

LOGIC AND APPLICATION

A SURVEY

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Abstract

This report presents the results of a limited survey of the views of logicians on a number of questions concerning logic and its applications, carried out by means of structured interviews.

It describes the theoretical background of the survey and the central questions and provides background information concerning the pool of logicians interviews and the ways in which the interviews were conducted.

It provides an overview of the various answers to the questions and analyses them in detail. It draws some general conclusions from the analysis, including recommendations on how to incorporate application in a logic curriculum in a systematic way.

Keywords: Logic; Applied logic; Application; Survey; Structured interviews; Logic teaching

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Of course, the responsibility for the analyses and the conclusions expressed in the report rests solely with the authors.

Introduction

This report presents the results of a survey of views on various questions about logic and its applications. The survey is a follow-up of a small working group that was held in December 2024 at the Tsinghua University – University of Amsterdam Joint Research Center for Logic. In three sessions, the members of the working group discussed a number of theoretical questions concerning logic and its application in various disciplines, as well as the actual experiences of the working group members.

From these discussions a number of general questions arose, and the working group decided it would be fruitful to conduct a survey to take stock of and analyse a wider variety of views on these issues from working logicians. To that end, it has conducted a series of structured interviews with a number of working logicians, analysed the results, and formulated some general tentative conclusions. These are presented in this report.

The report is organised as follows. Chapter 1 provides information about the background of the project and describes the set-up of the survey. Section 1.1 gives a brief introduction to the theoretical background and presents the central questions concerning logic and application that it gives rise to. In section 1.2 the design of the survey is described in detail. This includes the choice of interviewees, the set of questions asked during the interviews, and the way in which the results were transcribed and analysed.

Chapter 2 describes the answer space of the questions posed. Section 2.2 outlines the possible positions on the various issues raised during the interviews. These are used as a framework for subsequently identifying and analysing the positions that the interviewees actually hold, which are described in section 2.3.

The results are then analysed in detail in chapter 3 and chapter 4. In the final chapter 5 some general conclusions are drawn, open issues are identified, and some recommendations are made regarding the role that application of logic might be assigned in a logic curriculum.

The protocol that was followed during the interviews can be found in appendix A.

Appendix B gives some information about the original working group.

Chapter 1

Background and set-up

1.1 Background

The starting point of the working group that met in December 2024 was the observation that application to non-logical domains is a key aspect of much of contemporary logical research, and hence also of teaching logic. Of course, there is research that is concerned with questions that are internal to logic itself. But increasingly logic is concerned with matters of application. And this is not a one-way street: in its turn, application is an important driver of development in logic.

Historically, mathematics and philosophy were the main areas in which logic was applied. And already then, the relation was very much an interactive one. Research in the foundations of mathematics drove fundamental research in logic, concerns of a philosophical nature, e.g., those related to the analysis of modality and time, also prompted new developments in logic.

After, roughly, the mid-twentieth century, further diversification took place. The 1960s saw the advent of formal semantics, in which logic is applied in the study of natural language semantics. The development of theoretical and applied computer science also saw applications of logic, e.g., in modelling knowledge representation, in research into computational complexity, and so on. In the 1980s and onwards rapid developments in cognitive science also included applications of logic. And initially a lot of research in artificial intelligence was heavily influenced by logical concepts and methods. Contemporary research in AI, made possible by the phenomenal increase in computing power that allows the use of large data sets, is based on the use of stochastic methods. But here too it becomes increasingly evident that logic has a role to play.

So, application is central to modern logical research. In most cases, successful application involved some form of cooperation, between the one whose results and methods are being applied and the one whose problems these are applied to. Take the example of a formal semanticist. Being trained as linguist, they formulate problems and questions, contemplate possible solutions and answers. And at some time invoke the use of logical results and methods. That is, usually, not a matter of grabbing some standard tools and applying them. It usually, well at least in the interesting cases anyhow, involves also

a form of logical research: tweaking existing tool or even developing new ones. That is where the logician comes in: applying logic is a co-operative enterprise.

In an ideal world, where researchers are free from bias, have infinite time and attention spans, this coming together might happen whenever and wherever it is productive: if it makes sense to apply logic, it will be applied, no efforts needed. Reality is different, of course. Logicians need to show where and why their methods and results are useful (and perhaps also show where and when they are not, but that is a tall ask). To do so effectively requires sufficient knowledge of an application domain, a proper grasp of the problems and the associated solution space, as well as the ability to embed logical results into non-logical frameworks.

This requires an outward looking, open attitude and that in its turn might require a specific view on logic and its application potential as such. Here we can discern a variety of positions, situated in a space that is construed by two dimensions: the nature of logic itself and the nature of application.

Let us start with the dimension of the nature of logic. Here we find two opposing views. On the one hand there is the classical view that sees logic as basically one thing that is fundamental with regard to anything that it is applied to. This view is that of the founders of modern logic, as witnessed for example by the following quote from the preface of Frege's *Begriffsschrift* [Frege, 1879]:

The firmest proof is obviously the purely logical, which, prescind-
ing from the particularity of things, is based solely on the laws on which all knowl-
edge rests.

This view reflects the original motivation for the development of modern logic, viz., to serve as the secure foundation for core mathematics. That brings along both monism, – there is only one logic –, as well as independence of application, – when logic is applied it does not change with what it is applied to. This fundamental nature of logic is secured by assigning it a unique epistemological and ontological status. One of the most clear expressions of this vision can be found in Wittgenstein's *Tractatus* [Wittgenstein, 1960, 5.473]: 'Logic must take care of itself'. It is beyond epistemological vindication and ontologically fundamental.

On the opposite side of the spectrum we find pluralism: logic is not one thing, it is a manifold of different systems. And these are really different logics, not subsystems of one big overall system of logic. An early 'declaration' of pluralism can be found in Carnap's *The Logical Syntax of Language* [Carnap, 1937, p. xv]:

Up to now, in constructing a language, the procedure has usually been, first to assign a meaning to the fundamental mathematico-logical symbols, and then to consider what sentences and inferences are seen to be logically correct in accordance with this meaning. Since the assignment of the meaning is expressed in words, and is, in consequence, inexact, no conclusion arrived at in this way can very well be otherwise than inexact and ambiguous. The connection will only become clear when approached from the opposite di-

rection: let any postulates and any rules of inference be chosen arbitrarily; then this choice, whatever it may be, will determine what meaning is to be assigned to the fundamental logical symbols. (Carnap 1937: xv)

The subsequent development of a wide variety of logical systems has reinforced this ‘Principle of Tolerance’ espoused by Carnap.

That being said, pluralism of logic by itself is not a unique position, as it can be motivated in a variety of ways. And this is where the second dimension, that of application, comes in.

There are ontological motivations, that link different logics to different ontological domains. Example: non-classical quantum logic for describing quantum phenomena and classical logic for the dealing with phenomena at the macroscopic level. In a similar fashion one can motivate using different logics for dealing with different epistemological realms. Example: many-valued logics for dealing with matters of future (in)determinism and two-valued logics for the analysis of statements about the past and present; or static epistemic logic for the analysis of knowledge and belief structures versus dynamic epistemic logics for describing information exchange.

The sheer variety of logics and the diversity of their motivations then leads to the view that the term ‘logic’ describes a toolbox, with a variety of tools all geared to specific uses, that can be expanded as needs arise. From that perspective application is a main driver of development.¹ These two dimensions together create a space of possible positions, and one of the goals of the project is to see which positions in that space are actually occupied and, if so, for what reasons do logicians occupy them. Our primary interest is in the considerations surrounding the application of logic. This includes views on the nature of logic, but also on issues that are inherent to application as such.

We view logic and its application as *practices*, i.e., as shared human activities conducted in a socio-cultural context.² Key features of practices are that they involve multiple actors; that they ‘have a point’, i.e., actors engage in them for a reason; that they are based on both natural and acquired behavioural patterns; and that they are shaped by

1. The toolbox metaphor also appears in Wittgenstein’s description of the variety of language in *Philosophical Investigations* [Wittgenstein, 2009, § 11]:

Think of the tools in a toolbox: there is a hammer, pliers, a saw, a screwdriver, a rule, a glue-pot, glue, nails and screws. — The functions of words are as diverse as the functions of these objects. (And in both cases there are similarities.)

This pluralism has to be accepted for what it is, Wittgenstein continues [*ibid.*, § 14]:

Suppose someone said, ‘All tools serve to modify something. So, a hammer modifies the position of a nail, a saw the shape of a board, and so on.’ — And what is modified by a rule, a glue-pot and nails? — ‘Our knowledge of a thing’s length, the temperature of the glue, and the solidity of a box.’ — Would anything be gained by this assimilation of expressions?

2. This is not the place to dwell further on the analysis of the concept of practice. Suffice it to say that we draw inspiration from work done in practice theory (cf., e.g., Schatzki [1996, 2002]), and from work done in the philosophy and sociology of mathematics, where the view of mathematics as a social practice is explored (cf., e.g., Azzouni [2007], Mancosu [2008], Van Kerkhove [2009]).

explicit rules. What is important to note here is that a practice allows for a certain amount of *heterogeneity* of the realisation of these features in a practice. In a given practice these features allow for (limited) differences between (groups of) actors.

If we turn to the application of logic as practice, these features give rise to various sets of interrelated questions.

The first concern ‘ownership’. If logic is applied to a problem in a non-logical domain, then who formulates the problem? And when and how does that matter? Similarly, if the results are evaluated, then who determines the success criteria? And what if there is no agreement on the success criteria? I.e., what if the logician’s criteria for what constitutes a solution differ from those of the non-logician?

A second concern centres around the properties of the logic that is being applied. Any logic that is applied has in and of itself certain distinctive properties. Prominent among these are meta-logical meta-logical properties, such completeness, decidability, and so on. When a logic is applied to a non-logical problem is it relevant that it has such properties? If so, which ones? And why? Designing a logical system also involves considerations of other properties such as simplicity, survey-ability, elegance. Are such criteria important? If so, which ones? And why? And what if the logician’s criteria for what is a *good* solution differ from those of the non-logician?

Thirdly, there is the nature of the application area. Logic is applied to *a priori* disciplines, such as mathematics and philosophy. But it also finds application in empirical sciences, such as cognitive science, linguistics, some of the social sciences. And then there are ‘hybrid’ disciplines, such as computer science, and artificial intelligence. Key question here is: does it matter to which kind of application area logic is applied? Does it lead to different answers to, for example, questions of ownership, or the relevance of meta-logical properties?

And then there is pluralism. Commitment to pluralism in some form or other seems standard among present-day logicians. Few maintain that there is in fact only one logic. This commitment raises a number of questions when it comes to application. For instance, does pluralism ‘transfer’? I.e., given that there are a number of logics that can be applied to a problem, does that mean that the problem as such has a number of solutions in terms of the application area? Or does a given problem in a particular application require a unique answer? If so, uniqueness up to what level?

No doubt viewing application of logic as a practice also raises a lot of other questions. What we have formulated above are still fairly systematic questions that do not touch on such factors as historical development of interactions between disciplines, or concrete social structures, such as differences in intellectual prestige and status in academia. No doubt these too play a role in whether and how logic finds application in non-logical domains. But we need to leave a proper study of that to others.

1.2 Survey design

1.2.1 Interviewees

The decision to use structured interviews instead of a survey was motivated largely by the expectation that conducting interviews would give more detailed information, not just on the positions that logicians hold, but importantly also on their motivations. It does mean that representativeness for the relevant population as a whole is limited.

Another limitation on representativeness is that we were looking for logicians who have substantial experience with application of logic in a (usually variety of) non-logical domain(s). A follow-up in the form of a large survey that is based on the analyses presented in this paper might make up for that.

Given the small size of the group and the limited time available, it was decided to limit the group of interviewees. In the selection of candidate interviewees considerations concerning geographical spread, career stage, disciplinary profile played a role, as did availability.

Fourteen logicians were invited, of whom eleven accepted the invitation, an acceptance rate of almost 79%. The reasons given for non-acceptance were lack of time and lack of relevant expertise. One invitee did not respond to the invitation.

The following logicians accepted the invitation to be interviewed:

- Johan van Benthem (Stanford U.)
- Patrick Blackburn (U. Roskilde)
- Thomas Bolander (Technical U. Denmark)
- Thomas Icard (Stanford U.)
- Fenrong Liu (Tsinghua U.)
- Qi Feng (Tsinghua U.)
- Ram Ramanujam (IMS Chennai)
- Giorgio Sbardolini (U. of Amsterdam)
- Jeremy Seligman (U. of Auckland)
- Chenwei Shi (Tsinghua U.)
- Dag Westerstahl (U. of Stockholm)

Geographically, this places two interviewees in the USA, one in India, four in continental Europe, three in mainland China, and one in New Zealand.

In terms of career stage, two are early career, three are mid career, and six are late career researchers.³

As for experience with application of logic in non-logical domains, there is expertise on a wide variety of such domains: philosophy, mathematics, cognitive sciences, linguistics, computer sciences, artificial intelligence, social sciences.

3. Cf., section 3.1 for the definitions used.

This heterogeneity is also reflected in the academic backgrounds of the interviewees. Almost all of them have studied and worked not just in logic but also in various sciences, such as engineering sciences, physics, mathematics, philosophy, linguistics, computer sciences.

1.2.2 Interviewers

The interviews were conducted by:

- Penghao Du
- Qingyu He
- Yumin Ji
- Wenfei Ouyang
- Wenlong Zheng

Interviewers worked mostly in pairs to conduct the interviews. Pairs were matched with interviewees non-randomly, based on their academic backgrounds and pre-existing relationships. Each interviewing pair consisted of one member who was relatively familiar with the interviewee and another who was less familiar. Two interviews were conducted by a single interviewer.

The interviewers are all logic students, at various stages of their studies. One is an undergraduate student, two are graduate students, and two have recently completed their PhDs.

Just like the interviewees, the interviewers have mixed disciplinary backgrounds, combining logic with various other disciplines, such as philosophy and mathematics.

1.2.3 Interviews

Interviewees were invited by email and were informed about the background and goals of the survey. Also, they were sent the questions that were to be asked beforehand. The text of the invitation email and the questions can be found in appendix A.

The interviews took place between February 20th and June 4th. They took between 35 and 65 minutes, with an average of 50 minutes per interview.

Six interviews were conducted on-line, five were in person.

The recording and transcription of interviews were conducted using different methods based on the interview format. ‘Zoom’ was employed to record and transcribe online interviews, while in-person interviews were recorded using the built-in recording function on a mobile phone and transcribed using various platforms such as ‘TurboScribe’.

The transcripts were cleaned up lightly by the interviewers, who corrected obvious mistakes, filled in small gaps, and so on.

The cleaned up transcripts were then shared with the interviewees for a factual check. Nine interviewees took advantage of that opportunity.

The analyses presented in this report are based on the cleaned up and fact-checked transcripts.

Interviewees were informed about the way in which the materials provided by the transcripts would be used: that they would be used only to conduct analyses of various positions on various issues and their interrelationships; that concrete positions/answers would *not* be ascribed to individual interviewees; that short, anonymised quotes could be used for purposes of illustration only; and that the full transcripts would *not* be made public.

