View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Research Online

University of Wollongong

Research Online

University of Wollongong Thesis Collection 1954-2016

University of Wollongong Thesis Collections

1997

Interpreting graphs and tables with cognitive tools

Brian Ferry

Univerity of Wollongong, bferry@uow.edu.au

Follow this and additional works at: https://ro.uow.edu.au/theses

University of Wollongong

Copyright Warning

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following: This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of this work may be reproduced by any process, nor may any other exclusive right be exercised, without the permission of the author. Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material. Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.

Recommended Citation

Ferry, Brian, Interpreting graphs and tables with cognitive tools, Doctor of Philosophy thesis, Faculty of Education, University of Wollongong, 1997. https://ro.uow.edu.au/theses/1780

Research Online is the open access institutional repository for the University of Wollongong. For further information contact the UOW Library: research-pubs@uow.edu.au

NOTE

This online version of the thesis may have different page formatting and pagination from the paper copy held in the University of Wollongong Library.

UNIVERSITY OF WOLLONGONG

COPYRIGHT WARNING

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site. You are reminded of the following:

Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material. Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

Interpreting graphs and tables with cognitive tools

A Thesis submitted in fulfilment of the requirements for the award of the degree of Doctor of Philosophy (PhD)

from

The University of Wollongong

by

Brian Ferry

B.A., M. Stud. Ed., M. Ed. (Hons.)

Faculty of Education

1997

Declaration

I certify that this is my original work and that it has not been submitted for a degree at any other university or institution.

Brian Ferry
24.3.97

Acknowledgments

I wish to acknowledge the guidance, encouragement and support provided by my supervisors, Associate Professor Barry Harper and Associate Professor John Hedberg.

There are always many others to thank during a project such as this. First, I would like to thank the preservice teachers who took part in this study. Second, I would like to thank Sean Cruickshank, Peter Gracie, Matthew Fifield and Rob Wright for their technical assistance. Also I wish thank my colleagues Christine Brown and Peter Keeble who have provided valuable input at various stages of this study.

Last, but certainly not least, I wish to thank my family Chris, Michelle and Belinda for putting up with the constant talk about this study and the long periods of time that I spent working on this project.

Abstract

This study explores some ways in which cognitive tools may be used to assist learners to interpret graphs and tables. It investigates ways in which concept mapping tools may be applied to this task, and then it investigates how preservice teachers used a suite of simple cognitive tools designed to reduce cognitive load. All cognitive tools were developed with HyperCard™ software and these tools were used by preservice teachers (the subjects of this study).

The thesis is divided into three linked studies. Study 1 investigated the cognitive strategies employed by preservice teachers when they interpreted graphs and tables. The findings were then used to guide the design of the cognitive tools that were used in Study 2.

During Study 1 the ability of various groups of preservice teacher to interpret graphs and tables were compared. The findings showed that when these learners interpreted graphs and tables they had difficulties with understanding the context as described by the accompanying text, sorting and comparing relevant data in tables, and identifying specific global (eg. slope, turning points, discontinuities) and local features (eg. labels on axes, points on graphs) that were relevant.

During Study 2 a prototype of the cognitive tools was developed and trialled. These tools were designed to assist learners to interpret information in form of text, graphs and tables that related to the destruction of rainforests. During Study 3 the improved cognitive tools were used by 80 preservice teachers. Interviews, artefacts and tracking data were gathered and used to evaluate the tools.

The findings from all data sources suggest that there are procedures that we should employ to effectively introduce learners to cognitive support tools, as it is not just a matter of designing a suitable tool and then handing it over to the learner to use. Analysis of the concept maps and interview transcripts showed that the learners used one of three strategies to construct their concept maps, but in most cases there was little difference in the quality of the final map produced. It appears that one strength of the concept mapping tool was that it helps learners to visually organise knowledge in different ways. Also the other cognitive tools may have acted as mental devices that supported, guided and extended the thinking processes of learners.

