REVISITING THE INVISIBLE COLLEGE: A CASE STUDY OF THE INTELLECTUAL STRUCTURE AND SOCIAL PROCESS OF SINGULARITY THEORY RESEARCH IN MATHEMATICS

by

Alesia Ann Zuccala

A thesis submitted in conformity with the requirements
for the degree of Doctor of Philosophy
Faculty of Information Studies
University of Toronto

© Copyright by Alesia Ann Zuccala 2004

REVISITING THE INVISIBLE COLLEGE:
A CASE STUDY OF THE INTELLECTUAL STRUCTURE AND SOCIAL PROCESS OF SINGULARITY THEORY RESEARCH IN MATHEMATICS

Doctor of Philosophy, 2004
Alesia Ann Zuccala
Faculty of Information Studies
University of Toronto

ABSTRACT

This study revisits the invisible college concept in order to respond to Lievrouw's (1990) question about whether it is a *structure* of scholarship measurable from outside elements (i.e., published documents) or a *social process* rooted in informal communication behaviours, perceivable only to the researchers who carry out these behaviours. Focusing on the Singularity Theory community in Mathematics, the combined research techniques of Author Co-Citation Analysis, Social Network Analysis, and Ethnography of Communication are used to show that an invisible college constitutes both elements identified by Lievrouw. An invisible college is defined and observed as a multidimensional phenomenon where three factors — the subject specialty, the scientist/scholars as social actors, and the information use environment (IUE) — play interrelated roles in its orientation and growth.

ACKNOWLEDGEMENTS

A number of individuals were helpful to me during my journey towards completing my Ph.D. and I would like to take the opportunity to express my gratitude. First, I wish to acknowledge my parents, Norma and George Zuccala, my siblings Paul and Tonya and my 'kitties' Sushi and Zoë for believing in me and for standing by me through 'thick and thin.' A Ph.D. thesis is a time-consuming and at times, stressful project and I know that I could not have done it without the support of my family members.

My supervisor from the Faculty of Information Studies (FIS), Dr. Juris Dilevko, also believed in my capacity to carry out this project. He offered a tremendous amount of guidance throughout my Ph.D. program and ensured that financial resources were available during crucial research periods. With Dr. Dilevko's help I had the opportunity to travel to Drexel University in Philadelphia to acquire the skills needed to carry out my Author Co-citation Analysis (ACA) of the Singularity Theory community. Dr. Howard White and Dr. Kate McCain from Drexel took time out of their busy schedules to share their knowledge of the software and research techniques used in ACA and I will always be grateful to them for this. At the University of Toronto four additional advisors were essential to my progress. Dr Ethel Auster and Dr. Joan Cherry from the Faculty of Information studies were instrumental in helping me understand and recognize the fundamentals of quality research and scholarly writing. Dr. Barry Wellman from the Department of Sociology acted as my social network analysis/sociology of science mentor and gave me the opportunity to acquire both the software and skills needed to study the Singularity Theory community from a social network perspective. Without Dr. Edward Bierstone from the Department of Mathematics I could not have even begun to understand the Singularity Theory community; therefore I am grateful to him for acting as my key mathematics informant and for 'translating' documents that would help me acquire insight into the field's history. Several other Singularity Theory mathematicians – many of whom are named in this dissertation – provided me with insight into their work and I thank all of them for making this

project a success because they agreed to participate in an interview with me. And finally, this dissertation would not have been finalized without Dr. Liwen Vaughan from the University of Western Ontario who produced a thorough research review prior to my oral defense on March 15, 2004.

I am extremely grateful to Dr. Keith Moffatt, from the Isaac Newton Institute in Cambridge, England for granting me access to the Institute environment for the ethnographic stage of my research. Dr. Bradd Hart generously granted me a leave of absence from my Publication Manager duties at the Fields Institute so that I could travel to England. Also Dr. Barbara Spronk and Neil Spronk graciously opened up their home to me so that I would have a place to live in Cambridge while I was carrying out my fieldwork.

