Empirical Evaluation of a Technology-rich Learning Environment

by

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(ABSTRACT)

In the fall of 1996, the Computer Science Department at Virginia Tech initiated a joint project with a local school district, to determine how ready access to networked computing in the fifth grade would affect students. Called the PCs for Families (PCF) project, its goal was to learn what could be achieved if technology access, support, and curriculum integration could be eliminated as obstacles or constraints in the classroom and at home. A technology-rich classroom was created, with the classroom teacher trained in constructivist teaching practices and technology integration by a master teacher. Network computers were found on every desktop, with scanners, digital cameras, and other technologies scattered throughout the room. A computer was sent home with each child and teacher, and as much support as necessary was provided to all program participants, including parents. As part of this research, a yearlong field experiment was undertaken to explore the effects of the PCF intervention on the third cohort of students participating in the project. Macroergonomics served as the theoretical framework for the experiment, which focused on the in-depth, systematic assessment of those quantitative changes that resulted from exposure to the PCF fifth-grade network classroom. Students participating in the field research were randomly selected from the larger pool of students eligible for the PCF project at the school. Selected students were randomly assigned to either to the PCF fifth-grade classroom or the standard fifth-grade classroom, which served as a control group.

To first-time visitors walking into the PCF network classroom, the classroom bore little resemblance to its more traditional counterparts. However, the functioning of the PCF classroom was in many ways indistinguishable from that of its traditional counterparts. The yearly average for computer use in the PCF classroom was 4.275 hours, with computer use in the PCF classroom exceeding the three hours of computer laboratory time allotted to the control class only during the last 12 weeks of school. When used, the technology functioned as an electronic replacement for materials commonly found in traditional settings. Observers reported the pedagogy remained steadfastly teacher-centered and didactic. Despite limited utilization of the computer during classroom hours, analysis of individual, academic measures indicated PCF students made significantly greater gains than control students only on standardized writing tests. PCF students also performed significantly better than control students on measures related to technology skills. Boys in the PCF classroom also made greater improvements in their attitudes towards school than boys in the control classroom. At home, PCF students were found to interact with computer technology more often than their control counterparts. Despite lower overall home use, control students reported spending more time playing computer games than PCF students.

Correlational analyses indicated significant linear relationships between changes in student performance, student entry characteristics, and home computer use variables. Previous achievement was by far the strongest predictor of student SOL test performance, with computer use only linked to student standardized test performance on the writing and mathematics sections. As the number of email messages sent by the student increased, their writing performance increased with email usage accounting for almost ten percent of the total variance in the writing score. The only other computer use measure significantly associated with test performance was student self-reports of computer use, which accounted for less than four percent of the total variance in mathematics test performance. Computer use was associated more strongly with changes in student motivation. Student self-reports of home computer use accounted for fully 30 percent of the variance in changes on the school motivation survey.

Analyses of data from the PCF proxy server suggest that student web browsing overshadows other home Internet activities, with email taking precedence over chat. Further, unlike chat or email, family web usage was sustained long after students left the PCF classroom. Over 68 percent of family web usage each week was attributable to student, not family, characteristics suggesting students play a large role in determining family usage. Academic information finding provides a plausible explanation for these results, with family web usage declining somewhat during summer months when students were not in school. Stability of both web and email use was relatively high among students. In keeping with critical mass theory, student email use increased when other students used email. However, social variables were not found to have a significant effect on web usage. Girls were found to make greater use of email than boys, with this research suggesting highly visual students used email more often.

The field research also found a significant increase in student self-reports of musculoskeletal problems among the PCF students. A year-end examination of workstation fit found seat and monitor heights an average of two inches higher than the corresponding student dimensions. A participatory design study was used to elicit conceptions of computer workstations from PCF students, teachers, and parents. Children were interested in gaining greater control over the workstation, both in terms of individual technology and adjustability of furniture. Parents, however, focused on improving the richness of an individual student's workspace and de-emphasized collaborative work. Teacher opinions diverged more than other groups with designs strongly influenced by pedagogic beliefs.

Results from the field study provide evidence that macroergonomic methodologies for analysis and design of work systems are extensible to classroom systems, and provide a systematic framework for examining issues related to the introduction of classroom computing technology. A critical element of any successful effort to integrate technology into the curriculum is access to adequate classroom technology and support; however, as this research illustrates, they are not sufficient to ensure successful integration. This research demonstrates other forces are at work, and in keeping with macroergonomic theory, key to the success of such an effort is the "fit" between the new technology and the characteristics of the classroom system, especially those of the teacher who effectively functions as the gatekeeper for the technology.

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DEDICATION

For Calvin and Hobbes
Always beloved

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TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION ... 1

1.1 PROBLEM STATEMENT ... 2
1.2 FRAMEWORK FOR STUDYING CLASSROOM TECHNOLOGY ... 2
1.3 RESEARCH GOALS ... 3
1.4 RESEARCH SETTING ... 3
1.5 ORGANIZATION OF THIS DOCUMENT ... 4

CHAPTER 2. COMPUTERS AND CLASSROOMS ... 6

2.1 INTRODUCTION ... 7
2.2 CHANGES IN THE CLASSROOM ... 7
2.2.1 Teaching Pedagogies ... 8
2.2.2 Communication Patterns ... 9
2.2.3 Authority Structures ... 10
2.2.4 Physical Setting ... 11
2.2.5 Classroom Efficiency ... 12
2.2.6 Factors Mediating the Effects of Technology in the Classroom ... 12
2.3 CHANGES IN STUDENTS ... 14
2.3.1 Attitudes Towards Self ... 14
2.3.2 Attitudes Towards Learning ... 15
2.3.3 Perceptions of Classroom Life ... 16
2.3.4 Engagement in Learning ... 16
2.3.5 Academic Skills ... 17
2.3.6 Learning Outcomes ... 18
2.3.7 Factors Mediating the Effects of Technology on Students ... 19
2.4 CHANGES IN THE HOME ... 22
2.5 LOOKING FORWARD ... 23