Contents

Chapter 1: Introduction 1
The problem 2
Definitions of important terms used in the study 4
Tables and graphs 4
Interpreting graphs and tables 5
Cognitive tools 9
Concepts 10
Concept map 10
Purpose of the study 11
Theoretical perspective 12
The cognitive tools 13
Research questions and strategies 15
Brief discussion of the research questions 16
Data sources and research strategies 18
The subjects 19
Limitations 20
Significance of the study 20
Outline of the structure of the remainder of the thesis 21
Chapter 2: Supporting Educational Theory 24
Part 1: Relevant theoretical models of learning 24
Guidance from educational theory 27
Part 1: Summary 43
Part 2 : Learner processing of information in graphs and tables 44
Features of cognitive tools that support learner processing of information 44
Strategies that help learners to process information 45
Additional strategies that help learners to process information 64
Applying the research to educational settings 77
The design and presentation of cognitive tools that facilitate learner processing of information 79
Evaluation of cognitive tools that facilitate learner processing of information 81
Part 2: Summary 81
Chapter 3 Learner Interpretation of Graphs and Tables 83
Part 1: Relevant research relating to the interpretation of graphs and tables 83
The use of graphs and tables to support learning 86
Research related to the instructional effectiveness of graphs and tables 91
Part 1: Summary 101
Part 2: Applying the findings from Chapters 2 and 3 102
Layout and buttons 103
Specific cognitive tools 104
Chapter 4: Methodology-Overview of the three research studies 108
Study 1: Describing learner interpretation graphs and tables 111
Study 2: Development and evaluation of the prototype 112
Study 3: Researching use of the improved cognitive tools 112
Chapter 5: Study 1- Learner background and strategies as factors affecting their ability to interpret graphs and tables 113
Research questions and hypotheses 113
Methodology 115
Mathematics and science backgrounds of the preservice primary teachers 117
Variables investigated in this study 119
Measuring learner ability in interpreting graphs and tables 121
Analysis of graphs and tables test 122

Results - Study 1 122
The interviews with the seven preservice teachers 127
Chapter 6: Study 2-Development and evaluation of the prototype 141
Methodology - Study 2 142
Research questions - Study 2 142
Variables selected during Study 2 144
Analysis of concept maps 146
Analysis of the quantitative data gathered 149
Data from journal entries and interviews 150
Development of tools to support cognitive outcomes 151
Development of cognitive tools used in the rainforest prototype 154
Experimental procedure for Study 2 157
Use of all cognitive tools 160
Results for Study 2: Learner use of the prototypes of the cognitive tools 160
Use of cognitive tools that helped learners to analyse rainforest data 166
Summary of Study 2: Use of the prototypes of the cognitive tools 171
Chapter 7: Study 3-Use of the concept mapping and information handling cognitive tools 177
Research questions and hypotheses - Study 3 180
Experimental procedure-Study 3 182
Results from Study 3: Researching use of the improved cognitive tools 183
Use of the improved concept mapping tool 183
Use of the improved cognitive tools that assisted learners to analyse graphs and tables 208
Summary 234
Chapter 8: Discussion and Conclusion 237
Learner interpretation of graphs and tables 237
Introducing learners to cognitive tools 242
The impact of cognitive tools upon learners 248
Conclusion 257
Investigating learner interpretation graphs and tables 258
How to introduce learners to cognitive tools 258
Learner use of cognitive tools 259
Learner construction of knowledge with cognitive tools 260
Appendices 286
Appendix 1: Plate displaying graphs by William Playfair (1801) 287
Appendix 2: Multiple choice test on Graphs and Tables 288
Appendix 3: Skills grid for multiple choice test on Graphs and Tables 314
Appendix 4: Attitude to computers questionnaire 316
Appendix 5: Learning style inventory 318
Appendix 6: Journal questions used with prototype 319
Appendix 7: Interview questions used with preservice teachers who used the final version of the concept map 320
Appendix 8: Interview questions used with preservice teachers who used the analysis tools with the information about rainforest destruction 320
Appendix 9: Sample interview transcripts 321
Appendix 10: Preservice teacher concept maps revised away from the computer 327
Appendix 11: Concept mapping software 329
Appendix 12: Web sites for concept mapping software 330
Appendix 13: Permission documents and other relevant information 331