A special thanks goes to Matthew Duncan, my friend and fellow Ph.D. student from the University of Toronto. I could always count on him to be there for me both for statistics advice and advice on how to handle the trials and tribulations of being a doctoral student. My other friends from the University of Toronto, known as the "Secret Agents" were always available for fun, laughter, and understanding when it seemed like there was no light at the end of the tunnel (i.e., A. Siegenthaler, A. Quan-Hasse, B. Morton, etc. You know who you are!). Several individuals from outside the university gave me an enormous amount of encouragement, particularly, Dr. D. Slonowsky, E. Kaufman, B. Daly, J. Williams, S., M. Zurawinski, S. Wennerstrom, J. Hayman and S. Johansen. The members of the Bibliometrics and Informetrics group (BIRG) at the University of New South Wales, Australia, headed by Dr. Connie Wilson, provided me with many rich experiences as a researcher and lecturer. I am particularly grateful to Dr. Mari Davis from BIRG for reading drafts of my thesis prior to submission. Last, but not least, my good friends from Sydney, Australia, T. Hansen, K. Hansen and K. O'Brien supported me during the final stages of my thesis writing. I will always remember enjoying the "Aussie" sun, beaches, birds and kangaroos with them when I was well on my way towards completion.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES vii

APPENDICES viii

CHAPTER 1: INTRODUCTION 1
1.1 Problem Context 1
1.2 Research problem 8
1.3 Conceptual model for the research 12
1.4 Research assumptions and questions 15

CHAPTER 2: REVIEW OF THE RESEARCH LITERATURE 17
2.1 Scientific communication 17
2.2 The scientist as a social actor 20
2.3 Invisible college networks 22
2.4 Collaborative work in science 34
2.5 A new invisible college study 46

CHAPTER 3: RESEARCH METHODS 49
3.1 Citation analysis 49
3.2 Social network analysis 54
3.3 Ethnography of communication 59
3.4 "Triangulating" citation, social network and ethnographic data 65
3.5 Delimitations and limitations of the study 66

CHAPTER 4: THE INTELLECTUAL STRUCTURE OF SINGULARITY THEORY 70
4.1 Author co-citation analysis pilot 70
4.2 Selection of the final ACA author set 73
4.3 Pretest for name-forms, truncation effects and surname variations 76
4.4 Retrieval of author co-citation frequencies 77
4.5 Construction of the raw data matrix and Cosine proximity matrix 79
4.6 Multivariate analysis and mapping of co-citation clusters 82
4.7 Co-cited author connectedness 85
4.8 Factor analysis 85
4.9 Interpretation and validation 90
4.10 Discussion 101

CHAPTER 5: CO-AUTHORSHIP AND COLLABORATION IN SINGULARITY THEORY 116
5.1 Retrieval of co-authorship frequencies and social network illustration 116
5.2 Network density 118
5.3 QAP Correlation 119
5.4 Hierarchical cluster analysis 122
5.5 Interpretation of the ACA-Co-authorship map and clustering routine 125
5.6 First or sole authored publications versus co-authored publications 128
5.7 Collaborative behaviour 130

CHAPTER 6: COLLEGIALITY IN SINGULARITY THEORY AND THE INTERNATIONAL MATHEMATICS RESEARCH INSTITUTE'S ROLE IN FOSTERING INVISIBLE COLLEGE ACTIVITY 144
6.1 CONFERENCE ATTENDANCE AND THE COLLEGIAL NETWORK 146
6.2 NETWORK DENSITY, QAP CORRELATION AND HIERARCHICAL CLUSTER ANALYSIS 151
6.3 THE ISAAC NEWTON INSTITUTE AS AN INFORMATION USE ENVIRONMENT 155
6.4 ETHNOGRAPHY OF COMMUNICATION AT THE ISAAC NEWTON INSTITUTE 157
6.4.1 Gaining entry to the field 158
6.4.2 Physical layout of the Institute, staffing and services 160
6.4.3 The Singularity Theory program 168
6.4.4 The mathematicians' collegial experiences 175
6.5 MEASURING THE NEWTON INSTITUTE'S IMPACT ON MATHEMATICAL ADVANCEMENTS 189

CHAPTER 7: CONCLUSION 196

REFERENCES 232