roles in scientific experimentation.

The Philosophy of Scientific Experimentation
HANS RADDER (Ed.)
Pittsburgh, Penn., University of Pittsburgh Press, 2003
xii + 311 pp., ISBN 0 8229 5795 7, £ 24.50, $ 29.95 (paperback)

3. Boon, M. 2006. *How Science is applied in Technology.* International Studies in the Philosophy of Science. **20**(1): 27-47.

DRAFT (d.d. Oct. 10th 2005). This article has been published in: *International Studies in Philosophy of Science*, Volume 20, Number 1, March 2006, pp 27-48. Please quote or cite from the published article.

HOW SCIENCE IS APPLIED IN TECHNOLOGY

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Abstract

Distinctive to basic sciences, scientific research in advanced technologies aims to explain, predict, and (mathematically) describe, not phenomena in nature, but phenomena in technological artefacts, thereby producing knowledge that is utilized in technological design. This article first explains why the covering-law view of applying science is inadequate for characterizing this research practice. Instead, the covering-law approach and causal explanation are integrated in this practice. Ludwig Prandtl's approach to concrete fluid flows is used as an example of scientific research in the engineering sciences. A methodology of distinguishing between regions in space or phases in time that show distinct physical behaviours is specific to this research practice. Accordingly, two types of models specific to the engineering sciences are introduced. The diagrammatic model represents the causal explanation of physical behaviour in distinct spatial regions or time phases; the nomo-mathematical model represents the phenomenon in terms of a set of mathematically formulated laws.

5. Boon, M. 2008. *Diagrammatic models in the engineering sciences*. Foundations of Science. **13**: 127-142.

DIAGRAMMATIC MODELS IN THE ENGINEERING SCIENCES

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Abstract

This paper is concerned with scientific reasoning in the engineering sciences. Engineering sciences aim at explaining, predicting and describing physical phenomena occurring in technological devices. The focus of this paper is on mathematical description. These mathematical descriptions are important to computer-aided engineering or design programs (CAE and CAD). In the first part of this paper it is explained why a traditional view, according to which scientific laws explain and predict phenomena and processes, is problematic. In the second part, the reasons of these methodological difficulties are analyzed. Ludwig Prandtl's method of integrating a theoretical and empirical approach is used as an example of good scientific practice. Based on this analysis, a distinction is made between different types of laws that play a role in constructing mathematical descriptions of phenomena. A central assumption in understanding research methodology is that, instead of scientific laws, knowledge of capacities and mechanisms are primary in the engineering sciences. Another important aspect in methodology of the engineering sciences is that in explaining a phenomenon or process spatial regions are distinguished in which distinct physical behaviour occur. The mechanisms in distinct spatial regions are represented in a so-called diagrammatic model. The construction of a mathematical description of the phenomenon or process is based on this diagrammatic model.

6. Boon, M. (2011, in press). *Two Styles of Reasoning in Scientific Practices: Experimental and Mathematical Traditions*. International Studies in the Philosophy of Science. 25(3) page

TWO STYLES OF REASONING IN SCIENTIFIC PRACTICES: EXPERIMENTAL AND MATHEMATICAL TRADITIONS

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Abstract

This article outlines a philosophy of science in practice that focuses on the engineering sciences. A methodological issue is that these practices seem to be divided by two different styles of scientific reasoning, namely, causal-mechanistic and mathematical reasoning. These styles are philosophically characterized by what Kuhn called ‘disciplinary matrices’. Due to distinct metaphysical background pictures and/or distinct ideas on what counts as intelligible, they entail distinct ideas on the character of phenomena and what counts as a scientific explanation. It is argued that the two styles cannot be reduced to each other. At the same time, although they are incompatible, they must not be regarded as competing. Instead, they produce different kinds of epistemic results, which serve different kinds of epistemic functions. Moreover, some scientific breakthroughs essentially result from relating them. This view on complementary styles of scientific reasoning is supported by pluralism about metaphysical background pictures.