1.2.4 Structure

The interviews were structured, and all followed the same protocol. The actual protocol can be found in appendix A, here we summarise the main features.

After an introductory exchange the interviewers asked the interviewees opinions on four topics:

1. The ‘ownership’ with respect to questions of application
2. The relevance of meta-logical properties
3. The role of logical pluralism
4. The nature of disciplines in which logic is applied

The ownership topic concerns such issues as who formulates the application question(s) and who determines the adequacy criteria for proposed solutions.

The relevance of meta-properties topic addresses the role of specific meta-logical properties of applied logical systems (such as completeness, decidability, and so on), and the role of more general meta-properties such as elegance, simplicity and survey-ability.

The topic of logical pluralism centres around the question whether application challenges restrict, or even uniquely determine, the logical theories that can be used to solve them.

The topic of disciplinary nature focusses on differences between kinds of disciplines in which logic is applied: a priori disciplines, such as mathematics, philosophy); empirical sciences, such as cognitive sciences, linguistics; and ‘hybrid’ disciplines, such as computer science, artificial intelligence.

After these four topics the interviewees were asked to respond to three theses:

- A. Fixing the application domain entails fixing *the* logic of that domain
- B. Meta-properties of logics provide necessary criteria for successful applications
- C. The application of logic can contribute to clarification, but by itself does not constitute explanation

The interviews then ended with asking the interviewees how they evaluated their experiences of being involved in the application of logic.

The exact questions and the order in which they were to be asked was laid down in the protocol that can be found in appendix A. Not in all cases was it possible, or fruitful,

to follow the protocol exactly as stated. In some cases interviewees anticipated in their answer to a question another question that was to be asked only later. In other cases some parts of questions had to be left out for reasons of time. However, the differences in which these deviations have resulted are relatively minor and do not affect the analyses and general conclusions in any substantial way.

In general, the questions worked well. It did appear, though, that in some cases there was some overlap, in particular between topic 2, relevance of meta-properties, and thesis B: in quite a few cases interviewees already expressed their opinion on the thesis in their answer to the question. Also, in some cases the interviewees asked for a further specification of a question, or interpreted it spontaneously in a somewhat different way than intended. However, the interviewers were able to detect these non-/misunderstandings and could address them successfully.

Chapter 2

Positions

2.1 Introduction

The main goal of the project is to get a comprehensive and ‘real life’ insight in how application of logic in non-logical domains works. That means that it is not the views and thoughts of the individual interviewees per se that are the object of analysis, but the diversity of views on various topics and the patterns linking those views that they represent. So, the data provided by the individual interviewees serve as a means to get at those general issues.

The analysis presented below is the outcome of a three-step procedure.

First, we formulated for ourselves the possible positions we theoretically could associate with each of the questions and with the three theses. These possible positions are fairly abstract, unambiguous, and devoid of actual motivation. They are listed in section 2.2.

Second, we made an inventory of the actual positions taken by the interviewees. This results in a much more diverse set of positions, in which answers and motivations are combined and which are concrete and tied to actual experiences. An overview of these actual positions is given in section 2.3.

These possible and actual positions form the subject matter of this chapter

The third step is a more in-depths analysis of the various positions on the issues addressed in the interviews. This done both quantitatively: what is the distribution of answers over the various positions, and qualitatively: what are the core arguments provided for the various positions by the interviewees. The results are then used to trace correlations along a number of dimensions: answers to the various questions asked, the application areas interviewees have experience with, their disciplinary backgrounds, the career stage they are in. The results of that analysis form the subject matter of the next two chapters, 3 and 4.

In some cases the descriptions of actual positions and the analyses based on them are accompanied by brief quotations from the interviews. This is done sparingly, mainly to illustrate a particularly striking viewpoint or motivation.

2.2 Possible positions

As was already mentioned, if one outlines the possible positions that can be taken up with regard to the various issues from a purely theoretical perspective, the results are bound to be abstract, unambiguous and lacking nuance. Nevertheless, it is one way to provide structure to the description and analysis of actual positions taken up by people working in the field.

So what follows is best viewed as an abstract frame on which to plot the empirical data provided by the interviews. We list the possible positions for each of the issues that were brought up in the interviews, in some cases with some comments on the dimensions along which variations can be expected to occur.

Ownership

Issue:

Who is in charge of the problem definition, the success criteria, etc. ?

Positions:

1. Logician
2. Non-logician
3. Initiator
4. Joint ownership
5. Separate (everyone owns their own part)

Note:

It is to be expected that answers (also) depend on such parameters as:

- Goal of the project (how central is the logic?)
- Origins of the project (who initiated it? disciplinary history, ...)
- Nature of the discipline (formalisation playing a different role in different disciplines)

Meta-logical properties

Issue:

Do meta-logical properties matter for application?

Positions:

1. Always
2. Never
3. Sometimes

Note:

Relativisation is needed to accommodate:

- variation among properties: e.g., ‘decidability always, completeness sometimes’
- dependence on application area: e.g., ‘completeness relevant for application X but not application Y ’

Other properties

Issue:

Do properties such as elegance, simplicity, survey-ability matter for application?

Positions:

1. No
2. Yes
3. Sometimes

Note:

Relativisation is needed to accommodate:

- variation among properties: e.g., ‘elegance no, survey-ability yes’
- dependence on application area: e.g., ‘survey-ability relevant for a priori disciplines, not (so much) for empirical ones’
- practical consequences versus inherent value

Also, it is to be expected that answers may depend on such parameters as:

- practical consequences
- inherent value

Pluralism

Issue:

Does the application fix a unique logic?

Positions:

1. Application determines logic
2. Application allows different logics
3. Logic determines range of applications
4. No restrictions

Note:

We need to distinguish between ‘different logics’ as:

- different logical systems (e.g., extensional vs. intensional, different modal logics, ...)
- different types of logic (classical vs. intuitionistic vs. ...)

Also, answers may be dependent on the application area.

Nature of the application areas

Issue:

Are there principled differences between application in a priori sciences (mathematics, philosophy), empirical sciences (linguistics, cognitive science), and ‘mixed sciences’ (computer science)?

Positions:

1. Yes
2. No
3. Yes, but not principled ones

Note:

It is to be expected that answers may vary with the specific discipline within these three broad areas.

Thesis A

Thesis:

Pluralism of logics can only be motivated by pluralism of application domains, i.e., fixing the application domain entails fixing *the* logic of that domain.

Positions:

1. Yes
2. No
3. No opinion

Note:

Variation is to be expected with respect to application domains.

Thesis B

Thesis:

Meta-properties of logics (such as decidability, completeness, ...) provide necessary criteria for successful applications.

Positions:

1. Yes
2. No
3. No opinion

Note:

Variation is to be expected with respect to application domains.

Thesis C

Thesis:

The application of a logic in a non-logical domain can contribute to clarification, but by itself does not constitute explanation.

Positions:

1. Yes
2. No
3. No opinion

Note:

Some interviewees may reject the supposition that there is a strict difference between clarification and explanation.

2.3 Actual positions

Not unexpectedly, the actual positions taken up on the various issues are more varied than the rather abstract overview of possible positions presented in the previous section. Part of the variation that we observed is covered by the qualifications mentioned there, but there are also unexpected variations to be observed.

In general, we found that ‘opinions differ’ in this sense that there were no issues on which all interviewees held the same position for the same reasons. Even where there was an apparent majority opinion, the motivations for holding the same position often differed quite markedly. These differences reflect the differences in, e.g., disciplinary background and training and experience with various application domains, but also with career stage of the interviewees. Some correlations between positions held and these parameters will be covered in chapter 3.

In the following section, as well as in later chapters, positions will be linked to interviewees. We should note that these links are based solely on the interviews, no other sources were used. Since the focus of our project is positions and their argumentation, and not views of individuals as such, these links are anonymised by identifying interviewees by randomly assigned letters.

Ownership

There was quite some discrepancy to be observed between possible positions and actual positions in the answers to the question around the first topic, that of ‘ownership’ of the application project, as is shown by the following overview:

1. Logician: 2 [E, F]
2. Non-logician: 1 [J]

3. Initiator: 0
4. Joint ownership: 5 [A,C,D,H,I]
5. Separate (everyone owns their own part): 0
6. Depends on the goals of the project: 1 [B]
7. Depends on how the project was initiated: 2 [G,K]

No-one took up the position that ownership is exclusively a matter of who is the initiator (position 3). This is a clear indication that application of logic is not a one-way street: whoever initiates the project, whether that be the logician or the non-logician, applying logic is not exclusively dictated by either the former or the latter.

Also, no-one associated themselves with the position that ownership is strictly divided, with logician and non-logician each owning their own part of the enterprise, with no say of the other party (position 5).

This means that, according all interviewees, there is always some form of interaction. For five interviewees interaction between logician and non-logician is so strong that we can speak of joint ownership (position 4). However, the ‘ratio’ may differ, depending on the initial situation, as interviewee A points out:

Both of them, it depends on the question. If there are questions already there, logicians can analyse and solve them by using our approach, while we can also formulate the questions ourselves.

Interaction apparently is a key ingredient of application. One might think that makes joint ownership inevitable. But that is not case: for some interviewees interaction does not exclude that ownership *can* be attributed (primarily) to one of the parties involved. According to two interviewees ownership is with the logician (position 1), where one interviewee sees the non-logician as the owner (position 2).

It is interesting to look at the reasons that these interviewees give for their assessments. These are diverse. Interviewee [E] motivates their ascription of ownership to the logician as follows:

[...] a person with strong logical thinking can usually identify the key issues, whether big or small. People working in applied fields don’t always know exactly what the real questions are.

The other interviewee [F] who also ascribes ownership to the logician does so for a related, yet different reason: they see the initial interaction as a way for the logician to come up with new interesting questions that are primarily logical in nature and that need not be motivated by their relevance for the application domain:

But what is more typical with me is that I will hear about some problem from someone else and then often try to find *my own way of applying logic* to it.’[emphasis added]

Only one interviewee [J] sees application of logic as primarily owned by the non-logician. For them, application addresses problems that ‘come from outside the domain of logic’:

They mostly come from observations of people's behaviour, which can be linguistic behaviour, or in communication or decisions that people make. [...] Why are they saying certain things? Why are they doing certain things? [...] And you think there must be a reason why people act in certain ways. [...] So there's a logic. [...] So I would say then, the questions come from outside.

So far we have related seven interviewees with one of the five positions listed above. What about the other four?

One interviewee [B] did not take up a position because they think the answer depends essentially on the *goals* of the application project: different projects have different goals and it is the goals that dictate the answer to questions of ownership. In a similar vein, two interviewees [G, K] were of the opinion that ownership depends on how the application project in fact happens to get started and that, since that is a rather contingent matter, it is difficult to take up a position.

Two interviewees who took up position 4 [C, I] did emphasise that the success criteria of an applied logic project depend on practical considerations. They noted that internal, disciplinary considerations, e.g., with regard to journal rankings, and the role these play in determining 'success' as primarily an internally defined criterium, shape what counts as a successful project.¹

Key observations:

1. Application of logic *always* involves interaction between logician and non-logician
2. Interaction does *not* mean joint ownership of problem formulation and success criteria
3. *Practical considerations*, such as chances of getting results published in relevant journals, also shape attitudes towards application-oriented projects

Logics and their properties

This topic was concerned with the question whether, and if so, which and when, properties of logical systems are relevant when these systems are applied in a non-logical domain.

It falls apart in two sub-questions: one about meta-logical properties, the other about general properties.

Meta-logical properties

On this topic, too, there was a noted discrepancy between the possible positions identified above, viz., 'always', 'never' and 'sometimes', and the actual positions that the interviewees hold. No-one was of the opinion that meta-logical properties are always relevant, nor did anyone categorically hold the position that they never matter.

1. As we shall see in chapter 3 this position correlates with career stage.

So, all interviewees thought that meta-logical properties matter sometimes. However, but there is a meaningful distinction to be made between two (sub)positions:

1. Depending on the domain of application: 7 [A,B,C,G,H,I,K]
2. Almost never: 4 [D,E,F,J]

The view that the relevance of meta-properties is domain-dependent was shared by the majority of the interviewees (seven out of eleven). Some of them also singled out certain properties as relevant only for logic, not for application. As interviewee A stated:

I feel that completeness is more the logicians' hobby. We feel we have to find out whether the logic is complete or incomplete.

In their responses, the majority of interviewees linked relevance of these properties mainly to considerations concerning practical utility of logical systems exhibiting them. For example, several interviewees [A, B, C] mentioned model checking as an example of a meta-logical concept that is being effectively integrated into real-world computational tools. And where those tools are relevant, so is the meta-logical property.²

Then there was a substantial minority of four interviewees who denied that meta-logical properties of logical systems are relevant to their application in other domains. They may be of interest to the logician, but from the perspective of the application they do not matter.

It is interesting to observe that within the group of interviewees taking up position 1, there were three [C,I,K] who relativized the importance of meta-logical properties further. Not only is it domain-dependent, it is also secondary to the primary task of faithful modelling the phenomena by means of logical tools. A final observation concerns the question of additional meta-logical properties. The question about the relevance of meta-logical properties mentions the standard properties of completeness and decidability as examples. (Cf., appendix A.3). One interviewee, [B], observed that the application domain not only determines which standard meta-logical properties are relevant in that domain, but that it also may require the formulation and development of new meta-logical properties.

Key observations:

1. The importance of standard meta-logical properties of logical systems is by and large *internal* to logic, not to application
2. External relevance is *limited* to specific properties for specific applications

2. One interviewee [I] links this explicitly to the application domain:

I define a formal language, then I implement a model checker. And that's fine and I don't even need to know whether my logic is decidable. I don't need to have an axiom system proving soundness and completeness. I just need a model checker. That's what they do in verification.

Other properties

The second part of the question about the relevance of properties of logical systems concerned more general properties, i.e., not specifically properties of logic, such as simplicity and elegance.³

All three possible positions distinguished above, viz., ‘no’, ‘yes’ and ‘sometimes’, were indeed exemplified by the positions taken up by the interviewees. However, as was to be expected, the reasons for subscribing to a particular position diverged. Also, the lack of specificity of what counts as ‘elegant’ and ‘simple’ complicates the picture.

Two interviewees [A,D] took up the ‘no’ position. According to them simplicity and sundry properties are not relevant when it comes to application, the main reason being that these properties are intrinsic to the way the logicians evaluate their systems:

The logicians care about simplicity and elegance. Simple framework can do a lot. In propositional logic, we say if you can have two connectives that can express what five connectives could do, and then we may prefer those two connectives. If you have three axioms that can prove the rest theorems, then. You don’t want to have more axioms.

What about the other interviewees?

Two interviewees [E,F] maintained that these properties are always relevant. However, in line with was also noted above, the views of other interviewees called for qualification. Thus interviewee E thinks simplicity is always relevant, but not elegance, it being subjective:

As for elegance, that’s more subjective —“Beauty is in the eye of the beholder.” What counts as elegant? That’s an aesthetic question. If something feels right, we call it elegant. If it feels wrong or clumsy, we don’t. Everyone has their own intuition about it, and those intuitions may differ. Elegance is a subjective matter, so it’s hard to define precisely.

