ESF Exploratory Workshop

Applied Logic in the Methodology of Science

Bristol, 8-10 September 2006

Scientific Report

Convenors: Prof. Alexander Bird (Alexander.Bird@bristol.ac.uk)
Dr. Hannes Leitgeb (Hannes.Leitgeb@bristol.ac.uk
Hannes.Leitgeb@sbg.ac.at)

Ref.: EW05-213 (SCH)

1. Executive Summary:

The objective of the workshop was to explore the interdependence of logic and scientific methodology and the role that the former ought to play for the latter in near future.

When logical empiricism declined, logic seemed to lose its role as being the primary tool of investigating the methodology of science. Recent developments of logical methods in areas outside of traditional mathematical logic have excited new interest in the application of logic to questions in the philosophy of science, which prompted the organisation of this ESF Exploratory workshop.

On the practical level, the workshop started with an informal meeting in the evening of 7 September, continued with presentations and discussions from the morning of 8 September until noon of 10 September, and ended with a round-table discussion on "Logic and Methodology as a European Research Programme" in the afternoon of 10 September. The workshop was located at the Institute for Advanced Studies of Bristol University. In the evening of 9 September a conference dinner was organised. From the reactions of the participants during, as well as after, the event we can say that it was a great success.

The talks and the ensuing discussions could be broken down into four main sections, which reflected traditional and state-of-the-art accounts of applying logical methods in the analysis of scientific language, theories, and practices, but in which also possible future developments were outlined:

(A) Logic in Methodology of Science – Past,Present,Future (8 September):
Questions investigated: What role will logic play in the further development of the methodology of science? What role should it have? Did the logical reconstruction of empirical theories have a positive effect on science? What became of the logical empiricists' view of philosophy of science as "applied logic"?

The following papers addressed these issues:

Michael Stöltzner:	From the Logic of Science to Epistemology
Gabriel Sandu:	Logics of Dependence and Independence
Gerhard Schurz:	When Empirical Success Implies Realistic Reference: A Logical Correspondence Theorem

(B) Scientific Methodology and its Impact on Logic (8 September):
Questions investigated: Do scientific achievements change the logical systems that we use or do they at least change our view of logic? What is the philosophical status of quantum logic in quantum theory? Is it science or philosophy that is responsible for choosing our logical axioms and rules?

The following papers addressed these issues:

Johan van Benthem:	"The Logical Study of Science" Revisited
James Ladyman:	Implementation of Logical Operations by Physical Processes
Miklos Redei:	Operational and Logical Independence in Quantum Theory
Sonja Smets:	Dynamic Coinditionals in Quantum Logic, Belief Revision and Logics for Communications: Towards a Unifying Setting for Information Change

(C) The Logic of Theory Revision and Probability (9 September):
Questions investigated: Does the change of scientific theories conform to some sort of rationality that can be reconstructed logically? If so: what can recent developments in belief revision, non-monotonic logic, dynamic logic, and probabilistic logic tell us about the rationality of theory change?

The following papers addressed these issues:

Erik Olsson:	On the Role of the Research Agenda in Epistemic Change
John Cantwell:	The Ramsey Test Derived
Gabriella Pigozzi:	Logical Theories of Revision and Social Choice Theory
Krister Segerberg:	DDL, AGM and Other Three-Letter Words
Peter Flach:	Logic and Probability: Two Sides of Different Coins
Theo Kuipers:	Formal Explication in Service of Philosophy of Science: Challenges and Threats
Ronald Ortner:	To Generalize Is To Be An Idiot – Or A Machine. Machine Learning and The Problem of Induction

(D) Logic and Scientific Language (10 September):
Questions investigated: What can logic contribute to the investigation of the syntax, semantics, and pragmatics of scientific languages? Is science or the philosophy of science in need of intensional or probabilistic idioms? Do we need higher-order quantification in order to express scientific claims?

The following papers addressed these issues:

Leon Horsten and Igor Douven:	Antirealist Truth
Jeff Ketland:	Structuralism and Identity of Indiscernibles
Judit Madarasz:	Logical Foundations for Spacetime
Simon Huttegger:	Probabilistic Reasoning in Games

2. Scientific Content of the Event:

The main findings of the workshop can be summarised as follows:

(A) The application of formal/mathematical methods in philosophy constitutes an important new trend and is exemplified by:
- international logic and philosophy journals extending their scopes to include articles in which formal methods are applied in order to solve philosophical problems or to approach philosophical problems in a novel way (see e.g. *Synthese KRA* or *Studia Logica*)
- recent or forthcoming conferences or workshops such as: the *Formal Epistemology* workshops in Berkeley and Austin, US; the *Studia Logica* conference on "Towards Mathematical Philosophy" in Torun, Poland; the "Mathematical Methods in Philosophy" conference in Banff, Canada.