7. Boon, M. and T.T. Knuuttila (in press due date November 2011). *Breaking up with the Epochal break: The Case of Engineering Sciences*. Chapter 6 in: *Science Transformed? Debating Claims of an Epochal Break* A. Nordmann, H. Radder and G. Schiemann (eds.). Pittsburgh: Pittsburgh University Press. http://www.upress.pitt.edu/BookDetails.aspx?bookId=36252

BREAKING UP WITH THE EPOCHAL BREAK: THE CASE OF ENGINEERING SCIENCES

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Abstract

The epochal break thesis concerning knowledge production as defended by Mode 2 theorists is discussed from a philosophy of science perspective. Mode 2 theorist distinguish between two modes of research, defending that mode 2 research is a break away from the alleged theoretical, understanding-providing basic science (mode 1 research) towards interventive science taking place in the "context of application". As such, the epochal break, at least when it comes to scientific knowledge production, seems to reify those distinctions that have been criticized by the recent practice-oriented studies both in science and technology studies, and in the philosophy of science. We analyze the alleged divides between representing and intervening and between basic and applied research. Here representation and basic research would be typical of mode 1 research, while intervention and applied science would characterize mode 2. Since models are multifunctional epistemic tools, the uses of which may include both representing and intervening, and since modeling is, and has been for long, the core of the natural and, in particular, the engineering sciences, the epochal break between mode 1 and mode 2 research collapses. We suggest that there has never been mode 1 research. What has changed, though, is the political rhetoric that exploits mode 2 talk for legitimizing short-term accountability and commodification.

8. Boon, M. 2009, *Instruments in Science and Technology* in: *A Companion to Philosophy of Technology*, Jan-Kyrre Berg Olsen, Stig Andur Pedersen, Vincent F. Hendricks (eds.), Blackwell Companions to Philosophy Series, Blackwell Publishers. 78-84.

INSTRUMENTS IN SCIENCE AND TECHNOLOGY

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Abstract

Modern science and technology are interwoven into a complex that is sometimes called 'techno-science': the progress of science is dependent on the sophistication of instrumentation, whereas the progress of 'high-tech' instruments and apparatus is dependent on scientific research. Yet, how scientific research contributes to the development of instruments and apparatus for technological use, has not been systematically addressed in the philosophy of technology, nor in the philosophy of science. Philosophers of technology have taken an interest in the specific character of technological knowledge as distinct from scientific knowledge, thereby ignoring the contribution of scientific knowledge to technological developments. Philosophers of science such as the so-called New-Experimentalists, on the other hand, recently has become interested in the role of instrumentation, but merely focus on their role in testing scientific theories. By reviewing the two distinct developments and taking them a step further, an alternative explanation of the interwoveness of science and technology in scientific research is proposed. Additional to testing theories, instruments in scientific practice have an important role in *producing* reproducible *phenomena*, and these phenomena may have technological applications. Subsequently, technological development of these applications requires theoretical understanding of the phenomenon and of

materials and physical conditions that produce it, not for the sake of theories about the world, but for the sake of understanding a phenomenon and how it is technologically produced.

9. Boon, M. 2009. *Understanding in the Engineering Sciences: Interpretative Structures*. in: *Scientific Understanding: Philosophical Perspectives*. Henk W. de Regt, Sabina Leonelli, and Kai Eigner (eds.) Pittsburgh, Pittsburgh University Press. 249-270.

UNDERSTANDING IN THE ENGINEERING SCIENCES: INTERPRETATIVE STRUCTURES

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Extended Abstract (not part of book chapter)

Why is scientific understanding important to scientific practices and how do scientists acquire scientific understanding? From the perspective of scientific practices, in particular the engineering sciences, it is important to recognize that a theoretical explanation T of phenomenon P is used in further reasoning about P, which requires understanding of the explanation T of P. Therefore, assuming that an explanation T of P makes P intelligible (cf. De Regt and Dieks, 2005), cannot account for this use of theoretical explanations. Philosophy of science must explicate ‘why scientists understand an explanation’ – that is, ‘what it is about an explanation that allows for understanding it, and what it is about understanding an explanation that allows for using it’.

My central claim arises from the need to present a non-realist account of scientific explanation and understanding, which implies that an explanation of P cannot be regarded as a representation of what the world ‘behind P’ really is like. As a non-realist alternative, I propose that producing intelligible explanations consists in 'structuring and interpreting' phenomena in terms of relations between ‘data’ or ‘things’. These relations can be of different kinds (e.g., morphological, logical, mathematical, causal, statistical), yet, without assuming that these relations have an independent existence in the world behind the phenomena. In this activity of drawing relations between ‘data’ and ‘things’, scientists use already existing ‘interpretative structures’ (such as fundamental theories, mathematics, or more specific scientific models), thus producing new ‘interpretative structures’. Accordingly, my account views fundamental theories, scientific models, and scientific explanations as interpretative structures. Scientists understand the phenomenon to be explained in terms of specific interpretative structures. Additionally, they understand interpretative structures because these structures represent how they conceive of relations between data and things.