There were three interviewees [B,K,C] who also regard them as always relevant, i.e., independent of application domain, but only because these properties have a practical value, not an intrinsic one. A logical system that is simple and surveyable is easier to explain and thus has a higher chance of uptake, by aspiring logicians and by non-logicians working in the application domain.⁴

3. ‘...and surveyability.’ In designing the interview questions, we initially expected that logicians would exhibit the same attitude toward all such properties. Accordingly, the original plan was to select one or two of these properties to include in the interviews. However, it turned out that only those who emphasise accessibility of a system for students and researchers expressed the kind of nuanced and differentiated attitudes we anticipated. While all participants were asked about simplicity and elegance, only two were asked about surveyability. For this reason, our analysis of actual positions focuses on simplicity and elegance.

4. The importance of simplicity in teaching is worded by interviewee K as follows: :

So that might be like a really practical reason for elegance, like students won’t want to take this if it’s not a nice thing to work with, and therefore, you won’t develop as quickly, and it won’t be as applied as well.

And then there were three interviewees who linked the relevance to specific properties: simplicity [G,K] and elegance [H,K].

Thus, we can summarise the actual positions on this issues as follows:

1. No: 2 [A,D]
2. Yes: 7 [B,C,E,F,I,J,K]
 - 2.1 always, without qualification: 4 [E,F,I,J]
 - 2.2 always, but because of practical relevance: 3 [B,C,K]
3. Sometimes: 2 [G,H]

Key observations:

1. The non-logical nature of the properties in question is a key element in the reasons for taking up a particular, both negative as well as positive
2. The relevance of non-logical properties is *not* tied to application domains

Pluralism

Pluralism is a key feature of modern logic. For the working logician there is not one, single system of logic that they work with, there is a variety of logical systems that they construct, study, apply.

Pluralism expresses itself in at least the following two dimensions: there is variety in expressiveness and there is variety in what is expressed. The first is exemplified by, e.g., propositional logic and first-order logic, or by tense logic and epistemic logic. It is the language and its interpretation⁵ that determine what can be expressed by a particular logical system. The other type of variety is exemplified by different interpretations of the same language: for example, classical propositional logic versus intuitionistic propositional logic, or para-consistent logic. Here is the interpretation that varies, the language stays the same.

These are two distinct ways in which logics may differ, and thus two ways in which we can look at the question of pluralism. In our formulation of the issue we did not explicitly distinguish them, i.e., we did not ask the question twice, once for each of these two ways in which the concept of pluralism of logic can be understood. This has complicated the analysis of the answers of the interviewees. In most cases it was clear which sense of pluralism the interviewees used in their understandings of the question

Uptake by non-logicians is the other practical consideration. Interviewee B views simplicity as a property that eases uptake by non-logicians:

Yes, I definitely think so. And I do believe that these criteria are not particularly domain dependent... And mainly because the more elegant and simpler the characteristics are of the solutions that you're offering, the more widely accepted it becomes.

An even stronger stance is taken by interviewee C, who regards it as a necessary condition:

No matter how you approach logic, philosophers without a logic background will find it too complex and wonder why it can't be analysed in natural language.

5. Which can be model-theoretic, proof-theoretic, algebraic, and so on

and their answers. In some cases this was not completely straightforward and we had to rely on other material to determine what concept of pluralism was being applied.

Finally, we should note that the issue of pluralism was addressed at two distinct junctures: by asking the questions ‘Does the application fix a unique logic?’ and by asking interviewees to respond to thesis A, which reads: ‘Pluralism of logics can only be motivated by pluralism of application domains, i.e., fixing the application domain entails fixing the logic of that domain.’ These two ways of addressing the issue are obviously related, as is also testified by the answers that were given. More on that below.

After this clarification of the situation let’s return to the answers that the interviewees gave to the questions ‘Does the application fix a unique logic?’ Note that this is *not* a question about pluralism per se, in either sense distinguished above. It is a question about application areas in relation to logical pluralism: if we apply logic in a certain domain, does that domain by itself force the application of a a unique logic?

The positions that we found in the answers of the interviewees were the following:

1. Yes, the application determines the logic: 2 [G,J]
2. No, certain applications allow different logics: 6 [A,B,C,D,F,K]
3. No opinion: 2 [H,I]

In addition, one interviewee [E] rejected the question. This rejection was based on the interviewee’s conviction that there is no substantial pluralism when it comes to logic. Worth noting is also that one interviewee who answered ‘No’, pointed out that because in the end many logics can be formulated as particular first order systems the issue of pluralism is more a matter of convenience than of principle [A].

A similar observation regarding ‘convenience’ was made by one of the interviewees who answered ‘Yes’ and who qualified the answer by noting that although the application domain does indeed have a unique logic, as a matter of fact it may take logicians substantial time to determine what that logic is and in the meantime different logics can be used to highlight different perspectives.

As for the perspectives on pluralism that have informed the answers of the interviewees, we will get back to that in detail in chapter 4.

Key observations:

1. The pluralism that is characteristic for modern logic informs the view of a majority of logicians that an application domain does not determines its logic
2. Only natural language appears to qualify as an application that can determine a unique logic

Nature of application areas

This issue was concerned with the question whether application of logic is different in different types of domains. We proposed a distinction between:

- a priori sciences, such as mathematics and philosophy
- empirical sciences, such as linguistics, cognitive science, physics
- ‘mixed’ sciences, such as computer science, that have both a strong a priori component as well as an applied one

The actual positions were as follows:

Positions

1. Yes: 5 [A,B,D,H,I]
2. Yes, but not principled ones: 4 [C,F,G,J]
3. No: 2 [E,K]

As noted in the previous section, we expected that responses might vary with specific disciplines within these three broad areas. However, this was not the case.

In fact there is a lot of consensus here, given that the question of whether a difference is ‘principled’ or not was not the easiest to answer. If we disregard that qualification for a moment, we see that 9 out of 11 of our interviewees answered this question positively.

That being said, the motivations that were given were quite distinct and covered a variety of ways in which disciplines can differ. For example, one interviewee, [A], focussed on the function of logic in various domains, noting that logic helps philosophers formulate ‘rigorous arguments’, whereas in computer science it is part of the very foundations of the discipline.⁶ The latter observation also informed the perspective of interviewee B. This is a principled difference in so far as logic in computer science is considered to be part of the subject matter of the discipline whereas logic in philosophy really serves a different function.

What is interesting to note is that none of the interviewees seem to consider logic as *part* of philosophy, not even that part that is called ‘philosophy of logic’.

The main reason for interviewees to state that there are differences but that these are not principled ones have to do with a focus on what the differences means for logic and its application in these different domain. For example, interviewee [I] notes that even though it makes a difference whether one has to deal with empirical data (as, e.g., in cognitive science or in linguistics) or not (as, e.g., in philosophy or in mathematics), this does not fundamentally change the role that logic plays when it is applied in these different domains.

The two interviewees that do not see a difference do so because they reject the idea that there are differences between, e.g., a priori and empirical disciplines, or between empirical and hybrid ones. Interviewee [E] expresses this with regard to mathematics as follows:

6. This interviewee also brought in an historical perspective, noting that application modern logic started out in mathematics and philosophy and over time branched out to other disciplines, such as linguistics and cognitive science.

[Mathematics] comes from experience, but is highly abstracted. Of course, some people take these abstractions and generate useful concepts from them – that’s true. But originally, where did those ideas come from? They come from real-world experience.

The other interviewee, K, has a similar view with regard to philosophy:

And then it’s really only in the twentieth century, when philosophy took on this character in many corners of the world, of, you know, kind of just sitting in the armchair and just thinking really hard. Even people who are associated with that idea such as Descartes, they didn’t do that. They were thoroughly engaged in the sciences.’

And the interviewee then goes on to state: ‘Well, actually, I don’t know that I endorse any of the distinctions.’

According to these interviewees logic plays the same role everywhere where it is applied. As interviewee E states:

Our logic shouldn’t be shrouded in any mysterious veil. It is simply the work that ensures the correctness of our thinking. Because you need to gradually guide people working in the application domain to improve their logical thinking or literacy.

The other interviewee, K, who also takes up this position likewise thinks logic basically operates in the same way.

Key observations

1. A large majority holds that differences in the nature of disciplines makes a difference when it comes to application
2. Those that do not think that it makes a difference base this on a rejection of the distinction between empirical and a priori sciences (and *a fortiori* the concept of a mixed science).

Thesis A

Thesis A reads as follows:

Pluralism of logics can only be motivated by pluralism of application domains, i.e., fixing the application domain entails fixing the logic of that domain

Obviously, Thesis A is closely related to the question concerning pluralism and application that was asked earlier, viz.:

Does the application domain fix a unique logic?

In fact, this question being a yes/no one, positive and negative answers to it correspond to agreement/disagreement to the thesis. Therefore, one would expect that the answers to the question and the responses to the thesis would correlate. If one holds that application fixes a unique logic one would be expected to agree with Thesis A, and if one given a

fixed application still maintains pluralism as an option, then one would be expected to disagree.

That, however turned out not to be the case. There were two interviewees who agreed that the application domain determines a unique logic, yet no-one agree with Thesis A. Also, where there were two ‘abstainers’ on the first issue, i.e., interviewees who did not express an opinion on it, they, too, changed course vis à vis Thesis A. As a consequence, everyone rejected it:

Positions

1. Yes: 0
2. No: 11 [A,B,C,D,E,F,G,H,I,J,K]
3. No opinion: 0

The reasons for this change in stance are not immediately clear. One could conjecture that it is Thesis A being worded as a *thesis* that somehow ‘forced’ the interviewees to take an unambiguous stance, where the question being a question invited more nuanced responses, even though it is a yes/no question. This would suggest that the interviewees who stated in answer to the question that the application fixes its logic still had some reservations as to the motivation of their answers. The interviews provide some evidence for this conjecture.

For example, interviewee G, who answered the question positively yet disagreed with Thesis A qualified his positive answer by making a distinction between ‘in theory’ and ‘in fact’. This interviewee did hold that the application domain in theory fixed its logic but added that in practice, i.e., in actually doing research, this unique logic is not what is being used. The main reason this interviewee gave was that actual research proceeds stepwise and that different steps, when one is dealing with different aspects or with sub-questions or where one is building on results obtained so far, might require a different logic. This is a kind of ‘monism in theory, pluralism in practice’ stance. The wording of Thesis A then triggered a focus on the practice, rather than on the theory.

A similar switch from ‘in theory’ to ‘in practice’ seems to be what explain the different answers of interviewee H, who expressed no opinion on the question but disagreement with the thesis. This interviewee emphasised that logical pluralism is not, or cannot, always be motivated in terms of application domains. An important motivation for taking a pluralistic stance is the view that when one applies logic one is not *directly* driven by application-related concerns, but much more by an interest in identifying what this interviewee called ‘interesting play areas’ in various domains, i.e., areas where logic might offer insights. This rejects the focus on application domain as overly restrictive, while retaining the core link between pluralism and contextual relevance.

Another interesting view is that of interviewee K, who answered ‘no’ in both cases but pointed out that in fact the answer (also) depends on how one looks at logic as such. This interviewee noted that diversity in logic may have different sources. One can take a metaphysical stance and start from the concept of logic as related to the way things, at

bottom, are. This tends to favour monism. Or one can be more practical and application-oriented and that naturally leads to pluralism.

As we shall see in chapter 4 one's view on the nature of logic itself is an important distinguishing factor.

Key observations:

1. When considering the *practice* of application to logic the consensus is that pluralism is a fact
2. Monism functions only as a theoretical possibility and only for a small minority

Thesis B

Like Thesis A, Thesis B also is closely linked to a question that was already put to the interviewees when they were asked whether they agreed or disagreed with this thesis, which reads as follows:

Meta-properties of logics (such as decidability, completeness, ...) provide necessary criteria for successful applications

The question posed earlier on this topic was, again, a yes/no question: 'Do meta-logical properties matter for application?'. But this question is more open: there are more ways to matter than just being necessary. So more discrepancy between the answers given to the question and the positions taken up with respect to Thesis B could be expected. And this is what we found.

There were seven interviewees according to whom it really depends on the domain of application whether meta-logical properties matter, and four who stated that it almost never did. But for Thesis B, which formulates a stronger view, there was almost unanimity:

Positions

1. Yes: 1 [B]
2. No: 10 [A,C,D,E,F,G,H,I,J,K]

If we look at the motivations there were given for the responses to the question we can see why almost every interviewee disagreed with Thesis B. The considerations of the interviewees that underwrote their position that meta-logical properties matter were overwhelmingly of a practical and contextual nature: Where a particular property, e.g., decidability, matters for a particular application it is relevant, otherwise it is not. From that perspective it is perfectly reasonable to at the same time disagree with Thesis B.

The one interviewee who agreed with Thesis B, viz., B, has a much broader perspective on the range of meta-logical properties that one could take into account, emphasising the need to develop new notions in conjunction with application. That, it appears, informs the agreement of this interviewee with Thesis B.

Key observations:

1. Standard meta-properties have at best contextual, i.e., domain-dependent relevance according to the large majority

Thesis C

Thesis C reads as follows:

The application of a logic in a non-logical domain can contribute to clarification, but by itself does not constitute explanation.

And this is what we got:

Positions

1. Yes: 4 [D,E,H,I]
2. No: 4 [A,C,F,J,K]
3. No opinion: 3 [B,G]

That is quite a spread, one that suggests real diversity of opinion. But appearances may deceive here.

As was already noted in section 2.2 we need to keep in mind the possibility that not everyone understands ‘clarification’ and ‘explanation’ in the same way. Specifically, and this is what is illustrated by a number of responses, most interviewees do not use these terms as indicators of *disjoint* concepts, but rather as referring to distinct ones.⁷ This is evident from the motivations provided by interviewees, both of some who answered ‘No’ as well as some who answered ‘yes’.⁸

If we take into account that interviewees do not necessarily construct the concepts as disjoint and interpret the motivations they give for their answers, we see that most interviewees do make a distinction between clarification and explanation but as distinct rather than disjoint concepts. These interviewees see clarification and explanation as distinct but closely related concepts, with various connections: clarification and explanation, though distinct, cannot be separated. From such a perspective rejection of Thesis C is justified. And in that sense, there is actually more agreement with Thesis C than the distribution of yes/no answers shows.

Many interviewees see clarification as an integral part of explanation. For them the clarification that results from logical analysis is often a necessary condition for finding an explanation. For example, interviewee D states:

... [a good application of logic] helps clarify the issue. That’s in itself not explanation, but maybe it’s necessary for explanation.

Obviously, this assumes that clarification and explanation, though distinct, are intimately related.

7. We use ‘disjoint’ to characterise concepts with no overlap, and ‘distinct’ as ones that do overlap but are still different.

8. The wording of the thesis may have played a role here, although the ‘by itself’ does separate clarification from explanation, since that phrase makes sense only if the two are minimally *distinct* concepts.

And then there are some interviewees who maintain that application of logic is an important factor in creating a space of possible explanations. As on interviewee, B, put it:

Logicians bringing in logic helps in asking new questions, and I think the value of asking new questions is extremely important.