The speakers at the workshop agreed that this trend will lead to a general renewal of interest in logical and mathematical methods in the philosophy of science.

(B) The presentations and subsequent discussions focused on these topics:

- Notions of dependence/independence and their logical and mathematical analysis in philosophy of science (e.g. game-theoretic semantics of formal and natural language, quantum logic; G. Sandu, M. Redei). A. Bird and others suggested a modal-logical analysis of independence in order to determine which of these notions of independence are logically dependent on each other.
- Notions of information and ways of measuring the complexity of information or of information-carrying systems: logical, Shannon, Kolmogorov complexity (J. Ladyman).
- Formally "richer" accounts of scientific theories: preference relations for iterated revision/update (hypertheories and fallback positions; K. Segerberg); comparison with abstract data types in computer science (J. v. Benthem); research agenda as part of epistemic states (E. Olsson). J. v. Benthem suggested the following guiding question for the future: What is the best notion of theory, given that we are interested in a particular sort of theoretical process or a particular aspect of scientific progress?
- Formally "richer" accounts of relations between theories: relative interpretation, bisimulation, refined interpolation (J. v. Benthem, S. Smets, G. Schurz).
- Theories of scientific theory change: belief revision (AGM), belief update (KGM), and their extensions, such as: evidence encodes method of iterated revision (S. Smets & A. Baltag); revision of both belief/theory *and* the research agenda (E. Olsson); belief revision on "three-valued" propositions as a means of getting around Gärdenfors' impossibility result on the Ramsey test for conditionals (J. Cantwell); AGM and KGM formalised in dynamic doxastic logic (K. Segerberg); learning procedures in formal learning theory vs. revision procedures in iterated belief revision. One of the questions raised was: Is there a rationality in the actual history of theory

change that be described by some of these new formal mechanisms?

- Dynamic logic and its applications in quantum logic: measurement expressed by a dynamic modal operator ("action operator"; S. Smets).
- Varieties of consequence relations: deductive, confirmationally inductive, explanatorily inductive, abductive (P. Flach, J. v. Benthem); relations to logic of conditionals, nonmonotonic reasoning; consequence relations as formalizations of learning hypotheses from evidence (P. Flach).
- Logical treatment of the cognitive aspects of science: scientific agents which learn – belief revision, formal learning theory, machine learning, logical descriptions of neural networks.
- Logical treatment of social aspects of science: belief revision/dynamic epistemic logic in a multi-agent setting (S. Smets); belief/judgment aggregation with "experts belief sets" (G. Pigozzi); common belief vs. belief revision for languages with iterated belief operators (K. Segerberg); success postulate in AGM belief revision as belief merging with a highly authoritative agent (J. v. Benthem); game theory for a society of players (scientists?).
- Structures and structuralism: Structuralism in philosophy of mathematics vs. Structural Realism vs. Structuralism in the philosophy of science (J. Ketland).
- The balance of expressive power and complexity (cf. modal logic, but also machine learning ; J. v. Benthem, R. Ortner).
- Classical approaches/results in the philosophy of science of Logical Empiricism reappear with a new interpretation; e.g.: synthetic bilateral reduction sentences and structural realism (G. Schurz); inductive bias/no-free-lunch theorems in machine learning and the projectibility debate a la Goodman, Carnap, Hempel in inductive logic (R. Ortner); Carnap's continuum of inductive methods and reasoning/learning in games (S. Huttegger).

(C) Several of the speakers referred to areas in which scientists are rediscovering questions of logical/philosophical nature (e.g. quantum information theory, first-order formalizations and model theory of relativity theory; S. Smets, J. Madarasz). A typical such question is: Which assumptions are needed to derive the twin paradox or to derive that there can be no faster-than-light observers?