As an example, I present a fictitious case in which an apprentice-cabinetmaker learns to ‘interpret and structure’ a problem, such as a cabinet-door that does not fit (which is the phenomenon P), in the framework of Euclidian mathematics (which is an already existing interpretative structure). The resulting model (i.e., the interpretative structure, or explanation of P) allows for further reasoning about P – for instance, about interventions with the door so that it will fit. The point is that this explanation gives an understanding of the phenomenon, not because it represents how the world ‘really’ is (e.g., as relations between ‘data’ or ‘things’ that exist independent of us), but because it presents a mathematical structure that allows for reasoning about it.

Hence, the core of scientific understanding is that scientists conceive of relations between previously unrelated ‘data’ or ‘things’ in terms of e.g., already existing theoretical frameworks or interpretative structures, thus producing explanations (i.e., new interpretative structure) that represent relations between these ‘data’ or ‘things’. At the same time, their understanding is not ‘backed-up’ by the idea that these interpretative structures have an independent existence. To put it simple, the core of understanding is not that scientists have a picture that literally shows how things really are, but that they have constructed a picture (i.e., an interpretative structure) by which they can reason about the world and about their interventions with it. The apprentice-cabinetmaker, for instance, understands the interpretative structure that his master has drawn of the problem if he can use it in his reasoning towards a fitting door.

The engineering sciences are important as a case for showing that most scientific activity aims at developing explanations (i.e. interpretative structures) of phenomena that are technologically produced, rather than at 'discovering' high-level theories of nature. As a result, developing interpretative structures is a never ending scientific activity. By using theories and models in their reasoning about phenomena, scientists come up with ideas on how to technologically intervene with instruments or matter, thus producing new phenomena that are 'structured and interpreted' further, and so on and so forth.

An advantage of the presented non-realist account of explanation and understanding is that it allows for interpreting and structuring in terms of different types of relations between 'data' or 'things'. Choosing one type or the other is not true by nature but depends on the context of a problem. The problem that the door does not fit can also be explained in terms of material properties, such as the rigidity of wood, which might be an appropriate explanation if the cabinet-maker is looking for new concepts in cabinet-making. The non-realist account allows that explanations are given in terms of different types of relations, such as morphological, logical, mathematical, causal, statistical, etc., or combinations of them. This latter point disagrees with a basic assumption in the 'causalist-unificationist' debate, where both camps agree that one type of scientific explanation has priority over the other.

10. Boon, M. and T.T. Knuuttila 2009. *Models as Epistemic Tools in Engineering Sciences: A Pragmatic Approach.* in: *Handbook of the Philosophy of Technological Sciences*, Anthonie Meijers (ed.), Amsterdam, Elsevier Science. 687-719.

MODELS AS EPISTEMIC TOOLS IN ENGINEERING SCIENCES: A PRAGMATIC APPROACH

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Abstract

The engineering sciences strive through modelling to explain, predict or optimize the behaviour of devices or the properties of diverse materials, whether actual or possible. To understand this practice we need an account of how scientific models are produced and used, and, in particular, how models in engineering sciences acquire their cognitive value in their very orientation towards the artifactual. As our concern is in explaining how and why models give us useful knowledge, we will approach models from the pragmatic point of view, as epistemic tools. This amounts to considering modelling as a specific scientific practice which makes use of concrete representational means for specific purposes such as scientific reasoning, theory construction and design of other artefacts and instruments. The conception of models as epistemic tools is contrasted with the traditional view of models which assumes that models are representations of some target systems proceeding, then, to analyse this representational relationship. The Carnot model of the heat-engine is then examined as a case of how a model can function as an epistemic tool, even for its own development.

11. Boon, M. (2011). *In Defence of Engineering Sciences. On the Epistemological Relations between Science and Technology*. Techné: Research in Philosophy and Technology. 15(1): 50-73.

