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journal homepage: www.elsevier.com/locate/jvlcTwelve years of diagrams research[☆]

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ABSTRACT

Research into the use of diagrams is an interdisciplinary endeavour, encompassing disciplines as diverse as psychology, architecture and artificial intelligence. It is also a relatively new research area, with the first meeting of like-minded researchers interested in studying diagrams taking place in 1997. Now that diagrams research is more established, it is timely to review its scope, nature and progress. This paper reviews diagrams research over the past twelve years, as represented in the proceedings of the *International Conference on the Theory and Application of Diagrams*. In summarising the contents of these proceedings, a taxonomy describing the scope of diagrams research is proposed, the several research issues covered are identified, and the extent to which layout and aesthetics form part of this body of research is discussed. In concluding, trends and under-represented areas are noted and discussed. The aim of the paper is not only to summarise the research covered in this particular conference, but to provide a basis for on-going discussion on the changing nature of diagrams research.

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1. Introduction

Diagrams are ubiquitous, and, as a means of communicating information, can be found in all areas of research and practise. Leveraging off the power of the visual processing system (our primary means of perception), they provide a flexible means for representing information in an engaging and direct manner. Diagrams are, however, useless if not effectively communicated and understood – and fully understanding this comprehension process requires knowledge from a wide range of disciplines, including psychology, social science, applied linguistics, education, and communicative technologies. Bringing these areas together in an interdisciplinary forum enables diagrams themselves to be the focus of research endeavour.

The specific area of diagrams research may be said to have been launched by the publication of Larkin and Simon's [1] seminal 1987 *Cognitive Science* paper "Why a Diagram is (Sometimes) Worth Ten Thousand Words". This paper references no prior work specifically relating to

diagrams research, although, as befitting a cognitive science article, it refers to several papers on cognitive models and 'mental imagery'.

Prior to 1997, there was no specific forum for the interdisciplinary study of diagrams. The first *Thinking with Diagrams* workshop was held in Portsmouth in January 1997, with its discussion papers collated as a Medical Research Council Cognition and Brain Science Unit publication. An extract from the introduction to this document reads [2]:

There is increasing understanding of the benefits of diagrammatic representations for reducing cognitive load, enabling different styles of problem solving and exploiting perceptual judgement skills. It is important that this evidence be applied to both technology and general education, but there is surprising ignorance about the function of diagrams. New graphical representations and educational approaches are still being devised on a purely intuitive basis, and this brings some urgency to the need for a broader theoretical base and wider dissemination of specialist research on thinking with diagrams.

The second *Thinking with Diagrams* workshop in Aberystwyth in 1998 was entitled "Is there a science of diagrams?"

[☆] This paper has been recommended for acceptance by S.-K. Chang.
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and aimed to “directly address the lack of cohesion in the discussion as to the nature of diagrams”. The proceedings of this workshop was published by Springer Verlag as *Diagrammatic Representation and Reasoning* [3]. It posed the question [4]:

...are [we] in a position to claim that we have a science of diagrams? That is: a science which takes the nature of diagrams and their use as the central phenomena of interest; a science which is attempting to understand how diagrams differ from other representational systems and trying to develop principles for the design of effective graphical representations; a science which considers how diagrams communicate information and how they are used to solve problems.

In the introduction to a special issue of *Artificial Intelligence Review* on “Thinking with Diagrams” (Volume 15, Issue 1–2, March 2001), Blackwell [5] provides an explanation for the upsurge in interest in diagrams research:

...diagrammatic representations are becoming more common in everyday human experience. Bit-mapped computer displays have encouraged the use of diagrams in human-computer interaction. Improved publication technologies, especially the PostScript language, have provided the means for standardised reproduction of diagrams. Modern thought has already been greatly influenced by the ability to publish conventional pictorial illustrations in books and it seems that the widespread facility to create and interact with diagrams will encourage new styles of literacy in a similar fashion.

And so the Diagrams Conference Series was born. The first *International Conference on the Theory and Application of Diagrams* was held in Edinburgh in September 2000, and was described as “the joint successor of a number of workshop series: Thinking with Diagrams, Theory of Visual Languages, Reasoning with Diagrammatic Representations, and Formalizing Reasoning with Visual and Diagrammatic Representations”. It was motivated thus [6]:

Driven by the pervasiveness of diagrams in human communication and by the increasing availability of graphical environments in computerised work, the study of diagrammatic notations is emerging as a research field in its own right. This development has simultaneously taken place in several scientific disciplines, including, amongst others: cognitive science, artificial intelligence and computer science... It is intended to become the premier international conference series in this field and will attract participants from applied linguistics, architecture, artificial intelligence, cognitive science, computer science, education, graphic design, history of science, human-computer interaction, philosophical logic, psychology and others.

The Diagrams conference has been held every two years since then: in 2002 (Callaway Gardens, USA), 2004 (Cambridge, UK), 2006 (Stanford, USA), 2008 (Herrsching, Germany), 2010 (Portland, USA), and 2012 (Canterbury, UK), with all the proceedings published by Springer Verlag in their Lecture Notes in Artificial Intelligence series.

It emphasises its interdisciplinary nature by describing itself as “the only conference that provides a united forum for all areas that are concerned with the study of diagrams” [7].

After seven Diagrams conferences and twelve years, it is timely to review the nature of diagrams research over this period. While the publication of articles on diagrams research is obviously not confined to the Diagrams Conference Series (DCS), it is clear that, as the premier forum for this area, this is the most important place to look. This paper reviews the proceedings of all seven conferences in the DCS – effectively a ‘vertical census’ of diagrams research. Its aim is to review the nature of diagrams covered, and the range of research activities and trends. In addition, it considers the extent to which aesthetics and layout are features of this research.

1.1. Research questions and methodology

The aim of this paper is to address the following questions:

- (a) **What is the scope of 'diagrams research'?**
What are the types of diagrams considered, and how can we define and distinguish them?
- (b) **What is the nature of diagrams research, and what are the trends?**
What is the range of research questions and issues addressed by diagrams research, and have research priorities changed over time?
- (c) **To what extent do 'layout and aesthetics' feature in diagrams research?**
What do 'layout' and 'aesthetics' mean in the context of diagrams research, and how are they addressed?

All the papers and posters in the DCS proceedings (Table 1) were reviewed, summarised and classified. Short abstracts of keynote talks, tutorials or workshops were not included, as they give insufficient detail for classification.

Answering question (a) entailed classification of the types of diagrams used in the 312 papers and posters, based on the range and variety of all the diagrams included in these papers.

Answering question (b) entailed classification of each of the 177 papers by the research aim it addresses; sometimes this aim is obvious by the conference theme under which it is listed (where available), although this is not

Table 1
Papers and posters published in the Diagrams conference proceedings.

	papers	posters	
2000	31	9	40
2002	29	8	37
2004	21	37	58
2006	27	9	36
2008	25	28	53
2010	22	23	45
2012	22	21	43
total	177	135	312

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