3. Assessment and Future Directions:

Several problems that affect the applicability of logic and mathematics in current philosophy of science were mentioned in the course of the workshop:

(A) Problems on the Level of Content:

- Many relevant problems in science are simply not taken up by philosophers of science (M. Stöltzner).
- Logic and philosophy of science have drifted apart; formal explications come with risks (T. Kuipers). While the reunion was predicted to yield *the* new field of application for logical methods, logic actually turned to computer science, cognitive science, and linguistics – rather than to philosophy of science – in the 1980s (J. v. Benthem). On the other hand, the development of new logical methods might make these areas "drift together" again.
- Focus on "probability only" and "no-language" accounts of science (J. v. Benthem). But: spaces of propositions/events and logical systems are underlying probability measures; probability axioms have to be adapted to non-classical logics (J. Cantwell, L. Horsten & I. Douven); a probabilistic semantics for anti-realist truth is needed (L. Horsten & I. Douven); the probability semantics of nonmonotonic reasoning justifies the standard system P for nonmonotonic consequence relations; logic is needed in order to express the qualitative aspects of probability; what is called a "concept" in machine learning can be seen as the extension of a predicate – if this were made explicit, perhaps important closure conditions of PAC-learnability under logical connectives would emerge. As P. Flach pointed out, there are indeed approaches in machine learning where statistics is combined with symbolic knowledge representations and logical derivation mechanisms.

(B) Problems on the Level of Research Organisation:

- Formal sciences and foundational research in science are neglected by European research institutions (emphasis on applied science). Subjects are split arbitrarily (e.g., the ESF divides Cognitive Science into a Social Science and a Humanities section). The research index for the Humanities has to be improved (e.g., an excellent journal such as *Theoria* is not of merely "domestic" importance; I. Parvu).
- J. v. Benthem raised the question: Why do we have to demarcate logic and philosophy of science at all?

The workshop initiated several follow-up activities:

A special issue of *Studia Logica* on "Applied Logic in Philosophy of Science" will be edited by Leon Horsten & Igor Douven (two workshop speakers). If the Eurocores scheme proposal on *Logical Modelling* (G. Sandu et al.) is successful, then joint projects on topics discussed in the workshop will be submitted.

An extension of this ESF Exploratory Workshop in terms of an annual workshop series was planned (the next such workshop being in Düsseldorf, organised by G. Schurz).

A "local" cooperation and exchange of students will be initiated (e.g., Groningen vs. Bristol; T. Kuipers, A. Bird, H. Leitgeb).

Finally, if the ESF Research programme proposal on philosophy of science (T. Kuipers, M. Redei) is granted, then there will be a European network in which formal methods in the methodology of science might become a major research focus and the workshop participants will see to it that logical methods will not be neglected by the corresponding project groups.

4. Final Programme:

	Friday 8 Sept	Saturday 9 Sept	Sunday 10 Sept
	morning	*morning*	*morning*
	Logic in the Methodology of Science – Past, Present, Future	**The Logic of Theory Revision and Probability I**	**Logic and Scientific Language**
09.00	*welcome and introduction* presentation of the ESF	*introduction*	*introduction*
09.15	Stölzner Sandu Schurz	Olsson Cantwell Pigozzi Segerberg	Horsten & Douven Ketland Madarasz Huttegger
13.00	*lunch*	*lunch*	*"brown bag"-like lunch buffet with integrated discussion on:*
	afternoon	*afternoon*	
	Scientific Methodology and its Impact on Logic	**The Logic of Theory Revision and Probability II**	**Logic and Methodology as a European Research Programme**
14.30	*introduction*	*introduction*	*concluding roundtable discussion*
14.45	van Benthem Ladyman Redei Smets	Flach Kuipers Ortner	*moderator:* Leitgeb (There were coffee breaks after every two talks.)
18.30-19.00	discussion of day's conclusions	discussion of day's conclusions	

First Meeting point: Friday, 8 September 2006, 8.30
Institute for Advanced Studies
The Royal Fort House

Start of workshop: Friday, 8 September 2006, 9.00
End of workshop: Sunday, 10 September 2006, 17:00

5. Statistical Information on Participants

Age structure:

- *Senior scholars* (11): Alexander Bird, Leon Horsten, Gabriel Sandu, Gerhard Schurz, Miklos Redei, Johan van Benthem, Theo Kuipers, Ilie Parvu, Krister Segerberg, Peter Flach, James Ladyman.

- *Junior scholars* (11), i.e., permanent position-holders for less than five year or post-doctoral students: Hannes Leitgeb, Simon Huttegger, Ronald Ortner, Igor Douven, Sonja Smets, Michael Stöltzner, Judit Madarasz, Gabriella Pigozzi, John Cantwell, Erik Olsson, Jeff Ketland.

