

**UNIVERSITY OF CALIFORNIA, SAN DIEGO
and
SAN DIEGO STATE UNIVERSITY**

**Students' Development of Models of Magnetic Materials, Patterns of
Group Activity, and Social Norms in a Physics Classroom**

A dissertation submitted in partial satisfaction of the requirements
for the degree Doctor of Philosophy in
Mathematics and Science Education

by

Andrew P. Johnson

Committee in charge:

University of California, San Diego

Professor John Batali
Professor Doug Magde
Professor Gabriele Wienhausen

San Diego State University

Professor Fred Goldberg, Chair
Professor Janet Bowers
Professor Elsa Feher

1999

Copyright
Andrew P. Johnson, 1999
All rights reserved

The dissertation of Andrew Johnson is approved, and it is acceptable in quality and form for publication on microfilm:

Chair

University of California, San Diego

San Diego State University

1999

TABLE OF CONTENTS

Signature Page.....	iii
Table of Contents.....	iv
List of Figures	vi
List of Tables.....	viii
Acknowledgments.....	ix
Vita.....	x
Abstract.....	xi
1. Introduction to Issues.....	1
Understanding Physics Learning in Interactive Guided Inquiry Learning Environments.....	1
Taking Multiple Perspectives on Learning Processes.....	2
Summary.....	6
2. Theoretical Perspective and Review of Literature	9
Overview.....	9
Historical Models of Magnetic Materials.....	9
Student Thinking on Magnetism	23
Cognition in Interaction	30
3. Research Setting and Methods	45
Setting.....	45
Students in the Course.....	65
Research Methods.....	67
4. Analysis of Model Developments	79
Early Ideas.....	79
Nail Models in Cycle II.....	86
Progression of Group Models.....	94
Summary of Model Developments.....	97

5. Analyses of Group Interactions.....	101
Patterns of Interaction During Group Responses	101
Classroom Expectations and Obligations (Norms).....	119
Connections to the Development of Models	134
6. Discussion and Implications	149
Development of Models of Magnetic Materials.....	149
Activities and Norms in the Classroom.....	151
Further Implications	155
Appendix 1: Sample Documents.....	157
Appendix 2: Students' Diagrams of Magnetic Materials.....	175
Appendix 3: Sample Transcript of Group Work.....	205
References.....	227

LIST OF FIGURES

CHAPTER 1

Figure 1-1: Simplified model of classroom processes.....	1
Figure 1-2: A few details of classroom activity	6

CHAPTER 2

Figure 2-1: Gilbert's diagrams of broken magnet behavior, and his tree grafting analogy.....	11
Figure 2-2: Descartes' diagram showing aethereal matter passing through two lodestones	12
Figure 2-3: Aepinus' magnetic fluid model in a nail.	16
Figure 2-4: Aepinus' diagrams to explain breaking a magnet.	17
Figure 2-5: Coulomb's diagram of magnetic molecules.....	20
Figure 2-6: Ampère's current loops in molecules	22
Figure 2-7: A question from Maloney's instrument.	24
Figure 2-8: Magnetism as pulling.....	25
Figure 2-9: Magnetism as a cloud.....	25
Figure 2-10: Magnetism as electricity	25
Figure 2-11: Magnetism as electric polarization.....	26
Figure 2-12: Field model.....	27

CHAPTER 3

Figure 3-1: A single CPU cycle.....	46
Figure 3-2: "Differences" Idea Container with one pocket open.....	53
Figure 3-3: Test stand used to test attraction and repulsion.....	54
Figure 3-4: Prediction and observation tables for the magnet rubbed nail	55
Figure 3-5: Diagram showing how to float and hold nails.....	55
Figure 3-6: Group data and computer simulator picture of orientations around a magnet	56
Figure 3-7: One group's observed results.....	57
Figure 3-8: Group data of stirrer orientations around a wool rubbed styrofoam cup.....	57
Figure 3-9: One group's Cycle I Candidate Ideas.....	58
Figure 3-10: Two different representations of the target magnetism model.....	59
Figure 3-11: Instructions and prediction table	61
Figure 3-12: Diagram of the compass setup	61