So, it clarifies in that sense. It adds to explanations as well, because there are certain explanations that you never thought, that you never looked for.

Only a few of the interviewees claim that the clarification of concepts, problems, possible solutions that is the result of the application of logical tools in and of itself amounts to an explanation of a particular phenomenon.

Others go even further and claim that in some cases clarification *is* providing explanation, at least partially. Interviewee K expresses it as follows:

...absolutely giving a logical framework could be an explanation, it could be explanatory. [...] basically, it focuses [...] [a] person's attention on the right things. So, there's like the kind of essence of the phenomenon, and a logical framework can focus your attention on the essence of the phenomenon [...] And all I mean by essence of phenomenon is good explanation.

But for yet others that does not mean that the explanation provided by logic is necessarily acceptable by experts in the application domain. For example, interviewee A states:

If you have a clarification, you already provide some explanation. Whether the explanation is acceptable to some people is another issue, but you've already made a case.' [...] I've clarified the issue, and I've provided my explanation.

Key observations:

1. Clarification and explanation are considered to be distinct but also closely related
2. Thus, the large majority of the interviewees regard the clarification brought about by the application of logic as an integral part of the explanation of phenomena in the application domain

Chapter 3

Quantitative analysis

As illustrated in the previous chapter, section 2.3, the actual positions on the questions are often more diverse than is accounted for in the abstract overview of possible positions. Moreover, even when the same positions are held by different interviewees, the motivations behind these positions often vary.

However, behind this diversity of perspectives we can discern some commonalities and systematic relationships. In this chapter and the following one we try to bring some of these out. This chapter will look at the data from a quantitative point of view. In chapter 4, we will analyse two specific issues, pluralism and the nature of logic, in a more qualitative manner.

In what follows we will examine the following correlations: between responses and disciplinary backgrounds; between responses and career stage; and between responses and application area experience.

To facilitate a more efficient overview of these correlations, we start with an overview of the interviewees' backgrounds – specifically their career stage, disciplinary backgrounds, and application areas, – along with the actual positions analysed in section 2.3.

Before we start a word of warning is in order. Because of the small sample size a reliable quantitative analysis is not possible of course. So what follows should be read as very tentative.

3.1 Background information

This section provides information about the academic backgrounds of the interviewees. It lists the career stage they were in at the time of the interview (table 3.1), their disciplinary backgrounds (table 3.2), and the application area(s) they have worked in (table 3.3).

Career stage

Let us start with a look at the career stage of the interviewees. For determination of the career stage we have used the following definitions:¹

- early career: eight years or less since PhD
- mid career: between nine and sixteen years since PhD
- late career: more than fifteen years since PhD

Table 3.1: Career stage

	A	B	C	D	E	F	G	H	I	J	K
Early career			✓							✓	
Mid career	✓								✓		✓
Late career		✓		✓	✓	✓	✓	✓			

Academic backgrounds

The following table lists the disciplinary backgrounds of the interviewees, as indicated by them in the interviews:

Table 3.2: Disciplinary backgrounds

	A	B	C	D	E	F	G	H	I	J	K
Philosophy	✓		✓	✓		✓		✓		✓	✓
Mathematics				✓	✓	✓	✓				
Physics				✓							
Engineering		✓									
Computer science									✓		
Linguistics										✓	

What is notable here is that the majority of interviewees (eight out of eleven) have a ‘single’ disciplinary background. Two interviewees have a background in philosophy and mathematics (of which one also in physics), one in philosophy and linguistics.

The ratio of ‘hard’ sciences (mathematics, physics computer science, engineering, computer science) backgrounds to ‘soft’ sciences (philosophy, linguistics) ones is quite balanced: seven ‘hard’ to eight ‘soft’. So the nature of the academic background, ‘hard’ or ‘soft’, does not matter, one can come to logic from both.

That being said, another observation that is vindicated by these data is that mathematics and philosophy remain the two main gateways to logic. There is only interviewee who

1. These definitions align with how many funding organisations define career stages in their application schemes.

has neither as their background discipline and they come from computer science, which is closely related to mathematics.

In view of the history of modern logic this may not come as surprise. However, it stands in stark contrast with the much larger spread of disciplines in which logic is being applied, as is shown by the data in table 3.3 below. This suggests that despite the relevance and success of its applications in these areas logic has not yet found a place of its own in the respective curricula.

Application areas

Table 3.3: Application areas

	A	B	C	D	E	F	G	H	I	J	K
Philosophy	✓		✓	✓		✓		✓		✓	✓
Mathematics		✓		✓	✓						
Computer sciences		✓		✓					✓		✓
Linguistics				✓		✓	✓	✓		✓	✓
Cognitive sciences				✓							✓
Social sciences ²	✓			✓		✓					
Artificial intelligence	✓								✓		✓

First a note. As is shown by the data in table 3.2 a substantial number of logicians are also philosophers. However, by linking an interviewee with philosophy as (one of) their application area(s) we mean something more specific, viz., that they have been involved in the application of logic to some *non-logical area* in philosophy, such as epistemology, ethics, and so on.

If we compare the disciplines listed in table 3.2 with those mentioned in table 3.3, we note that engineering and physics are academic backgrounds but not application areas. And artificial intelligence, social sciences and cognitive sciences are application areas but not academic backgrounds.

With two exceptions, all interviewees have worked on applications of logic in at least one area of their own academic background. The exceptions are the one interviewee who has engineering as their background and one of the interviewees with mathematics as their background. The first one worked on application of logic in ‘hard’ areas related to engineering, viz., mathematics and computer science. The second one, however, ‘switched’ from ‘hard’ (mathematics) to ‘soft’ (linguistics).

When we compare career stage and disciplinary backgrounds to application areas we can see that early career stage interviewees stay close to, and often remain restricted to their disciplinary background as application areas. This is as expected.

². This includes works in which logic is applied to economics, social-network, etc.

3.2 Summary of responses

Table 3.4 summarises the responses of the interviewees to the questions asked, and table 3.5 does the same for the responses to the three theses.

Table 3.4: Summary of responses to questions

	A	B	C	D	E	F	G	H	I	J	K
Ownership											
Logician					✓	✓					
Non-logician										✓	
Joint ownership	✓		✓	✓				✓	✓		
Depends on the goals of the project		✓									
Depends on how the project was initiated							✓				✓
Meta-logical properties											
Depending on the domain of application	✓	✓	✓				✓		✓		✓
Almost never				✓	✓	✓		✓		✓	
Other properties											
No	✓		✓	✓							
Yes		✓			✓	✓				✓	✓
<i>Always, without qualification</i>					✓	✓					
<i>Always, but because of practical relevance</i>		✓									✓
Sometimes							✓	✓			
No position									✓		
Pluralism											
Yes, the application determines the logic							✓			✓	
No, certain applications allow different logics	✓	✓	✓	✓		✓		✓	✓		✓
No opinion					✓						
Nature of application area											
Yes	✓	✓		✓				✓	✓		
Yes, but not principled ones			✓			✓	✓			✓	
No					✓						✓

Table 3.5: Summary of responses to theses

	A	B	C	D	E	F	G	H	I	J	K
Thesis A³											
No	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

3. Thesis A: Pluralism of logics can only be motivated by pluralism of application domains, i.e., fixing the application domain entails fixing the logic of that domain

	A	B	C	D	E	F	G	H	I	J	K
Thesis B⁴											
Yes		✓									
No	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Thesis C⁵											
Yes				✓	✓			✓	✓		
No			✓			✓				✓	
No opinion	✓	✓					✓				✓

3.3 Correlations

In this section we discuss some key correlations between answers to various questions, academic backgrounds, application areas, and career stage. Of course, part of that is also to note where expected correlations actually do not appear to be substantiated by the data.

At this point it is perhaps good to note once more that the size of our sample is small and its representativeness low. So, whatever correlations we may see in this data set might very well disappear in a larger and more representative one.

Be that as it may, we do think there are some interesting observations to be made here, that might form the basis for a more comprehensive survey.

We look at correlations between responses to various questions and:

- disciplinary backgrounds
- application areas
- career stage

In the chapter 4 we give a qualitative analysis of two, closely connected, topics:

- pluralism
- the nature of logic

3.3.1 Disciplinary backgrounds

Sticking for the moment with the distinction between ‘hard’ and ‘soft’ disciplinary backgrounds, as circumscribed above, the question here is whether that distinction shows up in the responses to the various questions.

4. Thesis B: Meta-properties of logics (such as decidability, completeness, . . .) provide necessary criteria for successful applications

5. Thesis C: The application of a logic in a non-logical domain can contribute to clarification, but by itself does not constitute explanation

We use a slightly different classification here than we did above, because we want to separate out those interviewees with both a hard and a soft background. So we distinguish between interviewees:

- with a ‘hard’ background: B, E, G, I
- a ‘soft’ background: A, C, H, J and K
- and a mixed’ one: D, F

Ownership

Let us start with the responses to the question of ownership. Table 3.6 shows how the various responses we found were distributed over the three types of backgrounds:

Table 3.6: Background and ownership

	Hard	Soft	Mixed
Ownership			
Logician	1		
Non-logician	0	1	
Joint ownership	1	3	1
Depends on the goals of the project	1		
Depends on how the project was initiated	1	1	1

There is marked difference between interviewees with a hard or mixed background and interviewees with a soft background: the latter tend to favour the idea that application of logic in another domain is a matter of joint ownership, in the other groups no distinct preference can be discerned.

One possible explanation of the difference might reside in the nature of the backgrounds. Recall that except for one, all interviewees that are in the soft-group, have a ‘single’ background in philosophy. And these interviewees are all of the opinion that application is a matter of joint ownership. The other interviewee also has a background in linguistics and is of the opinion that ownership resides with the non-logician. Apparently, being trained solely in philosophy sets one up for viewing application as a collaborative enterprise. That might very well reflect the special position of philosophy: as an academic discipline its identity is not defined by its subject matter, but rather by the fact that it reflects on the subject matters of other disciplines, which makes it ‘inherently collaborative’.

Meta-properties

Next up are correlations between background and response to the question about the relevance of meta-properties:

Table 3.7: Background and meta-properties

	Hard	Soft	Mixed
Meta-logical properties			
Depending on the domain of application	3	4	
Almost never	1	1	2

No remarkable differences here, except perhaps that the interviewees with a mixed background agree that meta-logical properties almost never matter, whereas in the other groups the majority is of the opinion that it depends on the domain of application. It is not obvious what might explain the difference, if it needs explanation to begin with, because of the very small size of the mixed-background group.

Other properties

Do views on the relevance of properties such as elegance and simplicity correlate with academic background? Table 3.8 supplies the answer:

Table 3.8: Background and other properties

	Hard	Soft	Mixed
Other properties			
No		2	1
Yes	2	2	1
<i>Always, without qualification</i>	1	1	1
<i>Always, but because of practical relevance</i>	1	1	
Sometimes	1	1	
No position	1		

There is a moderate difference here between the soft- and mixed-groups and the hard-group in that half of the interviewees in first two groups state that properties such as elegance and simplicity do not matter, while no-one in the hard-group is of that opinion.

What might explain this difference is not immediately obvious.

Pluralism

Table 3.9 shows how the three answers to the question of pluralism were distributed over the three academic backgrounds:

Table 3.9: Background and pluralism

	Hard	Soft	Mixed
Pluralism			
Yes, the application determines the logic	1	1	
No, certain applications allow different logics	2	3	2
No opinion		1	
No answer	1 ⁶		

We will dive into pluralism and application more deeply in chapter 4, but this makes clear that, perhaps contrary to expectations, there are no correlations between the interviewees' backgrounds and their views on the matter.

Nature of application area

The last question was whether there were differences in the application of logic to areas of a different nature. The distribution of answers is given in table 3.10:

Table 3.10: Background and nature of application area

	Hard	Soft	Mixed
Nature of application area			
Yes	2	2	
Yes, but not principled ones	1	2	1
No	1		1

There is substantial agreement here, independent of background. Certainly if we lump the 'yes' and 'yes, but not principled' answers together.

Theses

A quick look at table 3.5 shows that there are no correlations to be found between academic background and answers to thesis A and thesis B: unanimity does not allow for differentiation.

The answers to thesis C were more varied and thus could show correlation. They are linked to the interviewees' backgrounds in table 3.11:

6. Recall from section 2.3 that there was one interviewee [E] who rejected the question. This rejection was based on their monistic view of logic as such.

Table 3.11: Background and nature of application area

	Hard	Soft	Mixed
Thesis C			
Yes,	2	1	1
No		1	1
No opinion	2	3	

As the data show, there is hardly any difference between the ways in which answers vary between the interviewees who share their background.

Summary: the role of academic background

In summary, we can conclude that academic background

- has a distinct influence on one's attitude towards ownership
- makes a difference for how one views the importance of 'non-logical' meta-properties
- is irrelevant for one's views on the relevance of meta-logical properties, on pluralism, or on the differences between application areas
- does not play a role in responses to theses A, B, or C

3.3.2 Career stage

Ownership

We start again with ownership and look at the responses given by interviewees in different career stages, as listed in table 3.12:

Table 3.12: Career stage and ownership

	Early	Mid	Late
Ownership			
Logician			2
Non-logician	1		
Joint ownership	1	2	2
Depends on the goals of the project	1		1
Depends on how the project was initiated		1	1

These data do not show any strong correlations. But it is interesting to note that the two interviewees who responded that ownership belongs to the logician are late career stage researchers. This might reflect a remnant of early training, but it could also signal a shift over time in the way in which the application of logic to a non-logical domain is conceived over the development of one's career. The latter is reinforced by the observation that the only response that assigns ownership to the non-logician comes from an early career researcher.

Meta-logical properties

Table 3.13 summarises the responses to the question about the relevance of meta-logical properties per career stage:

Table 3.13: Career stage and meta-properties

	Early	Middle	Late
Meta-logical properties			
Depending on the domain of application	1	3	2
Almost never	1		4

There appears to be a correlation between being a late career researcher and being somewhat sceptical about the relevance for application of standard meta-logical properties.

The explanation of the distribution that we see here that suggests itself is that more experience with a variety of cases engenders a more nuanced position on this matter. The data in table 3.4 provides some support for this conjecture.

Other properties

The next table, 3.14, gives an overview of the positions held on the question about the relevance of more general properties, such as simplicity or elegance, relative to career stage:

Table 3.14: Career stage and other properties

	Early	Middle	Late
Other properties			
No	1	1	1
Yes	1	1	3
<i>Always, without qualification</i>			2
<i>Always, but because of practical relevance</i>		1	1
Sometimes			2
No position		1	

Appreciation of the importance of such properties as simplicity and elegance apparently tends to grow with career stage. The explanation might be that these interviewees have more experience with the factors that determine effective uptake of the results of application of logic to a non-logical domain by the practitioners in that domain.

Pluralism

The various positions with regard to pluralism have been described in some detail in section 2.3. There we concluded that for the majority of the interviews the pluralism of

modern logic implies that application domains do not determine a unique logic. As the data in table 3.15 show, career stage is not a differentiating factor:

Table 3.15: Career stage and pluralism

	Early	Middle	Late
Pluralism			
Yes, the application determines the logic	1		1
No, certain applications allow different logics	1	2	3
No opinion		1	1
No answer			1 ⁷

Leaving that aside, we see that pluralism is more or less the shared position throughout the various career stages.