Countries of speaker's research institutions:

Austria (3):	Hannes Leitgeb, Simon Huttegger, Ronald Ortner
Belgium (3):	Igor Douven, Leon Horsten, Sonja Smets
France (1):	Gabriel Sandu
Germany (2):	Gerhard Schurz, Michael Stöltzner
Hungary (2):	Judit Madarasz, Miklos Redei
Luxembourgh (1):	Gabriella Pigozzi
Netherlands (2):	Johan van Benthem, Theo Kuipers
Romania(1):	Ilie Parvu
Sweden (3):	John Cantwell, Erik Olsson, Krister Segerberg
UK (4):	Alexander Bird, Peter Flach, Jeff Ketland, James Ladyman

Hannes Leitgeb and Johan van Benthem have positions in two countries (in Leitgeb's case, Austria and the UK, in van Benthem's case, the Netherlands and the US).

Male/Female:

Male (19):	Alexander Bird, Hannes Leitgeb, Simon Huttegger, Ronald Ortner, Igor Douven, Leon Horsten, Gabriel Sandu, Gerhard Schurz, Michael Stöltzner, Miklos Redei, Johan van Benthem, Theo Kuipers, Ilie Parvu, Johan Cantwell, Erik Olsson, Krister Segerberg, Peter Flach, Jeff Ketland, James Ladyman.
Female (3):	Sonja Smets, Judit Madarasz, Gabriella Pigozzi,

Despite significant efforts, we were not able to increase the number of female speakers, due to a general lack of female researchers in the relevant areas. (Additionally, Maria Luisa Dalla Chiara was finally not able to not follow our invitation).

6. Final List of Participants:

Convenors:

1. **Alexander Bird**
Department of Philosophy
University of Bristol
9 Woodland Road
Bristol BS8 1TB
UK
Tel: +44 117 928 7826
Fax: +44 117 928 8626
Email: Alexander.Bird@bristol.ac.uk

2. **Hannes Leitgeb**
Fachbereich Philosophie KGW
Universität Salzburg
Franziskanergasse 1
A-5020 Salzburg
Austria
Tel: +43 662 8044 4084
Fax: +43 662 8044 4074
Email: Hannes.Leitgeb@sbg.ac.at

and

Departments of Philosophy and Mathematics
University of Bristol
9 Woodland Road
Bristol BS8 1TB
UK
Tel: +44 117 928 8890
Fax: +44 117 928 8626
Email: Hannes.Leitgeb@bristol.ac.uk

Invited participants (ordered by country):

3. **Simon Huttegger**
Konrad Lorenz Institute for Evolution and Cognition Research
Adolf Lorenz Gasse 2
A-3422 Altenberg
Austria
Tel: +43 2242 32390
Fax: +43 2242 32390 4
Email: Simon.Huttegger@sbg.ac.at

4. **Ronald Ortner**
Department für Mathematik und Informationstechnologie
Lehrstuhl für Informationstechnologie
Universität Leoben
Franz-Josef-Straße 18
A-8700 Leoben
Austria
Tel: +43 3842-402-1503
Fax: +43 3842-402-1502
Email: Ronald.Ortner@unileoben.ac.at

5. **Igor Douven**
Hoger instituut voor Wijsbegeerte
Centrum voor Logica, filosofie wet.
Kardinaal Mercierplein 2
B-3000 Leuven
Belgium
Tel: +32 16 32 63 16
Email: igor.douven@hiw.kuleuven.be

6. **Leon Horsten**
Institute of Philosophy
Katholieke Universiteit Leuven
Kardinaal Mercierplein 2
B-3000 Leuven
Belgium
Tel: +32 16 326316
Fax: +32 16 326311
Email: Leon.Horsten@hiw.kuleuven.be

7. **Sonja Smets**
Center for Logic and Philosophy of Science (CLWF)
Free University of Brussels
5B457
Pleinlaan 2
1050 Brussels
Belgium
Tel: +32 2 644 26 77
Fax: +32 2 644 07 44
Email: sonsmets@vub.ac.be

8. **Gabriel Sandu**
IHPST (Paris I / CNRS / ENS – UMR 8590)
13, rue du Four
75006 Paris
Pleinlaan 2
France
Tel: +33 1 43 54 60 36
Fax: +33 1 43 25 29 48
Email: sandu@mappi.helsinki.fi