Figure 3-13: Diagram of the test tube and compass.....	62
Figure 3-14: Measuring magnetic strength in the simulator.....	64
Figure 3- 15: Groups in the class.	66
Figure 3-16: Overview of analysis schemes.....	70
Figure 3-17: Unit of analysis for magnetism models.....	70
Figure 3-18: Unit of analysis for patterns in group activity.....	72
Figure 3-19: Timeline and event coding terminology.....	73
Figure 3-20: Activity types terminology.....	74
Figure 3- 21: Units of analysis for classroom norms.....	74
Figure 3-22: Students and the class collective product.....	75
Figure 3-23: Relation of small group to whole class interaction	76

CHAPTER 4

Figure 4-1: Charges added or charge condition added	83
Figure 4-2: Numbers of groups using major model types.....	94
Figure 4-3: Pattern of progressions of group's models.....	95
Figure 4-4: Models used by ten groups in the course	96
Figure 4-5: Megan's Unrubbed and Rubbed model diagrams.....	97
Figure 4-6: Megan's broken nail pieces.....	97

CHAPTER 5

Figure 5-1: Group members pointing at nail diagrams	105
Figure 5-2: Different ideas about point - North nails	106
Figure 5-3: Diagrams of broken nail pieces.....	108
Figure 5-4: The picture Marge drew during the above discussion	109
Figure 5-5: Nail pieces question.....	111
Figure 5-6: Students' observations with floating nails and the simulator result.....	113
Figure 5-7: Two different charge separation models	115
Figure 5-8: Types of students' compromises.....	121
Figure 5-9: Marge's and Donna's refrigerator diagrams.....	135
Figure 5-10: First model change within the small group.....	135
Figure 5-11: How Marge thought a magnet would attract unrubbed metal ...	138
Figure 5-12: Second model change within the small group.....	141
Figure 5-13: The group's model and experimental observations.....	141
Figure 5-14: Marge's suggestion on Day 7.....	142
Figure 5-15: Nail diagrams that Anne drew	147

LIST OF TABLES

CHAPTER 2

Table 2-1: Cobb & Yackel's categories for classroom interactions.....	41
---	----

CHAPTER 3

Table 3-1: Schedule of the Static Electricity and Magnetism Unit.....	51
Table 3-2: Slightly modified interpretive framework.....	77

CHAPTER 4

Table 4-1: Individual students' models in Cycle I Elicitation.....	80
Table 4-2: Groups' models in Cycle I Elicitation	85
Table 4-3: Individual students' models in Cycle II Elicitation.....	87
Table 4-4: Group model diagrams in the Elicitation discussion.....	90
Table 4-5: Model diagrams drawn for Activity II-D1.....	91
Table 4-6: Model types beginning and ending II-D3	93
Table 4-7: Variations in Candidate Alignment Models	93

CHAPTER 5

Table 5-1: Categories of activity	102
---	-----

CHAPTER 6

Table 6-1: Model categories from initial Elicitation discussion	149
Table 6-2: Model categories from Cycle II	150

ACKNOWLEDGMENTS

Some people say cognition is dependent on social interactions, and the effort that led to this dissertation was no exception. I am extremely grateful for the many contributions a large number of people made to my thinking and to my work in general. Many people expressed confidence that I could finish this dissertation successfully, even when I wasn't so sure myself.

First of all, thanks to faculty members at UCSD and SDSU who made my graduate program possible. It has expanded my horizons beyond what I imagined when I began. I want to thank all of my fellow doctoral students for helpful conversations, particularly Valerie Otero and Dan Siebert. Valerie forced me again and again to clarify my language, which has made a big difference. Dan's immediate grasp of issues and his abiding love for students has been a great help to my understanding of issues in this dissertation.