IN DEFENCE OF ENGINEERING SCIENCES. ON THE EPISTEMOLOGICAL RELATIONS BETWEEN SCIENCE AND TECHNOLOGY

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Abstract

This article presents an overview of discussions in the philosophy of technology on epistemological relations between science and technology, illustrating that often several mutually entangled issues are at stake. The focus is on conceptual and ideological issues concerning the relationship between scientific and technological

knowledge. It argues that a widely accepted hierarchy between science and technology, which echoes classic conceptions of *epistêmê* and *technê*, engendered the need of emancipating technology from science, thus shifting focus to epistemic aspects of engineering design and design methodology at the cost of in-depth philosophical analysis of the role of scientific research in the engineering sciences. Consequently, the majority of current literature on this topic in the philosophy of technology presents technology as almost completely divided from and independent of science, thereby loosing sight of the epistemic relations between contemporary scientific practices and technology.

Keywords
Scientific practice, engineering science, engineering design, technological knowledge, *epistêmê* and *technê*.

12. Boon, M. (in press due date Jan 31, 2012). *Understanding Scientific Practices: The Role of Robustness Notions.* In: *Characterizing the Robustness of Science after the Practical Turn of the Philosophy of Science.* L. Soler, E Trizio, Th. Nickles, W. Wimsatt (eds). Springer: Boston Studies in the Philosophy of Science. http://www.springer.com/philosophy/epistemology+and+philosophy+of+science/book/978-94-007-2758-8?changeHeader

UNDERSTANDING SCIENTIFIC PRACTICES: THE ROLE OF ROBUSTNESS NOTIONS

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Abstract

Boon takes the engineering sciences as a paradigm example of scientific practices in which the notion of robustness plays a crucial role. She starts with several preliminaries on the aim and character of these epistemic practices, and suggests thereby that truth may not be needed as an explanation of the success and applicability of scientific results (e.g., to the invention and development technological applications). By means of a conceptual analysis of different roles of 'robustness', she analyses how and why this notion may present us with an account of the successfulness but also the epistemic limits of these scientific practices. More specific, she firstly distinguishes between the meaning of 'robustness' at different conceptual levels: The level of metaphysical beliefs (such as the belief that world is stable); the level of epistemological and ontological properties of scientific results (i.e., epistemic results are reliable for epistemic uses, and ontological results are stable to such an extent that we can create them or intervene with them); the level of regulative principles (i.e., the fundamental rules that guide scientists in producing empirical knowledge), and methodological criteria (i.e., criteria for methodologies that justify the attribution of epistemological or ontological properties to empirical and/or theoretical results). The question whether 'robustness' as an epistemological criterion is a truth-maker or an alternative to truth has been addressed by means of an analytical schema that is developed by reconstructing Van Fraassen's (1980) introduction of empirical adequacy as an alternative for truth. By using this schema, it is explained how the different levels of the meaning of robustness are related and support each other. Subsequently, Boon defends that 'robustness' interpreted along these lines is a good candidate for explaining the successes and the limits of these scientific practices, while she disputes that robustness (e.g., as a methodological criterion) can function as a truth-maker as the attribution of truth to scientific results transcends what can responsibly be justified.

13. Knuuttila T.T. and M. Boon (2011, online Sept 2nd 2011). *How do models give us knowledge? The case of Carnot's ideal heat engine*. European Journal Philosophy of Science. http://www.springerlink.com/content/e037750q0w5100tm/fulltext.html

HOW DO MODELS GIVE US KNOWLEDGE? THE CASE OF CARNOT'S IDEAL HEAT ENGINE

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Abstract:

Our concern is in explaining how and why models give us useful knowledge. We argue that if we are to understand *how models function in the actual scientific practice* the representational approach to models proves either misleading or too minimal – depending on how representation is defined. With representational approach we refer to those approaches that attribute the epistemic value of models to the representational relationship between a model and some real target system. In contrast we propose turning from the representational approach to the artefactual, which implies also a new unit of analysis: the activity of modelling. Modelling, we suggest, could fruitfully be approached as a scientific practice in which concrete artefacts, i.e., models, are constructed with specific representational means and used in various ways, for example, for the purposes of scientific reasoning, theory construction and design of experiments and other artefacts. Furthermore, we propose that in the activity of modelling the model construction is intertwined with the construction of new phenomena, theoretical principles and new scientific concepts. We will illustrate these claims by studying the construction of the ideal heat engine by Sadi Carnot.