Nature of application area

Distribution of answers to the question about differences between application areas over career stage are given in table 3.16:

Table 3.16: Career and nature of application area

	Early	Middle	Late
Nature of application area			
Yes	2	1	3
Yes, but not principled ones		1	2
No		1	1

No obvious correlations to be noted here.

Theses

Again, the only thesis where there could be correlations in the responses is thesis C:

7. Cf., above, footnote 6.

Table 3.17: Career and thesis C

	Early	Middle	Late
Thesis C			
Yes		1	2
No	2	1	2
No opinion		1	2

Middle and late career interviewees are divided: an equal number of them agree, disagree, and have no opinion. Early career interviewees unanimously disagree, but the small sample size does not really warrant any firm conclusions on this point.

Summary: the role of the career stage

In summary, we can conclude that:

- late career stage researchers are more inclined to ascribe ownership to the logician, rather than the non-logician
- late career stage researchers tend to have a more nuanced view on the relevance of meta-logical properties for applications in non-logical areas and also attach more importance to non-logical properties
- career stage makes no differences for one's views on ownership, on pluralism, or on the differences between application areas
- and career stage also does not play a significant role in responses to theses A, B, or C

3.3.3 Application area

Let us now look at correlations between the application areas in which interviewees work, or have worked, and their responses to the questions and the theses. Like in the case of the academic backgrounds of interviewees we look for correlations not at the level of individual disciplines, but at a higher level of aggregation. So we use more or less the same division of application areas in 'hard' and 'soft' as we did in characterising the academic backgrounds of the interviewees. We do it with those areas that did not figure in anyone's background but that interviewees did work in:

- hard: mathematics, computer science, artificial intelligence
- soft: philosophy, linguistics, cognitive sciences, social sciences

In some cases interviewees worked only in soft or hard applications areas, but there were also some that worked in both, as can be seen in the overview of application areas given in table 3.3. Using now 'hard', 'soft', and 'mixed' to refer to these three groups leads to the following classification of interviewees:

- Hard: B, E, I
- Soft: C, G, H, J
- Mixed: A, D, F, K

Ownership

We start again with ownership. Table 3.18 gives an overview of the interviewees' responses linked to the application area(s) that they have experience with:

Table 3.18: Application area and ownership

	Hard	Soft	Mixed
Ownership			
Logician	1		1
Non-logician		1	
Joint ownership	1	2	2
Depends on the goals of the project	1		
Depends on how the project was initiated		1	1

There are no clear correlations here, the various positions are more or less equally distributed among interviewees with hard, soft and mixed experience.

Meta-properties

Let us now take a look at the distribution of answers to the question about the relevance for application of standard meta-logical properties, as laid down in table 3.19:

Table 3.19: Application area and meta-properties

	Hard	Soft	Mixed
Meta-properties			
Depending on the domain of application	2	2	2
Almost never	1	2	2

Clearly the stance one takes on this issue is not linked to the kind of area one has experience with: whether it is with applying logic in a hard area, a soft, area or both kinds of areas, the distribution of answers is equal.

Other properties

How is that with other properties, such as elegance and simplicity? Do answers here correlate with the kind of experience one has had? The data can be found in table 3.20:

Table 3.20: Application area and other properties

	Hard	Soft	Mixed
No		1	2
Yes	2	1	2
<i>Always without qualification</i>	1	1	1
<i>Always but because of practical relevance</i>	1		1
Sometimes		2	
No position	1		

There appears to a slightly stronger correlation between experience with hard application areas and a positive answer than between experience with soft areas. Experience with mixed areas gives is split. One could venture that if the views of interviewees with mixed experience were to be split out between hard and soft, this connection might be stronger.

This correlation is not entirely unexpected: notions of elegance and simplicity seem to have a stronger foothold in areas such as mathematics and theoretical computer science where formal proof plays an important role.

Pluralism

The data concerning the issue of pluralism as separated out according to hard, soft and mixed experience can be found in table 3.21:

Table 3.21: Application area and pluralism

	Hard	Soft	Mixed
Pluralism			
Yes, the application determines the logic		2	
No, certain applications allow different logics	1	1	4
No opinion	2	1	

The question about pluralism (for the pluralism thesis, cf., below) was answered positively by only two of interviewees. As the data show, this answer correlates with experience in soft application areas. Both experience with hard areas as well as mixed experiences correlate clearly with an opposite point of view.

This seems to point to a difference in what application of logic means in various areas. In soft areas it is, – perhaps, but this clearly would need further investigation– , more a descriptive than an analytic process. from that perspective the view that the application determines the logic makes more sense.

Nature of application area

The last question concerned the nature of the application area. Whether there are any meaningful correlations with the interviewees' experiences with various types of application areas should appear from the data in table 3.22:

Table 3.22: Application area and nature of application area

	Hard	Soft	Mixed
Nature of application area			
Yes	2	1	1
Yes, but not principled ones		3	2
No	1		1

Only two interviewees were of the opinion that there were no differences between application areas of a different nature. Their experience is with hard and mixed areas, respectively. One might venture that the latter interviewee bases their negative answer on experience with hard areas. And that would support a mild correlation between hard experience and a negative answer. However, given the small numbers this remains rather speculative.

Theses

And again, the only thesis where there could be correlations in the responses is thesis C. Here are the data:

Table 3.23: Application area and thesis C

	Hard	Soft	Mixed
Thesis C			
Yes,	2	2	1
No		1	2
No opinion	1	1	1

The lack of a 'no' answer among the interviewees with experience in hard areas should be noted, but in view of the sample size it is hard to draw any firm conclusions from this.

Summary: the role of the application area

We can summarise these findings as follows:

- hard experience favours a positive view on the relevance of properties such as elegance and simplicity

- soft experience correlates with a positive view on whether the application determines its logic
- differences in experience do not correlate with different views on ownership, relevance of meta-logical properties, or the nature of the application area, nor with thesis C.

3.4 Conclusions

What we said at the beginning of this chapter deserves repeating: given the small sample size any conclusions drawn on the basis of these data should be regarded as very preliminary. Nevertheless a quantitative look at the data is informative, as it suggests possible connection between various parameters that may be worth investigating further using a much larger and more representative set of respondents.

At the end of the various sections we briefly summarised the main conclude with regard to potential correlation between various parameters and the responses given by the interviewees. The most interesting one' appear to be the following:

- academic background shapes attitude towards ownership: a background in philosophy or a humanities discipline predicts a more co-operative stance
- late career stage predicts a more nuanced view on the relevance of meta-logical properties and more importance attached to non-logical one
- experience with application in 'soft' areas predicts a positive view on whether the application determines its logic

The analysis of the various actual positions that was given in chapter 2 supplies further data that might serve as a basis for an explanation of these correlations.

Chapter 4

Qualitative analysis: pluralism

The advantage of conducting structured interviews lies in the ability to uncover unexpected perspectives on a range of issues. In chapter 2 we surveyed the diverse positions held by interviewees. And in chapter 3 we explored some correlations between answers and ket features: career stage, academic background, and experience with application of logic in various areas. In almost every case the informativeness of the responses gained enormously from the ability to also have a look at the underlying motivation.

In this chapter we take this a bit further and explore how their views on the nature of logic and on various aspects of its application in a non-logical domain help shape the interviewees' positions with regard to pluralism. Recall that pluralism was addressed at two points in the interviews: as a question, viz. 'Does the application fix a unique logic?' and in the form of Thesis A, viz., 'Pluralism of logics can only be motivated by pluralism of application domains, i.e., fixing the application domain entails fixing *the* logic of that domain.' As we shall see, analysis of the answers to the question and the thesis bring to light a rich variety of meta-level reflections on the application of logic. In what follows we will attempt to systematise them.

Specifically, we begin by identifying three key dimensions that emerged as central to the views of the interviewees as expressed in their responses. Those dimensions define a rich space of possible positions, and we will locate the eleven interviewees within that space. In this way we will chart, not only possible positions but also the intricate relations between them.

The positions discussed in this chapter are reconstructed from the interviews. In some cases, they have not been explicitly articulated by the interviewees themselves, but are reconstructed on the basis of the transcripts. Thus, the positions that we identify cannot be strictly linked with individual interviewees. Therefore, we refrain from associating individual interviewees with them. This choice reflects our aim to highlight how the dimensions we identify shape the interviewees' broader conceptions of the application of logic in relation to pluralism, rather than to focus on the views of particular individuals.

4.1 Three dimensions

As noted previously, ‘logical pluralism’ can mean quite different things, to different people. We distinguished between variety in expressiveness (e.g., propositional logics versus quantificational logics) and variety in what is expressed (e.g., classical logic versus intuitionistic logic). Arguably both play a role in sculpting a space of positions on pluralism. But there are also concerns that relate to considerations about ‘getting things done’ from a practical perspective.

This leads us to distinguish between three dimensions: views on the nature of logic, views on the demands of the application area in which logic is applied, and views on the demands made by the practice of applying logic. We discuss them separately the following sections, and then use them to construe a space of possible positions.

4.1.1 The ontological status of logic

When the question of pluralism is approached from an ontological perspective we find that there are two opposing views. At one end there is the view that there is only one logic. On the opposite end there is the view that multiple logics co-exist. The first view conceives of logic as being constrained by reality to the extent that logic is just this one thing. Per contrast, the second view holds that reality does not impose any constraints and permits multiple logics that co-exist without conflict.



Figure 4.1: Ontological status of logic

In between the two extremes we can find intermediate positions. For example, one could acknowledge both intuitionistic logic and classical logic as bona fide logics because they both have ontological groundings, but in different ontological domains, while at the same time rule out para-consistent logics as ‘not real logic’ because they lack such grounding.

4.1.2 The demands of application

Besides views on the ontological status of logic itself, considerations concerning the nature of the application area that logic is intended to capture may also play a role in determining one’s stance on the issue of pluralism. Again we have two extremes. On the one end there is the position that no matter what the application area is, everything can be done in one logic. On the other extreme we find the view that each application area calls for its own, possibly different logic.

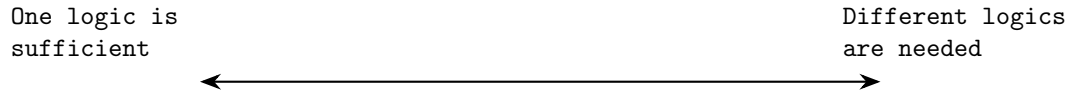


Figure 4.2: Demands of application

Again, there will intermediate positions, that acknowledge differences between application areas, but don't go to the extreme that different logics are needed to adequately capture an application.

Various kinds of considerations may determine one's position on this spectrum. They may concern the ontology of the application area, for example, quantum phenomena in contrast macroscopic phenomena, which may be considered to call for different logics. But one may also have epistemological considerations, that concern variations in the ways reasoning or knowledge is structured and represented. Here one can think of statements about the future, which one could argue call for a many-valued logic to handle questions of (in)determinism, versus statements about the past and present for which two-valued logics would be the suitable instrument.

Note that how one views the demands of a particular application area may also vary. Consider modelling belief structures. One may hold that there exists, in principle, one single logic that is capable of capturing the unique structure underlying beliefs. At the opposite extreme, however, it may be argued that belief structures as such necessitate the employment of distinct logics in order to represent different facets. For instance, agents may reason monotonically in some contexts while engaging in non-monotonic reasoning in others, thereby motivating the application of a plurality of logics within one application area.

4.1.3 The demands of practice

Finally, as was already noted in the discussion of actual positions on pluralism in section 2.3, several interviewees observed that, beyond the above two conceptual dimensions, other considerations are operative when logic is being applied in a non-logical domain. Being engaged in that as a concrete practice comes with its own demands, and as far as pluralism is concerned those demands determine a position on the following scale:

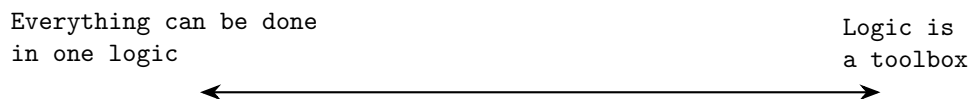


Figure 4.3: Demands of practice

To the left we find the position that everything can be done satisfactorily using one logic. The right endpoint is then motivated by the consideration that, even if, in principle, one could do the job using a single system, in practice the results of doing so may become excessively complex, thereby impeding understanding. Consequently, for practical reasons

different logics are needed to provide complementary perspectives on the same domain. In this sense, logic functions as a ‘toolbox’: one picks a particular instrument that is suited to do a particular job.

4.1.4 Relationships

The three dimensions defined above create a space of possible motivations for taking up a position with regard to pluralism. As we have seen in section 2.3 pluralism is almost universally accepted by our interviewees, but we have also seen there that their motivations differ, often quite substantially. The three-dimensional space aims to capture both resemblances and differences between positions by locating them in this space. But before turning to that there is one more thing to discuss, viz., the relative (in)dependence of the dimensions.

Note that the first two dimensions concern positions on the nature of logic and on the nature of application, respectively. These are more theoretical issues and the positions on these dimensions are therefore motivated from a largely theoretical perspective. The third dimension, however, captures positions that depend on practical considerations.

By and large the practical considerations seem to cross-cut the theoretical ones. For instance, the view that we need a ‘practical pluralism’ because simpler formalisations are generally easier to understand and manipulate, seems to be compatible with a monistic stance on the nature of logic itself as well as with the view that all application can be done in one logic. The only real tension appears to be between the ‘practical’ position that everything can be done in one logic and the view that different logics are needed, one of the extreme of the demands of application dimension.

What about connections between the theoretical dimensions? Here, too, positions on each of them appear to be by and large compatible. For example, the position on the ontological dimension that multiple logics co-exist appears compatible with both extremes on the demands of application dimension. Whether one logic suffices or different logics are needed from that perspective does not make a difference.

But what about the position on the ontological dimension that there is only one logic? Can that be compatible with the position on the demands of application dimension that different logics are needed to capture an application? This really depends on what one takes the latter to imply. If it is read in a ‘as a matter of fact’ manner, there seems to be no conflict. One may hold that a given application determines a single underlying logic, yet also hold that achieving a comprehensive understanding of that application may nonetheless require drawing on multiple logical systems. Unification is possible, yes, but it may not be achievable in practice. It may be a stage that the research never reaches, but that’s fine.

4.2 Positions of interviewees

In this section, we locate the interviewees within the conceptual space defined by the three dimensions introduced above. It is worth emphasising again that our aim is not to provide a detailed interpretation of each interviewee's stance on the three dimensions, but rather to explore how they jointly shape possible perspectives on the application of logic in the context of logical pluralism. We briefly touched on relationships between the three dimensions, but only in terms of their extremes. As we shall see, greater nuance emerges once we consider also intermediate positions.