CHAPTER 3. MACROERGONOMICS AS A FRAMEWORK FOR STUDYING CLASSROOM TECHNOLOGY ... 25

3.1 INTRODUCTION ... 26
3.2 SOCIOTECHNICAL SYSTEMS MODEL OF THE CLASSROOM ... 27
3.3 "MACRO" ELEMENTS OF THE CLASSROOM ... 29
3.3.1 Organizational Design ... 29
3.3.2 Technical Subsystem ... 30
3.3.3 Social Subsystem ... 31
3.3.4 Environment ... 32
3.4 "MICRO" ELEMENTS OF THE CLASSROOM ... 32
3.5 MACROERGONOMIC ANALYSIS PROCESS ... 33
3.5.1 Initial Scanning ... 33
3.5.2 Technical Subsystem Analysis ... 34
3.5.3 Technical Work Process Analysis ... 34
3.5.4 Variance Data Collection and Analysis ... 35
3.5.5 Social Analysis ... 36
3.5.6 Organizational, Joint, and Function Design ... 38
3.5.7 Roles and Responsibility Perception Analysis ... 38
3.5.8 Support System and Interface Design ... 38
3.5.9 Implement, iterate, and improve ... 38
3.6 ROLE OF MACROERGONOMICS IN THIS RESEARCH ... 39

CHAPTER 4. A MODEL FOR EVALUATING THE PCS FOR FAMILIES PROJECT 41

4.1 INTRODUCTION 42
4.2 RESEARCH MODEL 42
4.3 RESEARCH HYPOTHESES 44

CHAPTER 5. "MACRO" EVALUATION METHODOLOGY 47

5.1 INTRODUCTION 48
5.2 EXPERIMENTAL DESIGN 48
5.3 DEPENDENT VARIABLES.. 50
5.3.1 Learning Variables 50
5.3.2 Student Attitudinal Variables.. 52
5.3.3 Family Support Variables... 53
5.3.4 Computer Technology Variables 54
5.4 PARTICIPANTS.. 57
5.4.1 Protection of Participant Rights 58
5.5 MATERIALS AND APPARATUS 58
5.5.1 Experimental Instruments 58
5.5.2 Computer Usage Logging... 58
5.5.3 Classroom Video Taping... 59
5.6 PROCEDURE.. 59
5.6.1 Pilot Testing... 59
5.6.2 Data Collection Procedures.. 59

CHAPTER 6. ANALYSIS OF "MACRO" EVALUATION RESULTS 62

6.1 OVERVIEW.. 64
6.2 ANALYSIS OF INDIVIDUAL MEASURES 64
6.2.1 Changes in Student Attitudes and Motivation.. 65
6.2.2 Changes in Student Performance.. 70
6.2.3 Changes in Family Support 79
6.3 PATTERNS AND PREDICTORS OF COMPUTER USAGE 87
6.3.1 Classroom Computer Usage 87
6.3.2 Student Self-Reports of Home Computer Usage 91
6.3.3 Home Internet Usage By PCF Students.. 94
6.3.4 Evolution of Electronic Social Networks 106
6.3.5 Musculoskeletal Effects of PCF Student Computer Use 115
6.4 PATTERNS AND PREDICTORS OF STUDENT CHANGES... 117
6.4.1 Differences in Student Academic Efficiency 118
6.4.2 Patterns of Relationships Among Experimental Measures........................... 121
6.5 BRIEF SUMMARY 136

CHAPTER 7. "MICRO" EVALUATION OF THE PCF CLASSROOM WORKSTATION 137

7.1 INTRODUCTION 138
7.2 BACKGROUND LITERATURE.. 138
7.2.1 Fitting Workstations to Users 139
7.2.2 Supporting Collaboration in the Classroom... 140
7.2.3 Participatory Ergonomics and the Classroom.. 141
7.3 DESIGN OF THE ORIGINAL PCF CLASSROOM WORKSTATION............................ 142
7.3.1 Workspace Design 143
7.3.2 Computer Controls.. 144
7.4 METHODOLOGY 145
7.4.1 Participants... 145
7.4.2 Procedures.. 145
7.5 RESULTS FROM THE PARTICIPATORY SESSIONS.. 147

7.5.1 What Students Want in a Workstation 148
7.5.2 What Parents Think Students Need in a Workstation 151
7.5.3 What Teachers Think Students Need in a Workstation 151

CHAPTER 8. DISCUSSION 153

8.1 OVERVIEW 154
8.2 THE CLASSROOM SETTING 156
8.3 THE HOME ENVIRONMENT 160
8.4 THE STUDENTS 162
8.4.1 Patterns of Internet Use Among PCF Students 164
8.4.2 Patterns of Change Among PCF Students 166
8.5 THE STUDENT WORKSTATIONS 168
8.6 THE RESEARCH METHODOLOGY 170
8.7 IMPLICATIONS OF RESEARCH 173
8.8 DELIMITATIONS AND LIMITATIONS OF THIS RESEARCH 175
8.9 FUTURE DIRECTIONS 176
8.10 CONCLUSIONS 177

CHAPTER 9. REFERENCES 179

APPENDIX A: PCF IRB MATERIALS 204

A.1 PCF IRB PROTOCOL 205
A.2 INFORMED CONSENT FORMS FOR PCF SELECTION PROCESS 212
A.3 INFORMED CONSENT FORM FOR PARENTS 215
A.4 STUDENT ASSENT FORM 219
A.5 SIBLING ASSENT FORM 222

APPENDIX B: EVALUATION INSTRUMENTS 224

B.1 OVERVIEW 225
B.2 CHILD MUSCULOSKELETAL DISCOMFORT SURVEY 226
B.3 FAMILY HOMEWORK EFFORT 227
B.4 HOMEWORK DELIVERY TRACKING FORM 230
B.5 PARENTAL INVOLVEMENT FORM 231
B.6 TRAINING SKILLS CHECKLIST 233
B.6.1 Computer Skills Targeted by PCF Training 236

APPENDIX C: PROCEDURES USED FOR PRELIMINARY TESTING OF DATA 240

APPENDIX D: DESCRIPTIVE INFORMATION AND DETAILED ANALYSIS RESULTS 242

D.1 RESULTS FOR INDIVIDUAL MEASURES 244
D.1.1 Student Attitude and Motivation Results 244
D.1.2 Student Performance Results 261
D.1.3 Family Support Results 280
D.2 PATTERNS AND PREDICTORS OF COMPUTER USAGE 285
D.2.1 Classroom Computer Usage 285
D.2.2 Student Self-Reports of Home Computer Usage 288
D.2.3 Evolution of Electronic Social Networks 295
D.2.4 Physical Effects of PCF Student Computer Use 296
D.3 PATTERNS AND PREDICTORS OF STUDENT CHANGES 297
D.3.1 Differences in Student Academic Efficiency 297
D.3.2 Patterns of Relationships Among Experimental Measures 297