I also want to thank my dissertation committee. John Batali pointed out that a falsifiable claim is better than one that can't be checked, and suggested a very helpful book on Garfinkel. Gabrielle Wienhausen reminded me that the teacher is important, and she was right. Elsa Feher spurred me to action and gave me unique perspectives. Doug Magde has always been interested in my ideas. I want to give special thanks to Janet Bowers who patiently helped me refine my understanding of social constructivism and social norms. Her interest in discussions and my struggles to understand pushed us both farther along. Thanks also, Janet, for reading, rereading, and painstakingly annotating versions of this tome and my proposal. If my writing is readable, all of my committee deserves thanks, but especially Janet. Most of all, I wish to thank my advisor and mentor, Fred Goldberg, for his continual encouragement and support, his dedication to physics education, and his thoughtful approach to every idea I offered or struggled with. Fred, who always seems to have time for conversations, is a master of diplomatically supporting critical thinking. He has a knack for asking the question that helps me discover something new. His student - oriented approach to teaching and learning has influenced me fundamentally and permanently. I have enjoyed working with Fred.

I couldn't have done this work without a stable, supportive home life. How can I thank my wife enough? How many dinners did Barb save for me when I came home late again? Barb's patience and unwavering support inspired me to stick with it. I don't know where (or who) I would be without her. Thanks also to Leif and Forest for providing recreation when I was tired of typing.

Finally, I wish to thank the students in the course who were willing to be hardworking students and subjects of research. Most of all I thank Donna, Marge, and Anne, whose thoughtful conversations provided the basis of most of the analyses in Chapter 5.

VITA

Andrew Johnson

- 1957 Born in Denver, Colorado
- 1979-1984 BS in Physics, Colorado School of Mines, Golden, Colorado.
Member of (Engineering) and (Physics) honor societies
- 1984-1987 MS in Physics, Arizona State University, Tempe, Arizona.
Thesis: *The Surface Phase Diagram for Thin Nickel Films on Silicon (111)*
Advisor: Dr. Peter Bennett
- 1987-1988 Visiting Assistant Professor of Physics Canisius College, Buffalo, NY.
- 1988-1989 Visiting Assistant Professor of Physics Whitworth College,
Spokane, WA.
- 1989 - 1994 Senior Laboratory Coordinator for Physics,
Northern Arizona University.
- 1994-1999 Doctoral Candidate in Science Education,
San Diego State University and University of California, San Diego.
Advisor: Dr. Fred Goldberg, SDSU
- 1999 Ph.D. in Science Education,
San Diego State University and University of California, San Diego.

ABSTRACT OF THE DISSERTATION

Students' Development of Models of Magnetic Materials, Patterns of Group Activity, and Social Norms in a Physics Classroom

by

Andrew P. Johnson

Doctor of Philosophy in Science Education

University of California, San Diego

and

San Diego State University, 1999

Professor Fred Goldberg, Chair

This dissertation is a study of students' model development processes in a physical science course for preservice elementary teachers. It details the models of magnetic materials developed and used by students during a unit on static electricity and magnetism. In this inquiry-based course, the class developed and formally accepted a model, in the form of diagrams and descriptions, that is very similar to the accepted magnetic domains model. They did this without textbooks or lectures on magnetism. Before adopting this model, however, most groups in the class temporarily used models involving opposite charges at the two ends of magnetized nails.

How did the students do it? The explanation involves detailed study of the groups' interactions and use of structure in the classroom environment. This dissertation uses two theoretical frameworks to analyze interactions. It applies Yackel and Cobb's (1996) concepts of classroom social norms to characterize aspects of the classroom participation structure which affected groups' construction and declaration of models. It also applies distributed cognition ideas to analyze the sense-making conversations in a small group when constructing group responses.

This research found that conversations in one small group could be characterized into sixteen categories. Important categories included "extending ideas" which involved gradual deepening and elaboration of the group's understanding of their model(s), and "joint typing", an interactive process by which group members collaborated on typed statements or group diagrams and simultaneously developed common language for communicating their ideas to each other. Some of these categories of activity were closely connected to computer use.

Also, four classroom norms are described. One small group social classroom norm involved group members developing a "common ground" consisting of agreed-upon group statements. Three sociophysics norms which characterize the whole class interactions as well as those of the small group involved a distinction between generalizations of phenomena and theoretical statements, class criteria for accepting evidence, and the obligation for each group to have a model of magnetic materials that they could support with acceptable evidence.