Figures

Figure 1.1	A model of learner interpretation of information contained text, graphs and tables	7
Figure 1.2	A simple concept map (after White and Gunstone, 1992)	11
Figure 2.1	An information processing model of human performance (Romiszowski, 1990)	35
Figure 2.2	A model of the structure of human memory (after Gagne, 1987)	46
Figure 2.3	A holistic model of learning (after Cambourne, 1988)	55
Figure 2.4	A model of classroom literacy (after Cambourne, 1995)	56
Figure 2.5	The design of the concept mapping tool	61
Figure 2.6	Components of metacognition	66
Figure 2.7	The four quadrants of Kolb's Learning Style Inventory	74
Figure 3.1	Dale's Cone of Experience (1969)	84
Figure 3.2	A schematic diagram of the cognitive demands associated with various forms of information presentation	85
Figure 3.3	A model of the processes involved in interpreting graphs (after Janvier, 1978)	94
Figure 3.4	The original plans for the cognitive tools	103
Figure 4.1	An annotated flow chart of the study	109
Figure 4.2	Summary of the studies	110
Figure 6.1	A simple concept map used to show how the marking scheme was applied (after White and Gunstone, 1992)	147
Figure 6.2	A plan of the opening screen of the prototype	151
Figure 6.3	The original six buttons on the concept tools palette	152
Figure 6.4	A concept map in the process of creation with the prototype	154
Figure 6.5	The opening screen of the prototype of the support system to assist learners to interpret graphs and tables	155
Figure 6.6	The screen used to support the interpretation of tables	156
Figure 6.7	The screen used to support the interpretation of graphs	157
Figure 6.8	The redesigned palette of concept map construction tools	174
Figure 7.1	The revised opening screen	178
Figure 7.2	The revised concept mapping tool	178
Figure 7.3	The revised display of tabular information	179
Figure 7.4	The revised balloon help for the graphs	180
Figure 7.5	Sally's concept map	192
Figure 7.6	Mary's concept map	193
Figure 7.7	Kerry W's concept map	194

Figure 7.8	Adele's concept map undergoing modification	199
Figure 7.9	Barbara's first map	200
Figure 7.10	Barbara's second map	201
Figure 7.11	The four quadrants associated with Kolb's theory of experiential learning	213
Figure 7.12	A text screen showing words that were linked to a simple glossary	217
Figure 8.1	Kolb's model of learning	247

Tables

Table 2.1	A classification of visual tools as described by Hyerle (1996)	51
Table 2.2	Learning style inventories based upon information processing preferences (Curry, 1987)	73
Table 3.1	Probable functions of the hemispheres of the brain (Rose, 1985)	88
Table 3.2	The cognitive tools used during the study	105
Table 5.1	Preservice teachers involved in part 1 of the study	116
Table 5.2	One way ANOVA analysis of year - course enrolment and test scores	123
Table 5.3	Data about the subjects	124
Table 5.4	Previous study completed at senior high school	125
Table 5.5	Stepwise regression of the independent variables of gender, TER, age, Mathematics, Biology and English scores, and the dependent variable of test scores	126
Table 5.6	Details of the questions chosen for interviews	128
Table 5.7	How the analysis of interview transcripts were coded	129
Table 5.8	Data analysis for Question 1	130
Table 5.9	Data analysis for Question 2	131
Table 5.10	Data analysis for Question 3	132
Table 5.11	Data analysis for Question 4	133
Table 5.12	Data analysis for Question 5	134
Table 5.13	Data analysis for Question 6	135
Table 5.14	Data analysis for Question 7	136
Table 5.15	Summary of information from the observations and transcript analysis	137
Table 6.1	Composition of the stratified sample that used the prototype	142
Table 6.2	Descriptive statistics for preservice teachers who used the prototype of the concept mapping tool	161
Table 6.3	Analysis of the concept maps	164
Table 6.4	The summary statistics from the tracking data from the prototype	167
Table 6.5	Summary of tracking data	168
Table 6.6	Frequency distribution of the total time taken to use the prototype	169
Table 7.1	New features of the improved version of the rainforest program	177
Table 7.2	Organisation of instruction and collection of data	183
Table 7.3	Frequency distribution of the topics chosen by the preservice teachers	184

Table 7.4	Frequencies of the most popular topic areas in the first and second concept maps	185
Table 7.5	Summary statistics for the concept notes and link notes associated with concept maps 1 and 2	186
Table 7.6	Organisation of instruction and data collection	208
Table 7.7	Tracking data showing user access to information	209
Table 7.8	Times spent using the software	209
Table 7.9	Regression analysis for the relationship between frequency (independent variable) and time (dependent variable) for the various sources of information	210
Table 7.10	Descriptive statistics for age and gender	211
Table 7.11	Responses to survey on attitude to computers	212
Table 7.12	Paired t-test results for subscales	212
Table 7.13	Responses to kolb's learning style inventory	212
Table 7.14	Preferred learning style of preservice teachers interviewed and the information sources they preferred to use	214
Table 7.15	Summary statistics for multiple regression analysis of relationships among variables	215
Table 7.16	Result of multiple regression analysis of other factors examined	215
Table 7.17	A list of the questions asked	221
Table 7.18	Summary statistics for the concepts displayed on the maps	229
Table 7.19	The location and frequency of the concepts listed by the preservice teachers	230
Table 7.20	An alphabetical list of concepts and their frequencies	231
Table 7.21	A synthesis of attributed sources of information used by preservice teachers when they constructed their concept maps	233