APPENDIX E: SUMMARY TABLES OF SIGNIFICANT CORRELATIONS BETWEEN EVALUATION MEASURES 304

TECHNOLOGY SKILLS 305
TECHNOLOGY USAGE 308
STUDENT ATTITUDES 310
STUDENT PERFORMANCE 312
E.1.1 Homework Process *316*

APPENDIX F: WORKSTATION DESIGNS FROM THE PARTICIPATORY SESSIONS 317

F.1 ISSUES LIST 318
F.2 POST-SESSION STRUCTURED INTERVIEW PROTOCOL 318
F.3 DESIGN SUMMARIES 319

LIST OF FIGURES

FIGURE 3-1. THE SOCIOTECHNICAL SYSTEM MODEL OF THE CLASSROOM IS COMPRISED OF FOUR, INTERDEPENDENT SUBSYSTEMS: SOCIAL, TECHNICAL, ORGANIZATIONAL, AND ENVIRONMENTAL. .. 28
FIGURE 3-2. HIGH-LEVEL CLASSROOM PROCESS MODEL DEVELOPED FOR THE PCS FOR FAMILIES (PCF) PROJECT. 34
FIGURE 3-3. A PORTION OF THE PCF VARIANCE MATRIX. 36
FIGURE 3-4. HIGH-LEVEL ROLE NETWORK DEVELOPED FOR THE PCF CLASSROOM. SOLID LINES REPRESENT ACTUAL PATTERNS, DASHED LINES REPRESENT DESIRED PATTERNS, AND + INDICATES THOSE RELATIONSHIPS WHERE THE PCF INTERVENTION WAS EXPECTED TO RESULT IN MORE FREQUENT COMMUNICATION. 37
FIGURE 4-1. CONCEPTUAL MODEL FOR PCF INTERVENTION. 43
FIGURE 4-2. FACTORS AFFECTING CHANGES IN STUDENT ACHIEVEMENT AND QWL DURING FIFTH GRADE.44
FIGURE 6-1. EFFECT OF CLASS X GENDER INTERACTION ON SCHOOL ATTITUDE MEASURE. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, P > 0.05). POSITIVE VALUES INDICATE IMPROVEMENT. 68
FIGURE 6-2. EFFECT OF PERIOD MAIN EFFECT ON THE PERCENTAGE OF HOMEWORK ASSIGNMENTS DELIVERED ON-TIME. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, *P* > 0.05). 74
FIGURE 6-3. EFFECT OF PERIOD X CLASS INTERACTION ON THE PERCENTAGE OF HOMEWORK ASSIGNMENTS DELIVERED ON-TIME. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, *P* > 0.05). 75
FIGURE 6-4. EFFECT OF CLASS X GENDER INTERACTION ON STUDENT TYPING ACCURACY. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, P > 0.05). 78
FIGURE 6-5. EFFECT OF CLASS X PERIOD ON PARENTS' AVERAGE RATING OF HOME-SCHOOL COMMUNICATION QUALITY. LARGER VALUES INDICATE MORE POSITIVE ATTITUDES. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, *P* > 0.05). 81
FIGURE 6-6. EFFECT OF PERIOD ON PARENTAL SCHOOL CONTACTS. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, *P* > 0.05). 82
FIGURE 6-7. EFFECT OF MODE X CLASS INTERACTION ON PARENTAL SCHOOL CONTACTS. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, *P* > 0.05). 82
FIGURE 6-8. EFFECT OF THE DIRECT X ROLE INTERACTION ON THE NUMBER OF WEEKLY, EMAIL INTERACTIONS WITH PARENTS. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, *P* < 0.01). 84
FIGURE 6-9. PARENT INITIATED EMAIL COMMUNICATION AMONG PCF PARENTS AND TEACHERS FOR THE 1998-1999 SCHOOL YEAR. SQUARES INDICATE PARENTS, T1 REPRESENTS THE CLASSROOM TEACHER, AND T2 DENOTES THE CLASSROOM TECHNOLOGIST. 84
FIGURE 6-10. TEACHER INITIATED EMAIL COMMUNICATION AMONG PCF PARENTS AND TEACHERS FOR THE 1998-1999 SCHOOL YEAR. SQUARES INDICATE PARENTS, T1 REPRESENTS THE CLASSROOM TEACHER, AND T2 INDICATES THE CLASSROOM TECHNOLOGIST. LINES DENOTE EMAIL COMMUNICATION BETWEEN INDIVIDUALS, WITH LINE WIDTH DENOTING FREQUENCY. 85
FIGURE 6-11. CHANGES IN EMAIL ENABLED PARENT - STAFF COMMUNICATION DURING THE SCHOOL YEAR. T1 REPRESENTS THE CLASSROOM TEACHER, AND T2 INDICATES THE CLASSROOM TECHNOLOGIST. . 85
FIGURE 6-12. EFFECT OF CLASS X PERIOD INTERACTION ON THE TIME PARENTS SPENT HELPING STUDENTS WITH HOMEWORK. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, *P* > 0.05). 86
FIGURE 6-13. CHANGES IN THE AVERAGE DAILY AMOUNT OF CLASSROOM COMPUTER USE ACROSS THE SCHOOL YEAR. 89
FIGURE 6-14. CHANGES IN CLASSROOM APPLICATION USE OVER THE COURSE OF THE SCHOOL YEAR. 90
FIGURE 6-15. EFFECT OF PERIOD ON APPLICATION USE IN THE PCF CLASSROOM. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, *P* > 0.05). 90