4.2.1 The sculpted space of positions

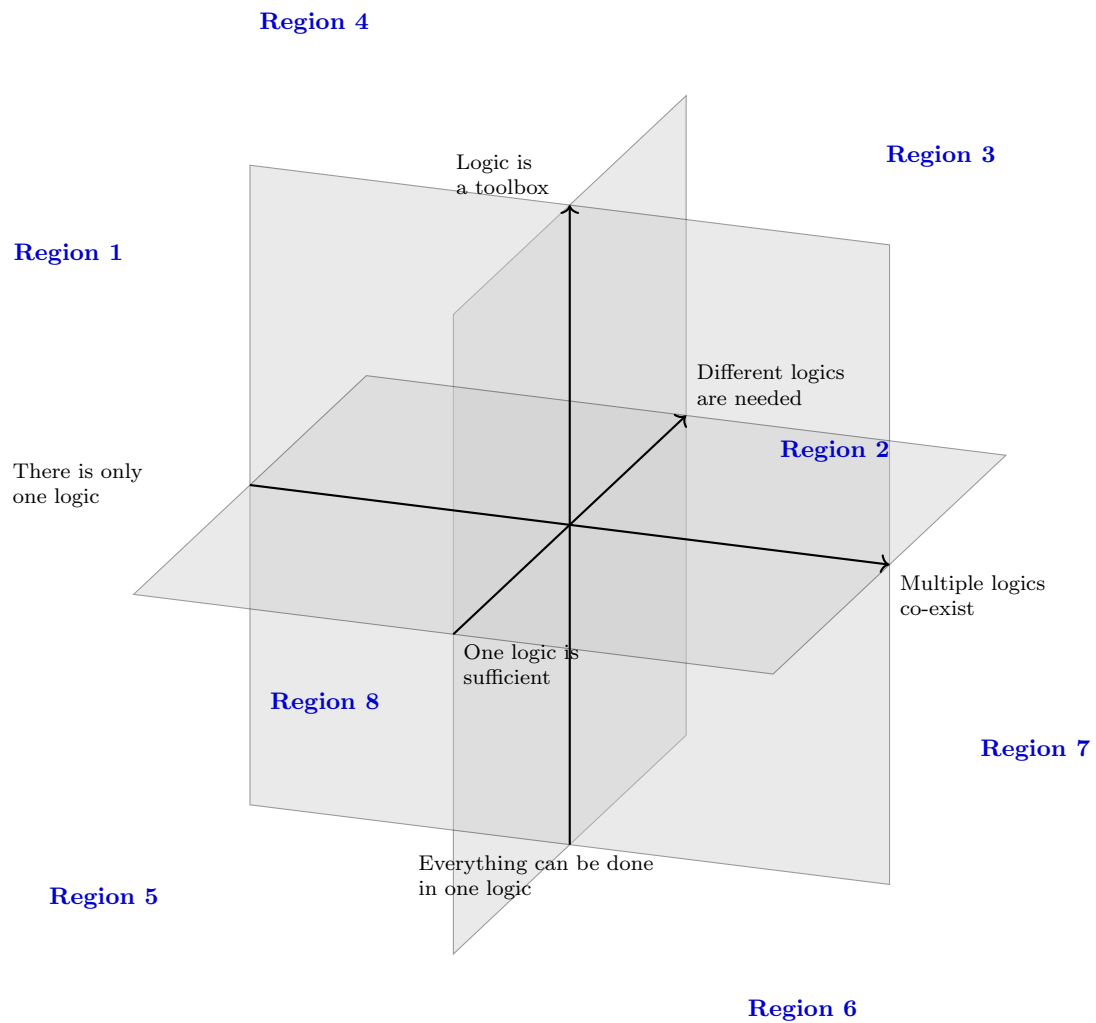


Figure 4.4: Sculpting the space of positions

The three dimensions we introduced above sculpt the space of positions as shown in

figure 4.4. The space total consists of eight different regions, which we will use to locate the specific positions occupied by the interviewees.

As a start we should note that there regions that are not occupied by any of our interviewees. And for one of them this is no accident: there is one region that seems conceptually impossible. This is Region 7, which encompasses a positive degree of commitment to the position that there coexist multiple logics, to the position that different logics are needed for capturing the application, and to the position that everything could be done in one logic. That is not a conceptually coherent space.

Apart from Region 7 all others appears to be potentially ‘inhabitable’. As a matter of fact, though, no interviewee occupies Region 2 or Region 6. That is, regardless of the third dimension, that of demands of practice, no-one maintains a positive degree of commitment to the position that there coexist multiple logics and the position that one logic is sufficient for capturing the application.

A tentative interpretation of this finding may be the following. If reality permits multiple logics, then different logics must at least capture some distinct aspects of the application that no single logic can fully represent. Conversely, if one logic is sufficient for capturing the application, then, in principle, reality itself may determine a single correct logic. However, we should note that the small sample size, and its selective nature, might also explain why Region 2 and 6 are not inhabited by one of the interviewees.

In the following, we first discuss the remaining five regions, accompanied by figures highlighting the positions being taken. At the end, we present a comprehensive figure that displays all regions together with all marked positions (figure 4.10).

4.2.2 Region 8

We start with Region 8, which is depicted in figure 4.5. It is inhabited by only one interviewee, [J]. This region seems to present an awkward position. It combines the position that there is only one logic (dimension 1) with the position that different applications require different logics (dimension 2), while at the same time also maintaining the position that everything could be done in one logic (dimension 3). The one interviewee that inhabits Region 8 is located at the extreme end of each dimension.

To understand this interviewee’s position their view on the nature of logic is especially important. They do not see logic as a pre-existing, abstract mathematical theory that is subsequently applied to other domains. Instead, they think of logic as something that is to be ‘discovered’ in the study of human reasoning and communication. In the short introduction this interviewee gave before the interview, they mentioned that they sees logic as ‘a theory of human reasoning’. Thus, they regard not just the formal systems of mathematical logic, but also everyday reasoning and argumentation as belonging to field of logic. This is based on their conviction that there is a genuine logical structure behind these as well.

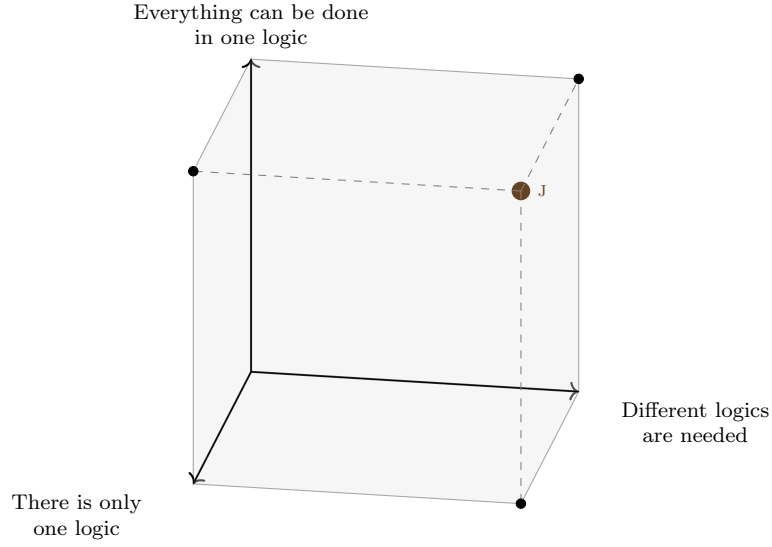


Figure 4.5: Region 8

In the nature of logic dimension, we locate the interviewee at the extreme left end, since they believe that the basis of logic is the human mind and its inherent capacities of reasoning and communication. This foundational belief may resolve the awkwardness of their position. From this perspective, there is indeed only one logic because logic is ultimately rooted in human cognition, with its complex, but unified architecture. It is logic as the single, natural phenomenon that this interviewee seeks to understand. However, this cognitive architecture manifests itself in the real world in a variety of ways. And because of that a plurality of formal systems is required to adequately model and explain them. Indeed, ‘different logics are needed’. Thus, the position that everything can be done in one logic does not refer to a single, simple formal system, such as classical first order logic, but rather to ‘the logic of the mind’, which, due to its richness, can only be partially approximated by various formal logical frameworks. This interviewee’s position is not that any logic can be arbitrarily applied, but that the nature of the application domain, viz., rational human behaviour, justifies a well-delineated pluralism .

Thus rather than holding an awkward, perhaps untenable position, we see that the interviewee’s stance exemplifies a nuanced understanding of pluralism, where the unity of logic is found in its cognitive origins, while its diversity is necessitated by the diverse ways in which human reasoning and communication manifest themselves.

4.2.3 Region 5

Next we turn to Region 5. It is represented in figure 4.6. This region is inhabited by two interviewees, [G] and [E].

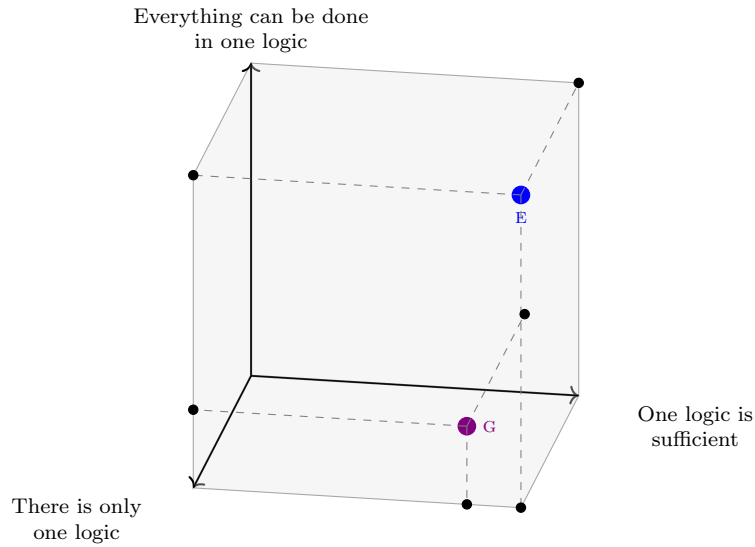


Figure 4.6: Region 5

The position of interviewee [E] represents a stance that takes all three dimensions at their extreme values—that is, a monist position with respect to each issue. It should be noted, however, that this is not a Fregean kind of monism that insists there is only one true logic capable of capturing all valid reasoning. Instead, the interviewee holding this position, [E], advocates a softer, more pragmatic form of unity. They see logic primarily as a collection of instruments for reasoning and remain largely silent on its ontological nature. When asked about the use of logic across different domains, this interviewee did not explicitly deny the need for multiple systems, yet they did express doubt about the real usefulness of such distinctions in practice: from the standpoint of set theory all these systems can be understood as different manifestations of the same underlying logical structure.

At the same time, interviewee [E] cautions against the idea of enforcing any single logic: thought should remain free and no-one should impose their framework on others. Faced with pluralism, we should keep an open mind and allow different perspectives to co-exist and interact. And perhaps one day we may realise that all these logics are simply different ways of viewing the same underlying reality. This suggests that, in principle, there is one logic that grounds all others – a single conceptual framework within which different logics operate as specialised tools.

The second interviewee that inhabits Region 5, [G], does not commit to strong monism but to a more moderate version. In their answer to the question about pluralism, they emphasised that they oppose relativistic forms of pluralism, according to which an inference may be correct according to one logic and incorrect according to another one, without there being any way to decide which is right and which is wrong. This interviewee believes that once one has established what the main primitives in one's logic mean, then

there is no room for pluralism. This suggests a commitment to the position that there is only one logic.

However, the interviewee also acknowledged that in practice different logics might be needed to capture different aspects of an application. That indicates a more pluralistic stance on the demands of application and the demands of practice dimensions. Whereas interviewee [E] grounds pluralism in the idea of logic as a collection of instruments and sees all systems as expressions of a single logical framework, interviewee [G] distinguishes more sharply between theoretical unity and practical diversity. For them, pluralism in use does not undermine the underlying unity of logic. Rather, it reflects the complexity of the domains to which logic is applied. In this way, both positions converge on a vision of ‘soft monism’, – one that preserves the ideal of a unified logical foundation while recognising the legitimacy and necessity of using multiple logics in practice.

4.2.4 Regions 1 and 4

We group Region 1 and Region 4 together because the three interviewees that inhabit these two regions share similar positions on pluralism. Each of them notes that, in practice, the logical systems used in their application areas are largely fragments of classical predicate logic – either first-order or second-order. Hence, along the nature of logic dimension, they are all located at the position that there is only one logic, a view grounded in their working experience with classical logic.

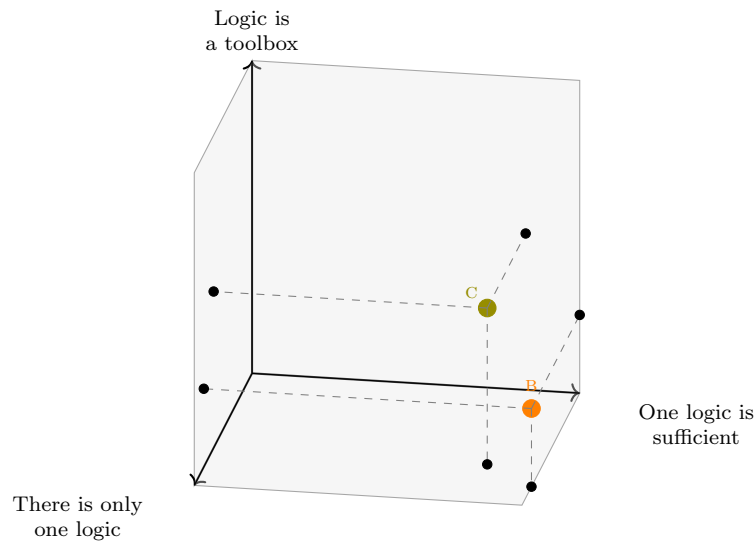


Figure 4.7: Region 1

However, there are also differences. The two interviewees in Region 1, [C] and [B], emphasised that the logics they work with can, in most cases, be faithfully translated into classical first-order logic or into fragments of second-order logic. This is why we placed

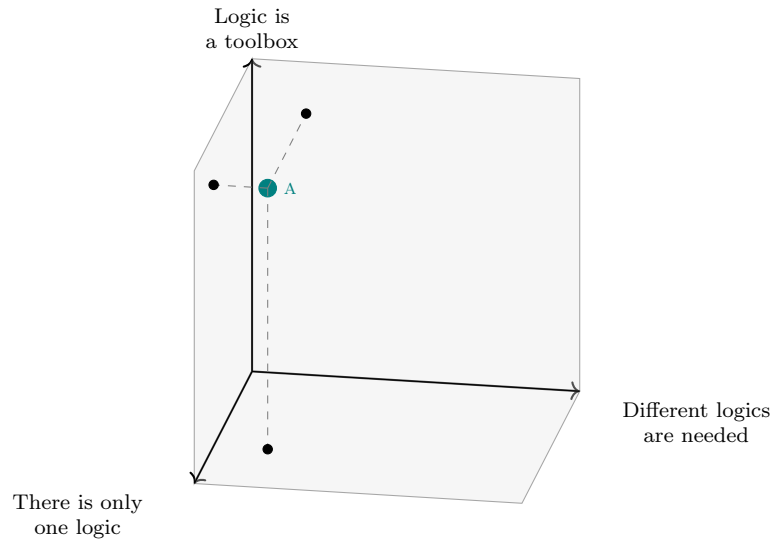


Figure 4.8: Region 4

them quite close toward the position that one logic is sufficient for capturing the application in the demands of application dimension. The interviewee who inhabits Region 4, [A], did not make such explicit claims and is therefore positioned further away from that position.