9. **Gerhard Schurz**
Philosophisches Institut
Universität Düsseldorf
Universitätsstraße 1
Gebäude 23.21
D-40225 Düsseldorf
Germany
Tel: +49 211 81 12914
Fax: +49 211 81 15764
Email: gerhard.schurz@phil-fak.uni-duesseldorf.de

10. **Michael Stöltzner**
Interdisziplinäres Zentrum für Wissenschafts- und Technikforschung
Universität Wuppertal
Gaußstraße 20
D-42097 Wuppertal
Germany
Tel: +49 202 439 3605
Fax: +49 202 439 3610
Email: Stoeltzn@uni-wuppertal.de

11. **Judit Madarasz**
Alfred Renyi Institute of Mathematics
Hungarian Academy of Sciences
H-1364 Budapest, P.O. Box: 127
Hungary
Tel: +36 1 483 8313
Fax: +36 1 483 8333
Email: madarasz@renyi.hu

12. **Miklos Redei**
Department of History and Philosophy of Science
Faculty of Sciences
Lorand Eotvos University
P.O. Box 32
H-1518 Budapest 112
Hungary
Tel: +36 209 0555 6678
Fax: +36 372 2924
Email: redei@hps.elte.hu

13. **Gabriella Pigozzi**
Computer Science and Communications (CSC)
Faculty of Sciences, Technology and Communication (FSTC)
University of Luxembourg
6 Rue Richard Coudenhove Kalergi
L-1359
Luxembourg
Tel: +352 46 66 44 5442
Fax: +352 46 66 44 5500
Email: gabriella@pigozzi.org

14. **Johan van Benthem**
Institute for Logic, Language & Computation (ILLC)
University of Amsterdam
Plantage Muidergracht 24
1018 TV Amsterdam
The Netherlands
Tel: +31 20 525 6051
Fax: +31 20 525 5206
Email: johan@science.uva.nl

15. **Theo Kuipers**
Department of Theoretical Philosophy
University of Groningen
Oude Boteringestraat 52
9712 GL Groningen
The Netherlands
Tel: +31 50 363 6151
Fax. +31 50 363 6160
Email: T.A.F.Kuipers@philos.rug.nl

16. **Ilie Parvu (ESF Representative)**
Department of Theoretical Philosophy and Logic
University of Bucharest
Splaiul Independenţei, Nr. 204
70609, Bucharest, Sector 5
Romania
Tel: +021 410 29 74
Fax. +021 411 52 89
Email: ilieparvu1@yahoo.com

17. **John Cantwell**
Division of Philosophy
Royal Institute of Technology
Teknikringen 78 B
S-100 44 Stockholm
Sweden
Tel: +46 8 790 9208
Fax: +46 8 790 9517
Email: cantwell@kth.se

18. **Erik Olsson**
Department of Philosophy
Lund University
Kungshuset, Lundagard
SE-222 22 Lund
Sweden
Tel: +46 22 20925
Email: Erik_J.Olsson@fil.lu.se

19. **Krister Segerberg**
Filosofiska institutionen
Uppsala Universitet
Box 627
751 26 Uppsala
Sweden
Tel: +46 18 471 73 52
Fax: +46 18 471 73 70
Email: Krister.Segerberg@filosofi.uu.se

20. **Peter Flach**
Department of Computer Science
University of Bristol
The Merchant Venturers Building
Woodland Road
Bristol BS8 1UB
UK
Tel: +44 117 954 5162
Fax: +44 117 954 5208
Email: Peter.Flach@bristol.ac.uk

21. **Jeff Ketland**
Department of Philosophy
University of Edinburgh
George Square
Edinburgh EH8 9JX
UK
Tel: +44 131 650 3662
Fax +44 131 650 3660
Email: jeffrey.ketland@ed.ac.uk

22. **James Ladyman**
Department of Philosophy
University of Bristol
9 Woodland Road
Bristol BS8 1TB
UK
Tel: +44 117 928 7609
Fax: +44 117 928 8626
Email: James.Ladyman@bristol.ac.uk

Three invited speakers were finally not able to come: Reinhard Kleinknecht, Maria Luisa Dalla Chiara, Franz Huber.

In the course of the workshop application and organisation, Gabriella Pigozzi moved from Konstanz (Germany) to London (UK) and then to Luxembourg (see address above).