FIGURE 6-16. EFFECT OF PERIOD ON TIME SPENT USING THE HOME COMPUTER. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, *P* > 0.05). 92
FIGURE 6-17. CHANGES IN INTERNET TECHNOLOGY ACCESS AMONG PCF STUDENTS. 94
FIGURE 6-18. DIFFERENCES IN THE PERCENTAGE OF STUDENTS ACCESSING THE AVAILABLE INTERNET TECHNOLOGIES. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, *P* > 0.05).95
FIGURE 6-19. DIFFERENCES IN THE PERCENTAGE OF DAYS EACH MONTH STUDENTS ACCESSED INTERNET TECHNOLOGY. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, P > 0.05). 96
FIGURE 6-20. DIFFERENCES IN THE PERCENTAGE OF DAYS EACH MONTH STUDENTS ACCESSED THE DIFFERENT INTERNET TECHNOLOGIES. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, *P* > 0.05). 96
FIGURE 6-21. WEEKLY NUMBER OF FAMILY WWW ACCESSES BY STUDENT GENDER. 99
FIGURE 6-22. DISTRIBUTION OF THE TOTAL NUMBER OF WWW ACCESSES MADE BY FAMILIES DURING THE FIELD EXPERIMENT. 99
FIGURE 6-23. WEEKLY NUMBER OF EMAIL MESSAGES SENT BY STUDENTS.. 101
FIGURE 6-24. WEEKLY NUMBER OF EMAIL MESSAGES SENT TO STUDENTS.. 101
FIGURE 6-25. DISTRIBUTION OF THE NUMBER OF STUDENT EMAIL MESSAGES OVER THE COURSE OF THE FIELD EXPERIMENT. 102
FIGURE 6-26. WEEKLY CHAT USAGE BY STUDENTS. 103
FIGURE 6-27. DISTRIBUTION OF THE NUMBER OF CHAT LINES FOR STUDENTS DURING THE YEAR. 104
FIGURE 6-28. GROUP SIZES DURING CHAT SESSIONS.. 105
FIGURE 6-29. EFFECT OF GENDER X CATEGORY INTERACTION ON HOME CHAT USAGE. MEANS WITH THE SAME LABEL ARE NOT SIGNIFICANTLY DIFFERENT (LSD, *P* > 0.05)... 106
FIGURE 6-30. GRAPH OF THE EMAIL COMMUNICATION NETWORK AMONG PCF STUDENTS AND TEACHERS FOR THE YEAR. SQUARES INDICATE BOYS, CIRCLES DENOTE GIRLS, T1 REPRESENTS THE CLASSROOM TEACHER, AND T2 DENOTES THE CLASSROOM TECHNOLOGIST. LINES INDICATE EMAIL COMMUNICATION BETWEEN INDIVIDUALS, WITH LINE WIDTH INDICATING FREQUENCY.................. 107
FIGURE 6-31. GRAPH OF THE CHAT COMMUNICATION NETWORK AMONG PCF STUDENTS AND TEACHERS FOR THE YEAR. SQUARES INDICATE BOYS, CIRCLES DENOTE GIRLS, T1 REPRESENTS THE CLASSROOM TEACHER, AND T2 DENOTES THE CLASSROOM TECHNOLOGIST. LINES INDICATE CHAT COMMUNICATION BETWEEN INDIVIDUALS, WITH LINE WIDTH INDICATING FREQUENCY.................. 108
FIGURE 6-32. CHANGES IN STUDENT-TEACHER NETWORK DENSITY AS A FUNCTION OF COMMUNICATION MEDIUM AND THE NUMBER OF WEEKS SINCE THE HOME NETWORK TECHNOLOGY WAS FIRST AVAILABLE. STUDENTS LEFT THE NETWORK CLASSROOM DURING WEEK 36...................................... 109
FIGURE 6-33. DIFFERENCES IN NETWORK DENSITY FOR STUDENT-TEACHER AND STUDENT-ONLY EMAIL COMMUNICATION NETWORKS. STUDENTS LEFT THE NETWORK CLASSROOM DURING WEEK 36. 110
FIGURE 6-34. SUMMARY ROLE NETWORK FOR PCF PARTICIPANTS.. 115
FIGURE 6-35. COUNTS OF STUDENT CITING PAIN IN A PARTICULAR BODY AREA ON THE *CHILD DISCOMFORT SURVEY*.. 116
FIGURE 6-36. . IMPACT OF STUDENT ENTRY ACHIEVEMENT ON STUDENT DEA EFFICIENCY SCORE. 119
FIGURE 6-37. RELATIONSHIP DIAGRAM FOR DEPENDENT MEASURES AND SIMPLIFIED CONCEPTUAL MODEL ELEMENTS. 122
FIGURE 6-38. AVERAGE LINKAGE DENDOGRAM, R-ANALYSIS OF VARIABLES FROM THE SIMPLIFIED CONCEPTUAL MODEL. * INDICATES MEASURES THAT WERE CONVERTED TO RANKS FOR ANALYSIS.128
FIGURE 7-1. SHARED WORKSTATION USED FOR THE PCF CLASSROOM INTERVENTION. 143
FIGURE 7-2. PROTOTYPE WORKSTATION THAT COULD BE LITERALLY DIVIDED IN HALF ALONG THE LINE SHOWN IN THE PHOTO. EACH HALF COULD FUNCTION INDEPENDENTLY WHEN DIVIDED.................. 149
FIGURE 7-3. PROTOTYPE WORK SURFACE THAT WAS DIVIDED INTO THREE AREAS: THE COMMON PORTION SUPPORTING THE MONITOR AND TWO SEPARATE STUDENT WORK SURFACES. 150
FIGURE 7-4. DOLL-SHAPED CPU CREATED BY A TEAM OF GIRLS DURING PARTICIPATORY SESSIONS. 150
FIGURE 8-1. LAYOUT OF THE PCF CLASSROOM IN THE NEW SCHOOL. PICTURE TAKEN FROM CLASSROOM DOORWAY. 158
FIGURE F-9-1. WORKSTATION DESIGN PRODUCED BY THE CHILD2 TEAM. 321

FIGURE F-9-2. WORKSTATION REVISED BY PARENTS FOR STUDENTS. NOTE THAT DESIGN FACILITATES INDIVIDUAL COMPUTER WORK BUT DISCOURAGES COLLABORATION ON COMPUTER TASKS AS STUDENTS WILL SIT BACK-TO-BACK WHEN WORKING AT THE COMPUTER. 324