At the same time, all three interviewees agreed that logic is a toolbox and explicitly rejected the view that everything can be done in one logic. This suggests that there is a tension in their thinking between monism and pluralism. On the one hand, they see logic as unified in principle –a single framework of reasoning that grounds all others. On the other hand, they recognise that, in practice, no single system can handle every kind of problem with equal clarity. Different domains may call for different formal tools, even if these tools ultimately rest on the same foundation. Their position, therefore, presuppose that theoretical monism can be combined with practical pluralism.

4.2.5 Region 3

Region 3 represents the most pluralistic area within the conceptual space, characterised as it is by a strong endorsement of pluralism across all three dimensions. It is also the most densely populated one: the majority of interviewees –five in total– are located in this region. Rather than using the singular term ‘logic’ the interviewees in this area prefer the plural ‘logics’ to describe their research. In application areas such as mathematics, computer science and philosophy, they do not think applications fix their logic. Instead, they believe that different logics are needed to capture different aspects of the same application area.

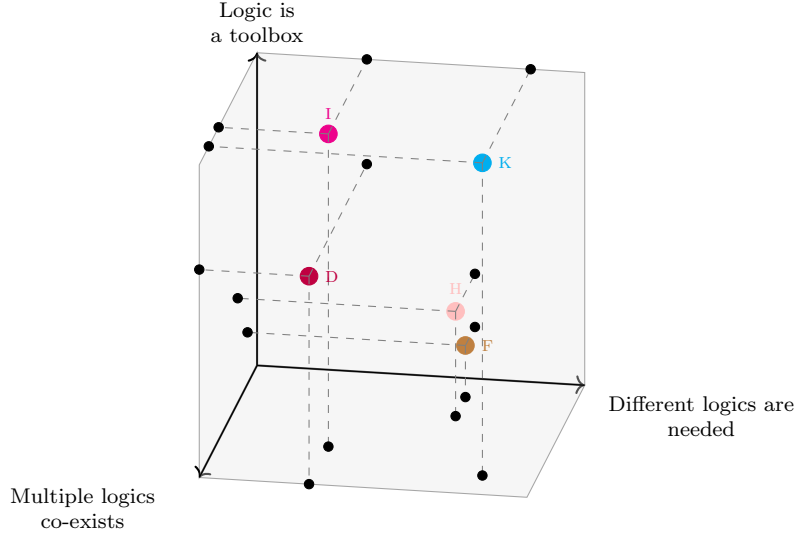


Figure 4.9: Region 3

The examples cited by the interviewees in support of their positions provide ample illustration of their pluralistic attitudes. For example, interviewee [D] notes that mathematics as such does not force one to use a specific logic and that different logics can be used to study different parts of mathematics. Another example comes from temporal logic. Various interviewees, e.g., [I] and [B], observed that there are many different formal systems that can be used to understand temporal aspects of reasoning, though these systems may describe them in quite different ways. Or consider quantum phenomena: often cited as requiring a non-classical logic, interviewee [D] claims that classical logic with dedicated modal operators may do the job as well. Even though these systems can often be translated into one another, they still offer different perspectives on the same phenomena and can be extended to new contexts. Even when two logics have the same expressive power, one may prove more convenient or illuminating for a particular purpose.

This pluralistic stance is not merely about using different symbols or formal systems. By allowing multiple frameworks to co-exist, researchers can approach the same questions from complementary angles. Pluralism here is seen as a way to increase understanding rather than to fragment it. Different logics highlight different structural features of reasoning and reveal connections that might otherwise remain hidden.

Note that the interviewees in Region 5 hold that once an application is fixed, one logic is sufficient to capture it. For them, diversity arises only when moving *between* domains. The interviewees in Region 3, however, maintain that even *within* a domain, multiple logics may be equally valid and jointly useful. This contrast shows a shift from monism in principle to pluralism in practice: diversity is not a symptom of confusion but a deliberate methodological choice.¹

1. That being said, there are notable differences between these interviewees, reflected in the different

4.3 Conclusions

We end this qualitative analysis of positions with regard to pluralism with some general observations about the distribution of interviewees in the conceptual space we have constructed. Figure 4.10 then presents the ‘sculpted space inhabited’.

Firstly, regardless of their individual positions, most interviewees accept a simple form of pluralism: there are many logics in the world. At the same time, most logics used in applications are fragments or variants of more complex systems, and their semantics can often be treated as objects within set theory or model theory. Where interviewees differ is in how they interpret the meaning of this plurality. For some, the existence of multiple logics is merely a descriptive fact: different systems serve different technical purposes but do not challenge the idea of a single underlying logical core. For others, the diversity of logics reflects genuine conceptual differences, suggesting that the very notion of logic itself may vary depending on context, goals, kind of reasoning involved. This interplay between unity and diversity sculpts the conceptual space and determines how the interviewees position themselves between theoretical monism and practical pluralism.

Secondly, several interviewees adopt what may be called a ‘two-level view’ of pluralism. They combine a monist attitude toward the nature of logic with a pluralist attitude toward its application. In principle, logic is seen as unified, grounded in a single framework; in practice, however, multiple logics may be needed to analyse different aspects of reasoning, language, or communication.

Thirdly, the overall pattern shows that most interviewees lean toward pluralism not as a rejection of uniqueness but as a practical way of dealing with complexity. Even when two logics describe the same phenomena and share the same expressive power, they may emphasise different features of those phenomena and therefore prove useful in different ways. Pluralism, for most of them, is thus less a statement about the nature of logic than a recognition that multiple perspectives can co-exist within one coherent view of what constitutes logical inquiry and application of logic in non-logical domains.

positions they occupy in Region 3. We can discern three clusters. The first consists of interviewees [F] and [H]: they hold a position that bears a similarity to that of A in Region 4, the difference being that these interviewees hold that an application may permit multiple coexisting logics.

The second cluster covers interviewees [D] and [I]: they stand out because of their commitment to the position that multiple logics co-exist. On this view applications do not determine a specific logic but rather inspire call for application of a range of different ones. These interviewees do differ among themselves in their views whether multiple logics are in fact required to fully capture a single application. Uncertainty at this point is correlated with uncertainty on the demands of practice dimension: different logics might serve particular practical purposes, yet it remains unclear whether such diversity necessarily contributes to a deeper understanding of the application itself.

The third cluster is formed by [J] and [K]: they fully adopt the view that logic is a toolbox on the demands of practice dimension. For them, the choice of logic depends primarily on the specific goal of a project, with meta-properties of logics –such as decidability, traceability, or computational efficiency– playing a central role. Their views diverge slightly regarding how such practical considerations influence inquiry into the application. Whereas [J] does not emphasise these pragmatic factors, [K] maintains that different logics motivated by such considerations may each offer distinct contributions to our understanding of the application.

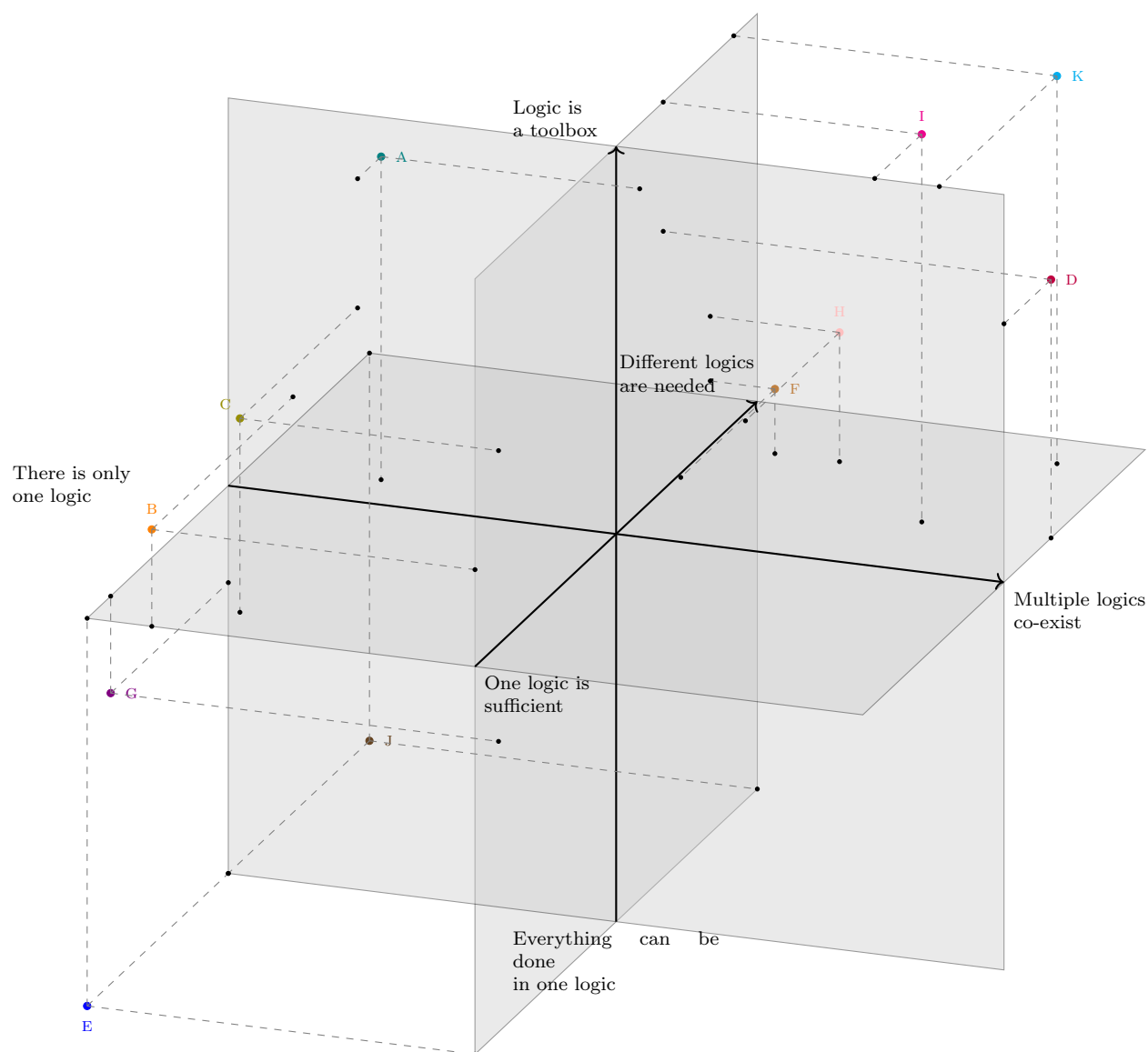


Figure 4.10: The sculpted space inhabited

Finally, it is worth noting that several interviewees who endorsed pluralism referred to research in AI as an example when discussing the practical advantages of using multiple logics. In that area, they observed, different frameworks –temporal, epistemic, probabilistic, and so on– are used to model different aspects of reasoning and information processing. To them this demonstrates the value of pluralism in practice. Other interviewees, however, who have a more monist orientation observed that the success of AI lies precisely in its ability to integrate diverse reasoning systems within a single computational framework. This contrast suggests that AI offers an interesting test case for logic

application. It illustrates both the practical power of logical diversity and the possibility that such diversity might still rest on a unified foundation.

As we hope the analysis in the foregoing has shown, and as the overall picture also illustrates, pluralism and monism are not radical opposites, they do not present a ‘yes-or-no’ kind of choice. Rather, the complementary pulls of unity and diversity call for nuanced views that strike a balance between these two opposites. The multiplicity of positions that we have identified in the interviewees’ responses reflect a multiplicity of ways to understand what logic is and how it can be applied in non-logical domains. That the positions of contemporary logicians display such a richness of views and arguments is, we are convinced, the opposite of a weakness: it is a strength to foster and take advantage of.

Chapter 5

Conclusions and recommendations

We already formulated a number of observations and conclusions along the way. In chapter 2 we mentioned key observations following the descriptions of the actual positions we could extract from the interviews. In chapter 3 we summarised the quantitative analyses of answers against a set of parameters, noting both correlations as well as the absence of them. And chapter 4 followed up with an in-depth analysis of two background factors, — the interviewees’ views on the nature of logic and their views on pluralism –, the result of which were displayed in figure 4.10.

So what’s left? In this final chapter we will do two things. In section 5.1 we will formulate some ‘concluding conclusions’ that are based on and inspired by the interviewees’ views on the various topics but that are not necessarily reflected in any of them. And in section 5.2 we will formulate some recommendations for the design of ‘the ideal logic curriculum’ that are as well inspired by the interviewees’ responses to various questions but do not necessarily follow from any of them.

5.1 ‘Concluding conclusions’

5.1.1 Topics

We first list some ‘concluding conclusions’ under the by now familiar headings:

- Ownership
- Meta-logical and other properties
- Pluralism
- Domain differences

Ownership

Ownership of a project that applies logic in a non-logical domain is shared: no party has an exclusive say in its formulation and execution. The input and stakes of the logician and the non-logician may vary with the nature of the project and its goals, but there is always a common interest. Communication between parties is key to strike and maintain

a balance between the stakes of all parties involved. Awareness that success criteria are typically more discipline-specific is of special importance.

Meta-logical and other properties

The relevance of meta-logical properties of logical systems for their application in a non-logical domain varies with the domain. In case there is relevance, it needs a dedicated effort to explain the how and why of that relevance. Thinking from the perspective of the application is a way of extending the scope of possibly relevant meta-logical properties beyond the traditional ones.

Properties such as simplicity, elegance and survey-ability are not domain-dependent and are crucial for communicating the relevance of logical results.

Pluralism

Current pluralism in logic is primarily viewed from a practical perspective. The theoretical (conceptual-philosophical) dimension of pluralism hardly plays a role, as it is not tied to application of logic in a non-logical domain. However, it would seem important to pay attention to it as it creates a reflection point at a distance of actual practice that may help understanding how the current pluralism came about and may foster new developments.

That there may be non-logical applications that dictate a unique logical analysis is not excluded but must be considered an exception. In almost all cases considerations about what logic to apply to a given problem are both contextual and practical in nature.

Domain differences

Differences ‘in nature’ between non-logical domains exist, but do not result in principled differences in the application of logic in those domains. The dynamics of disciplinary boundaries, as exemplified for instance in the cognitive sciences and artificial intelligence, indicate that the application of logic, too, is a matter of gradual adaptation, rather than fundamental changes. And logic can be a factor in disciplinary boundaries shifts as well.

5.1.2 Correlations

We follow up with some ‘concluding conclusions’ regarding various correlations. Again we do so using the by now familiar categories:

- Academic background
- Career stage
- Application area

Academic background

Actual correlations between academic background and responses are weak, no doubt due to the small sample size. However the following seem plausible conjectures.

A background in computer science and AI is conducive to an interest in non-standard meta-logical properties of applied logic systems. With the increasing importance of these application domains, this is good reason to pay more attention to them, already in the training of logic students.

A background in an empirical humanities discipline such as linguistics fosters a stronger commitment to the view that the non-logical application forces a unique logic.