LIST OF TABLES

TABLE 3-1. THE PCF INTERVENTION IN TERMS OF THE STS CONCEPTUAL MODEL. 40
TABLE 5-1. ALTERNATIVE DEPENDENT VARIABLES FOR LEARNING PERFORMANCE....... 51
TABLE 5-2. ALTERNATIVE DEPENDENT VARIABLES FOR HOMEWORK PROCESS. 52
TABLE 5-3. STUDENT ATTITUDINAL DEPENDENT VARIABLES....... 53
TABLE 5-4. FAMILY SUPPORT DEPENDENT VARIABLES. 54
TABLE 5-5. COMPUTER ATTITUDE DEPENDENT VARIABLES....... 54
TABLE 5-6. TECHNOLOGY USAGE DEPENDENT VARIABLES....... 56
TABLE 5-7. TECHNOLOGY "FIT" DEPENDENT VARIABLES....... 57
TABLE 6-1. SUMMARY DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER INTERACTION OF THE SCHOOL ATTENDANCE MEASURES. A NEGATIVE VALUE INDICATES IMPROVED ATTENDANCE. 65
TABLE 6-2. SUMMARY DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER INTERACTION OF CHANGES IN SAM SCORES OVER THE COURSE OF FIFTH GRADE. A POSITIVE VALUE INDICATES IMPROVEMENT.67
TABLE 6-3. SUMMARY DESCRIPTIVE INFORMATION FOR CLASS EFFECT ON CHANGES IN KNUDSON WRITING SCORES. A POSITIVE VALUE INDICATES IMPROVEMENT. 69
TABLE 6-4. SUMMARY DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION OF STUDENT COMPUTER ATTITUDE MEASURES. HIGHER SCORES INDICATE BETTER ATTITUDES TOWARDS COMPUTERS. 70
TABLE 6-5. SUMMARY DESCRIPTIVE INFORMATION FOR FIFTH GRADE SOL SCALED SCORES....... 72
TABLE 6-6. SUMMARY DESCRIPTIVE INFORMATION FOR CHANGES IN STUDENT GPA. A POSITIVE VALUE INDICATES IMPROVEMENT....... 73
TABLE 6-7. SUMMARY DESCRIPTIVE INFORMATION FOR CLASS X PERIOD INTERACTION OF THE HOMEWORK PERFORMANCE MEASURES. 73
TABLE 6-8. SUMMARY DESCRIPTIVE INFORMATION FOR THE STUDENT TECHNICAL SKILLS AND KNOWLEDGE MEASURES. 77
TABLE 6-9. SUMMARY DESCRIPTIVE INFORMATION FOR THE FAMILY SUPPORT MEASURES. 80
TABLE 6-10. DESCRIPTIVE STATISTICS FOR NETWORK CLASSROOM COMPUTER USE BY 12-WEEK PERIOD.89
TABLE 6-11. SUMMARY DESCRIPTIVE INFORMATION FOR THE STUDENT SELF-REPORTS OF HOME COMPUTER USE. SELF-REPORT VALUES ARE GIVEN IN MINUTES....... 91
TABLE 6-12. TEST OF SIGNIFICANCE OF FAMILY WWW USAGE MODEL PARAMETERS. 100
TABLE 6-13. TEST OF SIGNIFICANCE OF EMAIL USAGE MODEL PARAMETERS. 103
TABLE 6-14. TEST OF SIGNIFICANCE OF CHAT USAGE MODEL PARAMETERS....... 104
TABLE 6-15. TEST OF SIGNIFICANCE OF MODEL PARAMETERS FOR STUDENT EMAIL CENTRALITY....... 112
TABLE 6-16. TEST OF SIGNIFICANCE OF MODEL PARAMETERS FOR STUDENT CHAT CENTRALITY. 113
TABLE 6-17. TEST OF SIGNIFICANCE OF MODEL PARAMETERS FOR STUDENT EMAIL PRESTIGE. 114
TABLE 6-18. SUMMARY DESCRIPTIVE INFORMATION FOR THE STUDENT SELF-REPORTS OF MUSCULOSKELETAL COMPLAINTS. HIGHER VALUES INDICATE GREATER DISCOMFORT. 116
TABLE 6-19. DEGREE OF DISPARITY BETWEEN STUDENT BODY DIMENSIONS AND PCF CLASSROOM WORKSTATION DIMENSIONS. ALL VALUES ARE GIVEN IN INCHES. 117
TABLE 6-20. SUMMARY OF INPUT AND OUTPUT MEASURES INCLUDED IN THE DEA MODEL. 119
TABLE 6-21. SUMMARY DESCRIPTIVE INFORMATION FOR DEA EFFICIENCY SCORES. 119
TABLE 6-22. TEST OF SIGNIFICANCE OF EMPIRICAL MODEL PARAMETERS FOR ACADEMIC EFFICACY SCORES OF THE PCF STUDENTS....... 121
TABLE 6-23. SUMMARY INFORMATION FOR CANONICAL CORRELATION ANALYSES OF SOLUTION CLUSTERS. F* IS THE APPROXIMATE F VALUE FOR THE HYPOTHESIS THAT ALL CANONICAL CORRELATIONS ARE ZERO. 129
TABLE 6-24. TEST OF SIGNIFICANCE OF MODEL PARAMETERS FOR GPA GAIN....... 130
TABLE 6-25. TEST OF SIGNIFICANCE OF MODEL PARAMETERS FOR AVERAGE WEEKLY PERCENTAGE OF HOMEWORK ON-TIME. 131
TABLE 6-26. TEST OF SIGNIFICANCE OF MODEL PARAMETERS FOR SOL READING SS. 131
TABLE 6-27. TEST OF SIGNIFICANCE OF MODEL PARAMETERS FOR SOL WRITING SCORES....... 132
TABLE 6-28. TEST OF SIGNIFICANCE OF EMPIRICAL MODEL PARAMETERS FOR SOL SOCIAL STUDIES SS.. 132

TABLE 6-29. TEST OF SIGNIFICANCE OF MODEL PARAMETERS FOR SOL SCIENCE SS. 133
TABLE 6-30. TEST OF SIGNIFICANCE OF EMPIRICAL MODEL PARAMETERS FOR SOL MATHEMATICS SS. ... 133
TABLE 6-31. TEST OF SIGNIFICANCE OF MODEL PARAMETERS FOR SOL TECHNOLOGY SCORES. 134
TABLE 6-32. TEST OF SIGNIFICANCE OF MODEL PARAMETERS FOR ABSENCE GAIN. 134
TABLE 6-33. TEST OF SIGNIFICANCE OF EMPIRICAL MODEL PARAMETERS FOR SAM NP CHANGE. 135
TABLE 6-34. TEST OF SIGNIFICANCE OF MODEL PARAMETERS FOR KNUDSON SURVEY SCORE CHANGE. .. 136
TABLE 7-1. SUMMARY TABLE OF PROBLEMS WITH PCF WORKSTATION. FIVE CHILD TEAMS, FOUR PARENT TEAMS, AND 2 TEACHERS PARTICIPATED IN THE STUDY. 148
TABLE 8-1. SUMMARY RESEARCH HYPOTHESES AND EXPECTED OUTCOMES FOR PCF STUDENTS AND PARENTS. 156
TABLE D-1. MEANS (*M*) AND STANDARD DEVIATIONS (*STD*) FOR THE CLASS EFFECT ON THE ATTENDANCE MEASURES. 244
TABLE D-2. MEANS AND STANDARD DEVIATIONS FOR THE GENDER EFFECT ON THE ATTENDANCE MEASURES. 244
TABLE D-3. MEANS AND STANDARD DEVIATIONS FOR THE CLASS X GENDER INTERACTION OF THE ATTENDANCE MEASURES. 244
TABLE D-4. MANOVA RESULTS FOR THE EFFECT OF CLASS ON ATTENDANCE MEASURES. 244
TABLE D-5. MANOVA RESULTS FOR THE EFFECT OF GENDER ON ATTENDANCE MEASURES. 244
TABLE D-6. MANOVA RESULTS FOR THE EFFECT OF CLASS X GENDER INTERACTION ON ATTENDANCE MEASURES. 245
TABLE D-7. SUMMARY DESCRIPTIVE INFORMATION FOR CHANGES IN SAM SCORES OVER THE COURSE OF FIFTH GRADE. 245
TABLE D-8. ANOVA SUMMARY TABLE FOR OVERALL SAM MEASURE. 245
TABLE D-9. ANOVA SUMMARY TABLE FOR THE SAM / MOTIVATION FOR SCHOOLING MEASURE. 246
TABLE D-10. ANOVA SUMMARY TABLE FOR THE SAM / STUDENT'S SENSE OF CONTROL OVER PERFORMANCE MEASURE. 246
TABLE D-11. ANOVA SUMMARY TABLE FOR THE SAM / ACADEMIC SELF-CONCEPT -- PERFORMANCE BASED MEASURE. 247
TABLE D-12. ANOVA SUMMARY TABLE FOR THE SAM / ACADEMIC SELF-CONCEPT -- REFERENCE BASED MEASURE. 247
TABLE D-13. ANOVA SUMMARY TABLE FOR THE SAM / STUDENT'S INSTRUCTIONAL MASTERY MEASURE.247
TABLE D-14. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER INTERACTION OF CUMULATIVE CHANGE IN THE KNUDSON WRITING ATTITUDE SURVEY SCORE. 248
TABLE D-15. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE KNUDSON WRITING ATTITUDE SURVEY SCORE. 248
TABLE D-16. DESCRIPTIVE INFORMATION FOR THE GENDER X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE KNUDSON WRITING ATTITUDE SURVEY SCORE. 248
TABLE D-17. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE KNUDSON WRITING ATTITUDE SURVEY SCORE. 248
TABLE D-18. ANOVA SUMMARY TABLE FOR CUMULATIVE CHANGES IN THE KNUDSON WRITING SCORE.249
TABLE D-19. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER INTERACTION OF CUMULATIVE CHANGES IN THE PREFERS WRITING SCALE SCORE. 249
TABLE D-20. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE PREFERS WRITING SCALE SURVEY SCORE. 249
TABLE D-21. DESCRIPTIVE INFORMATION FOR THE GENDER X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE PREFERS WRITING SCALE SURVEY SCORE. 250
TABLE D-22. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE PREFERS WRITING SCALE SURVEY SCORE. 250
TABLE D-23. ANOVA SUMMARY TABLE FOR PREFERS WRITING SCALE CUMULATIVE CHANGES. 250
TABLE D-24. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER INTERACTION OF CUMULATIVE CHANGES IN THE POSITIVE VIEW OF SELF AS A WRITER SCALE SCORE. 251
TABLE D-25. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE POSITIVE VIEW OF SELF AS A WRITER SCALE SURVEY SCORE. 251

TABLE D-26. DESCRIPTIVE INFORMATION FOR THE GENDER X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE POSITIVE VIEW OF SELF AS A WRITER SCALE SURVEY SCORE. ... 251
TABLE D-27. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE POSITIVE VIEW OF SELF AS A WRITER SCALE SURVEY SCORE. ... 251
TABLE D-28. ANOVA SUMMARY TABLE FOR POSITIVE VIEW OF SELF AS A WRITER SCALE CUMULATIVE CHANGES. ... 252
TABLE D-29. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER INTERACTION OF CUMULATIVE CHANGES IN THE COMPETENT WRITER SCALE SCORE. ... 252
TABLE D-30. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE COMPETENT WRITER SCALE SURVEY SCORE. ... 252
TABLE D-31. DESCRIPTIVE INFORMATION FOR THE GENDER X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE COMPETENT WRITER SCALE SURVEY SCORE. ... 253
TABLE D-32. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE COMPETENT WRITER SCALE SURVEY SCORE. ... 253
TABLE D-33. ANOVA SUMMARY TABLE FOR COMPETENT WRITER SCALE CUMULATIVE CHANGES. ... 253
TABLE D-34. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER INTERACTION OF CUMULATIVE CHANGES IN THE WRITING ACHIEVEMENT SCALE SCORE. ... 254
TABLE D-35. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE WRITING ACHIEVEMENT SCALE SURVEY SCORE. ... 254
TABLE D-36. DESCRIPTIVE INFORMATION FOR THE GENDER X PERIOD SCORE. ... 254
TABLE D-37. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE WRITING ACHIEVEMENT SCALE SURVEY SCORE. ... 254
TABLE D-38. ANOVA SUMMARY TABLE FOR WRITING ACHIEVEMENT SCALE CUMULATIVE CHANGES... 255
TABLE D-39. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER INTERACTION OF CUMULATIVE CHANGES IN THE IMPORTANCE OF WRITING SCALE SCORE. ... 255
TABLE D-40. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE IMPORTANCE OF WRITING SCALE SURVEY SCORE. ... 255
TABLE D-41. DESCRIPTIVE INFORMATION FOR THE GENDER X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE IMPORTANCE OF WRITING SCALE SURVEY SCORE. ... 256
TABLE D-42. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE IMPORTANCE OF WRITING SCALE SURVEY SCORE. ... 256
TABLE D-43. ANOVA SUMMARY TABLE FOR IMPORTANCE OF WRITING SCALE CUMULATIVE CHANGES. 256
TABLE D-44. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER INTERACTION OF CUMULATIVE CHANGES IN THE LETTER/NOTE WRITING SCALE SCORE. ... 257
TABLE D-45. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE LETTER/NOTE WRITING SCALE SURVEY SCORE. ... 257
TABLE D-46. DESCRIPTIVE INFORMATION FOR THE GENDER X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE LETTER/NOTE WRITING SCALE SURVEY SCORE. ... 257
TABLE D-47. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER X PERIOD INTERACTION OF CUMULATIVE CHANGES IN THE LETTER/NOTE WRITING SCALE SURVEY SCORE. ... 257
TABLE D-48. ANOVA SUMMARY TABLE FOR LETTER/NOTE SCALE CUMULATIVE CHANGES. ... 258
TABLE D-49. DESCRIPTIVE INFORMATION FOR THE PERIOD MAIN EFFECT OF THE STUDENT COMPUTER ATTITUDES MEASURE. ... 258
TABLE D-50. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER INTERACTION OF THE STUDENT COMPUTER ATTITUDES MEASURE. ... 258
TABLE D-51. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION OF THE STUDENT COMPUTER ATTITUDES MEASURE. ... 259
TABLE D-52. DESCRIPTIVE INFORMATION FOR THE PERIOD X GENDER INTERACTION OF THE STUDENT COMPUTER ATTITUDES MEASURE. ... 259
TABLE D-53. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER X PERIOD INTERACTION OF THE STUDENT COMPUTER ATTITUDES MEASURE. ... 259
TABLE D-54. ANOVA SUMMARY TABLE FOR STUDENT COMPUTER ATTITUDES. ... 259
TABLE D-55. DESCRIPTIVE INFORMATION FOR THE PERIOD MAIN EFFECT OF THE STUDENT COMPUTER WRITING ATTITUDES MEASURE. ... 260