Career stage

One strong correlation, and one that is quite to be expected, is that for early-career, and to some extent also mid-career, researchers concerns about publication in the ‘right’ venues is of greater importance than for late career researchers. That this puts a strain on joint publications with non-logical researchers, who may be subject to similar constraints, is obvious. This is something to be reckoned with when designing application projects, as well as when evaluating them.

Application area

In relatively new non-logical domains, such as cognitive science or artificial intelligence, with a relative short history of application of logic, there is a wider variety of options when it comes to choosing which logic to apply. In more established domains, such as mathematics and philosophy, tradition dictates choices to a much higher degree. Both situations have pros and cons (‘anything goes’; ‘this is how it’s done’), and awareness of this is needed.

5.2 ‘The ideal logic curriculum’

We end this chapter with a brief discussion of an issue that has not been discussed so far and that has not been addressed in the interviews: the outline of the ideal logic curriculum.

Why? Well, it seems clear that application in non-logical domains has become of increasing importance for logic. And there seems to be no reason to think that this will not remain to be the case. Of course, there will always be research in logic that is primarily concerned with questions and developments that are internal to the discipline. That is, and will continue to be, a crucial area of logic research. However, certainly in terms of employment the majority of logicians will be working, at least partly, on problems that are driven by concerns from non-logical domains. In order to prepare future logicians this reality should be reflected in the way in which they are trained.

Now there is no such thing as ‘the’, standard logic curriculum that we can use as a baseline for suggestions for changes. However, there are elements that recur in (almost) any logic curriculum and that might be worth reconsidering in the light of the fact that application is such an import part of the logician’s daily work. The suggestions listed here pertain to such stable parts of ‘the’ logic curriculum.

5.2.1 Context

Like lots of mathematics, logic tends to be taught in a context-independent way, without much reference to its history, its development, and its applications. But awareness and a bit of knowledge about how and why logic came to be what it is now and how it sits between various fields (mathematics, computer science, cognitive science, philosophy) would benefit the logic student and prepare them for the complex environment in which they will find themselves if they were to pursue a career in logic. And it would give a more informed picture of how logic relates to their own discipline for students who study logic as a side-interest.

Here are some recommendations:

1. *Pay attention to the historical context:*
Pay attention to the history of logic, preferably from a cross-cultural perspective. Knowing how logic has come to be what it is now, helps the students to gauge new developments. A cross-cultural perspective helps to place logic as a discipline in a wider intellectual setting.
2. *Emphasise application as a driver of logical innovation:*
Emphasise the role of application as a driving force behind the development of logic. Illustrate this with concrete examples, preferably from non-neighbouring disciplines.

5.2.2 Meta-logical properties

A key area where there appears to be room for improvement concerns meta-logical properties of logical systems. As the interviews made clear, many logicians regard these properties as integral to the logician’s concern, yet many also think that their relevance for application is unclear, or even non-existent. That is reflected in the way in which these matters are usually taught: they are introduced and motivated purely in terms of a logical system.

Here are some recommendations that might change that this negative appraisal:

1. *Emphasise relevance:*
Put more emphasis on the relevance of meta-logical properties for various application areas. For example, explain the relevance of completeness by discussing the advantages of being able to switch between a proof-theoretic and a model-theoretic perspective. But also discuss in what kind of application areas these properties are less, or not relevant.

2. *Extend the scope:*

Relax the emphasis on classical meta-properties (soundness, completeness, decidability) and also pay attention to properties such as model checking, complexity, definability. Illustrate these with reference to the role of logic in designing and studying complex systems such as used in computer science, AI, ...

5.2.3 Pluralism

Pluralism is a key characteristic of modern logical practice, both theoretically as well as in application-oriented research. A logic curriculum that remains restricted to classical proposition logic and first-order logic tends to obscure this important fact. Consequently, such a curriculum does not prepare the student who will pursue logic further for the actual practice that they will find themselves in. And to students from other disciplines it will give a one-sided idea of logic that might hamper their views on how their own discipline can benefit from logic research. Pluralism therefore needs to be a core ingredient of a logic curriculum, and should be treated both from a theoretical (philosophical) as well as a practical point of view.

Here are some recommendations:

- *Discuss pluralism:*

Discuss different kinds of pluralism and their motivations. Introduce different concepts of validity (classical, intuitionistic, ...) and show their application to reasoning in various domains. Introduce different logics, e.g., modal proposition logic or a simple form of type theory, and show how their set-up is derived from the demands of particular applications, such the philosophical analysis of modality or the analysis of linguistic constructions.

- *Illustrate pluralism:*

Illustrate pluralism by showing how the same problem can be approached using different logics. Examples: constructive versus classical reasoning in mathematics using intuitionistic and classical logic; or temporal reasoning using Priorean tense logic and an event-type first order calculus.

5.2.4 Application

Logic and application is what this project is all about. Application in non-logical domains is a key feature of modern logic. In an ideal logic curriculum there would be ample room to introduce students to this fact and to train them in a range of suitable applications. Merely mentioning the role of logic in other domains is not enough, the student should receive some hand-on training in order to develop a feel for what is at stake.

Here are some recommendations:

1. *Foster active engagement:*

Encourage students to engage with basic problems in application domains. This will help them identify core issues that can benefit from logical analysis. It will

also make them sensitive to other concerns than logical ones that go into defining solutions.

2. *Include ‘applied’ applications:*

Applications of logic in various disciplines tend to focus on theoretical-conceptual problems. But logic also plays a role in more applied context, e.g., in computer science applications and AI research. Getting exposed to that type of application broadens the students’ horizon and might serve as another stimulus to pursue a career in logic research.

3. *Include the role of communication:*

Application is one thing, communicating the results effectively to a non-logical audience is another. The role of simplicity and survey-ability of presentations of logical results is key here.

5.2.5 Implementation

Can all these recommendation for an ideal logic curriculum be incorporated in a real logic curriculum? Presumably not. But then that’s acknowledged in very term: an ideal is something to strive for, not something that can, let alone does, in fact exist. And much depends, of course on the scope of the curriculum. A single one-semester course obviously has less room for incorporating these suggestions than a two-year full-time program.

Be that as it may, we do think that paying attention to the elements mentioned in the above recommendations, if only briefly, will make the teaching of logic more rewarding, for both teachers and students, and more commensurate with actual logical practice.

5.3 Future work

This concludes our analyses of the data provided by the structured interviews we had with a group of eleven logicians. As we mentioned already, the sample size was small and the group of interviewees was not representative for the logic community as a whole.

Nevertheless, the data we have gathered from the interviews brought a number of interesting things to light on the broad topic of logic and application. As such, these results would be a good, solid basis to examine these issues further, for example by means of a questionnaire that could gather input from a much larger and much more representative group of logicians.

However, that is work for the future. For now, our work is done.

Appendix A

Protocol

This appendix contains the protocol that was used by the interviewers.

A.1 Invitation email

Dear Prof. XXX,

Last December a group of students and teachers at the Tsinghua-UvA Joint Research Center in Logic organised a series of meetings around the theme of ‘Logic and Application’. We discussed various questions that are raised by the application of logic in non-logical domains, such as linguistics, mathematics, philosophy, computer science and artificial intelligence.

At some point in our discussions we felt it would be very illuminating to learn the opinions of accomplished researchers in these areas. We are anxious to learn from their insights and experiences to come to a better and more comprehensive overview of how the application of logic works. We therefore decided to hold a series of structured interviews with key researchers.

The interviews will take approximately 45 minutes. They will be conducted by two members of the team and will take place on-line. The interviews will follow a protocol with set questions to make the answers of different interviewees comparable. These questions are set up in such a way that the same range of topics are addressed, but they will leave enough room for individual variation. The interviews will be transcribed using open source software and transcriptions will be cleaned up where necessary. The transcriptions will then be analysed by the whole team and the conclusions will be written down in a report. In the report quotes from interviewees may be used for purposes of illustration and clarification. Of course, quotations and all other references to source materials will be properly anonymised.

We plan to conduct the interviews during the months of March and April, and aim to finish the report by June.

We would be honoured if you would accept our invitation to be one of the interviewees. Your extensive experience and accomplishments in logical research and your ideas about logic and its applications in non-logical domains will be of immense value for our undertaking.

Please let us know at your earliest convenience whether you are willing to accept the invitation. If you are, we will then make arrangements for the interview to take place at a date and time that is suitable for you. We will send you the list of questions a few days before the interview takes place.

If you have any questions about our project or about the invitation, please do not hesitate to get back to us.

We are looking forward to hearing from you!

With best regards,

The L & A Discussion Group
Penghao Du
Qingyu He
Yumin Ji
Wenfei Ouyang
Wenlong Zheng
Martin Stokhof

A.2 Interview structure

All interviews proceed along the following lines:

- Introductory
- Application or Other
- Closing off

Introductory:

- Short intro on background of the survey [background document has been made available]
- Consent form: anonymised use of the transcription text
- Background of interviewee: training, research
- Work on application?
 - If so, on to questions *Application*
 - If not, on to questions *Other*

Application:

- What areas?
- Why? (accidental, independent interest, background related, ...)
- *The questions*

- Experiences: positive – negative

Other:

- Why no work on application?
- Is application a core area/aspect of logic research?
- Second-hand experiences? If yes, loop back to questions Application (modified as questions about second-hand experiences)

Closing off

- Short statements on theses A, B, C
- Any further thoughts?
- Thank you

A.3 Questions

Ownership

Who is in charge:

- who formulates the questions/problems? is that the logician? the non-logician? both?
- when and how does this matter?
- who determines the success criteria? is that the logician? the non-logician? both?
- what if there is no agreement on the success criteria? ‘who wins’?

Logics and their properties

Relevance of internal considerations:

- when are meta-logical properties (completeness, decidability, ...) relevant for application?
- to what extent are criteria such as simplicity (elegance, survey-ability) relevant? are these criteria domain-dependent? (e.g., elegance in logic $\neq$ elegance in application domain?)
- what if the logician’s criteria for a *good* solution differ from those of the non-logician?

Pluralism

[NB: Pluralism is understood as there being different logics for the same domain; e.g., classical versus intuitionistic versus minimal versus paraconsistent ... first order logic.]

Pluralism of logics:

- does pluralism transfer, i.e., if there are different logics that can be applied, does that mean that they give rise to different applications? or does application require

- a unique answer and thus force the use of a unique logic? if so, uniqueness up to what level?
- is there a priority issue, i.e., can the application dictate the use of a particular logic? does that depend on the nature of the application area?

The nature of the application area

Are there principled differences between logic as applied to:

- a priori disciplines: mathematics, philosophy ?
- empirical sciences? are there differences between physical sciences, social sciences, humanities?
- what about ‘hybrid’ disciplines such as computer science? artificial intelligence?

The theses

[NB: if (part of) the theses has been discussed already, mention that, but do ask for a short statement (to enhance comparability across interviewees)]

- A. Pluralism of logics can only be motivated by pluralism of application domains, i.e., fixing the application domain entails fixing *the* logic of that domain
- B. Meta-properties of logics (such as decidability, completeness, ...) provide necessary criteria for successful applications
- C. The application of a logic in a non-logical domain can contribute to clarification, but by itself does not constitute explanation

Appendix B

Working group

This appendix contains the description and set-up of the three-week working group on ‘Logic and Application’ that was held in December 2024 at the Joint Research Center in Logic at Tsinghua University.

B.1 The Why

Application is an important aspect of logical research. Of course, there is also research in pure logic, in which one studies logical systems as such. But many areas of logical research are at least partly driven by considerations concerning application. The areas in which logic is applied are numerous and varied: mathematics, philosophy, linguistics, cognitive science, artificial intelligence, social sciences, . . . What motivates and shapes the application of logic in these disciplines varies, of course. Yet, there are a number of questions and concerns that apply across the board.

B.2 The How

First of all there are interesting *theoretical* questions that concern the relationship between logic and other disciplines:

- where exactly is logic relevant in a particular field and on what features of logic and of the field does this relevance rest?
- what are success criteria by which we evaluate applications of logic and where do they originate?
- what meta-properties of logical systems are relevant for their application in a particular field?
- how does the pluralism of logic sit with the regulative idea of truth?

Secondly, there are also *practical* challenges:

- how and to what extent does the application of logic need to be informed by concerns in the field of application?

- how do logicians convince practitioners in these other fields of the relevance of their results?
- how do logicians balance their need for abstraction with the descriptive-explanatory concerns of the practitioners in the field?
- how is the fine line between abstraction and idealisation to be negotiated?

Of course, these are not questions that come up on a daily basis. And they are also questions that are difficult to answer and that perhaps even defy an answer. Nevertheless, it is worthwhile to every now and then take a step back and reflect on them. And there is a number of reasons for that. The theoretical questions provide interesting intellectual challenges, worth pursuing in their own right.

The practical challenges arise when logicians cooperate with researchers in other fields and need to convince them of the relevance of their results for the concerns of the others. And it is not only in pursuing scientific collaborations that this need arises. When applying for a job, or submitting a grant, the expertise of logicians and the relevance of their contributions will almost always be evaluated by non-logicians.

Thus for reasons of both intellectual relevance and practical impact it is of vital importance that logicians have a clear and convincing story to tell about the connections between logic and its implications.

B.3 Schedule

There are three meetings scheduled, with the possibility of a follow-up. The planning of the three meetings is as follows:

Meeting 1, November 28

- introduction to the framework of practice theory that will serve as a conceptual background
- illustrations of the ‘practical’ nature of research in logic, philosophy, mathematics
- inventory of key questions that arise concerning logic and application against this background

The first two elements will take the form of a quick introduction; the inventory will be the result of in-group discussions

Meeting 2, December 5

The second meeting is reserved for presentation and discussion of concrete cases by the participants.

The presentations need to focus on the *application dimension* of ongoing work, taking the inventory of key questions as a guide line.

Each presentation should take about 15-20 minutes, which will be followed by 20 minutes of discussion.

Presentations will be given by:

- He Qingyu
- Du Penghao

Meeting 12, December 12

The third meeting is devoted to the formulation of conclusions and recommendations.

If there is an interest in doing so, the working group could also discuss a potential follow up. It would certainly be interesting to get more views and experiences.

To collect those we could draw up a short survey, along the lines of Maddirala [2014], send that out, sample the answers and produce a report based on them. This could be done in one or two follow-up sessions, if necessary on-line.

B.4 Reading suggestions

Here are some reading suggestions for those who want to explore some topics in more detail. On each of them there is a wealth of material, but these references should provide a first entry.

- On pure logic and applied logic: Cohnitz and Estrada-González [2019, chapter 1]
- On logical pluralism: Cohnitz and Estrada-González [2019, chapter 7]
- On practice theory: Schatzki [2002, page 70–88], Schatzki [1996]
- On philosophical logic as a practice: Maddy [2014, chapter 6], Sunday Grève [2017], Kuusela [2019, chapters 5, 6]
- On mathematics as a practice: Van Kerkhove and van Bendegem [2007, introduction], Azzouni [2007], Sørensen [2009], Stam et al. [2022]
- On abstraction versus idealisation: Stokhof and van Lambalgen [2011], Stokhof and van Lambalgen [2016]

These materials are available on-line at: [link~suppressed]

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