TABLE D-56. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION OF THE STUDENT COMPUTER WRITING ATTITUDES MEASURE. 260
TABLE D-57. ANOVA SUMMARY TABLE FOR STUDENT COMPUTER WRITING ATTITUDES. 260
TABLE D-58. MEANS AND STANDARD DEVIATIONS FOR THE CLASS EFFECT OF SOL ENGLISH: READING / LITERATURE AND RESEARCH SCALED SCORES. 261
TABLE D-59. MEANS AND STANDARD DEVIATIONS FOR THE GENDER EFFECT OF SOL ENGLISH: TEACHING / LITERATURE AND RESEARCH SCALED SCORES. 261
TABLE D-60. MEANS AND STANDARD DEVIATIONS FOR THE CLASS X GENDER INTERACTION OF SOL ENGLISH: TEACHING / LITERATURE AND RESEARCH SCALED SCORES. 262
TABLE D-61. MANOVA RESULTS FOR THE EFFECT OF THE COVARIATE ON SCALED SCORES FROM THE SOL ENGLISH: TEACHING / LITERATURE AND RESEARCH CATEGORY. 262
TABLE D-62. MANOVA RESULTS FOR THE EFFECT OF CLASS ON SCALED SCORES FROM THE SOL ENGLISH: TEACHING / LITERATURE AND RESEARCH CATEGORY. 262
TABLE D-63. MANOVA RESULTS FOR THE EFFECT OF GENDER ON SCALED SCORES FROM THE SOL ENGLISH: TEACHING / LITERATURE AND RESEARCH CATEGORY. 262
TABLE D-64. MANOVA RESULTS FOR THE EFFECT OF CLASS X GENDER INTERACTION ON SCALED SCORES FROM THE SOL ENGLISH: READING / LITERATURE AND RESEARCH CATEGORY. 263
TABLE D-65. MEANS AND STANDARD DEVIATIONS FOR THE CLASS EFFECT OF SOL ENGLISH: WRITING SCALED SCORES. 263
TABLE D-66. MEANS AND STANDARD DEVIATIONS FOR THE GENDER EFFECT OF SOL ENGLISH: WRITING SCALED SCORES. 263
TABLE D-67. MEANS AND STANDARD DEVIATIONS FOR THE CLASS X GENDER INTERACTION OF SOL ENGLISH: WRITING SCALED SCORES. 263
TABLE D-68. MANOVA RESULTS FOR THE EFFECT OF THE COVARIATE ON SCALED SCORES FROM THE SOL ENGLISH: WRITING CATEGORY. 264
TABLE D-69. MANOVA RESULTS FOR THE EFFECT OF CLASS ON SCALED SCORES FROM THE SOL ENGLISH: WRITING CATEGORY. 264
TABLE D-70. MANOVA RESULTS FOR THE EFFECT OF GENDER ON SCALED SCORES FROM THE SOL ENGLISH: WRITING CATEGORY. 264
TABLE D-71. MANOVA RESULTS FOR THE EFFECT OF CLASS X GENDER INTERACTION ON SCALED SCORES FROM THE SOL ENGLISH: WRITING CATEGORY. 264
TABLE D-72. ANOVA SUMMARY TABLE FOR THE SOL COMPOSING WRITTEN EXPRESSION SCALED SCORE. 264
TABLE D-73. ANOVA SUMMARY TABLE FOR THE SOL WRITING USAGE-MECHANICS SCALED SCORE. 265
TABLE D-74. MEANS AND STANDARD DEVIATIONS FOR THE CLASS EFFECT OF SOL MATHEMATICS SCALED SCORES. 265
TABLE D-75. MEANS AND STANDARD DEVIATIONS FOR THE GENDER EFFECT OF SOL MATHEMATICS SCALED SCORES. 265
TABLE D-76. MEANS AND STANDARD DEVIATIONS FOR THE CLASS X GENDER INTERACTION OF SOL MATHEMATICS SCALED SCORES. 266
TABLE D-77. MANOVA RESULTS FOR THE EFFECT OF THE COVARIATE ON SCALED SCORES FROM THE SOL MATHEMATICS CATEGORY. 266
TABLE D-78. MANOVA RESULTS FOR THE EFFECT OF CLASS ON SCALED SCORES FROM THE SOL MATHEMATICS CATEGORY. 266
TABLE D-79. MANOVA RESULTS FOR THE EFFECT OF GENDER ON SCALED SCORES FROM THE SOL MATHEMATICS CATEGORY. 266
TABLE D-80. MANOVA RESULTS FOR THE EFFECT OF CLASS X GENDER INTERACTION ON SCALED SCORES FROM THE SOL MATHEMATICS CATEGORY 267
TABLE D-81. MEANS AND STANDARD DEVIATIONS FOR THE CLASS EFFECT OF SOL HISTORY AND SOCIAL STUDIES SCALED SCORES. 267
TABLE D-82. MEANS AND STANDARD DEVIATIONS FOR THE GENDER EFFECT OF SOL HISTORY AND SOCIAL STUDIES SCALED SCORES 267
TABLE D-83. MEANS AND STANDARD DEVIATIONS FOR THE CLASS X GENDER INTERACTION OF SOL HISTORY AND SOCIAL STUDIES SCALED SCORES. 267

TABLE D-84. MANOVA RESULTS FOR THE EFFECT OF THE COVARIATE ON SCALED SCORES FROM THE SOL HISTORY AND SOCIAL STUDIES CATEGORY. 268
TABLE D-85. MANOVA RESULTS FOR THE EFFECT OF CLASS ON SCALED SCORES FROM THE SOL HISTORY AND SOCIAL STUDIES CATEGORY. 268
TABLE D-86. MANOVA RESULTS FOR THE EFFECT OF GENDER ON SCALED SCORES FROM THE SOL HISTORY AND SOCIAL STUDIES CATEGORY. 268
TABLE D-87. MANOVA RESULTS FOR THE EFFECT OF CLASS X GENDER INTERACTION ON SCALED SCORES FROM THE SOL HISTORY AND SOCIAL STUDIES CATEGORY. 268
TABLE D-88. ANOVA SUMMARY TABLE FOR THE SOL HISTORY SCALED SCORE. 268
TABLE D-89. ANOVA SUMMARY TABLE FOR THE SOL GEOGRAPHY SCALED SCORE. 269
TABLE D-90. ANOVA SUMMARY TABLE FOR THE SOL ECONOMICS SCALED SCORE. 269
TABLE D-91. ANOVA SUMMARY TABLE FOR THE SOL CIVICS SCALED SCORE. 269
TABLE D-92. MEANS AND STANDARD DEVIATIONS FOR THE CLASS EFFECT OF SOL SCIENCE SCALED SCORES. 269
TABLE D-93. MEANS AND STANDARD DEVIATIONS FOR THE GENDER EFFECT OF SOL SCIENCE SCALED SCORES. 270
TABLE D-94. MEANS AND STANDARD DEVIATIONS FOR THE CLASS X GENDER INTERACTION OF SOL SCIENCE SCALED SCORES. 270
TABLE D-95. MANOVA RESULTS FOR THE EFFECT OF THE COVARIATE ON SCALED SCORES FROM THE SOL SCIENCE CATEGORY. 270
TABLE D-96. MANOVA RESULTS FOR THE EFFECT OF CLASS ON SCALED SCORES FROM THE SOL SCIENCE CATEGORY. 270
TABLE D-97. MANOVA RESULTS FOR THE EFFECT OF GENDER ON SCALED SCORES FROM THE SOL SCIENCE CATEGORY. 270
TABLE D-98. MANOVA RESULTS FOR THE EFFECT OF CLASS X GENDER INTERACTION ON SCALED SCORES FROM THE SOL SCIENCE CATEGORY. 271
TABLE D-99. MEANS AND STANDARD DEVIATIONS FOR THE CLASS EFFECT ON SUBJECT GRADE CHANGES. 271
TABLE D-100. MEANS AND STANDARD DEVIATIONS FOR THE GENDER EFFECT ON SUBJECT GRADE CHANGES. 271
TABLE D-101. MEANS AND STANDARD DEVIATIONS FOR THE CLASS X GENDER INTERACTION ON SUBJECT GRADE CHANGES. 271
TABLE D-102. MANOVA RESULTS FOR THE EFFECT OF CLASS ON SUBJECT GRADE CHANGES. 272
TABLE D-103. MANOVA RESULTS FOR THE EFFECT OF GENDER ON SUBJECT GRADE CHANGES. 272
TABLE D-104. MANOVA RESULTS FOR THE EFFECT OF CLASS X GENDER INTERACTION ON SUBJECT GRADE CHANGES. 272
TABLE D-105. ANOVA SUMMARY TABLE FOR CHANGES IN THE LANGUAGE ARTS GPA. 272
TABLE D-106. ANOVA SUMMARY TABLE FOR CHANGES IN THE MATHEMATICS GPA. 272
TABLE D-107. ANOVA SUMMARY TABLE FOR CHANGES IN THE SCIENCE GPA. 273
TABLE D-108. ANOVA SUMMARY TABLE FOR CHANGES IN THE SCIENCE GPA. 273
TABLE D-109. DESCRIPTIVE INFORMATION FOR THE PERIOD MAIN EFFECT ON THE PERCENTAGE OF HOMEWORK ASSIGNMENTS DELIVERED ON-TIME. 273
TABLE D-110. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER INTERACTION ON THE PERCENTAGE OF HOMEWORK ASSIGNMENTS DELIVERED ON-TIME. 273
TABLE D-111. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION ON THE PERCENTAGE OF HOMEWORK ASSIGNMENTS DELIVERED ON-TIME. 274
TABLE D-112. DESCRIPTIVE INFORMATION FOR THE PERIOD X GENDER INTERACTION ON THE PERCENTAGE OF HOMEWORK ASSIGNMENTS DELIVERED ON-TIME. 274
TABLE D-113. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER X PERIOD INTERACTION ON THE PERCENTAGE OF HOMEWORK ASSIGNMENTS DELIVERED ON-TIME. 274
TABLE D-114. ANOVA SUMMARY TABLE FOR THE RANKS OF THE PERCENTAGE OF HOMEWORK ASSIGNMENTS DELIVERED ON-TIME. 274
TABLE D-115. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER INTERACTION OF AVERAGE DAILY TIME SPENT ON HOMEWORK ACTIVITIES (MINUTES). 275

TABLE D-116. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION OF AVERAGE DAILY TIME SPENT ON HOMEWORK ACTIVITIES (MINUTES). 275
TABLE D-117. DESCRIPTIVE INFORMATION FOR THE GENDER X PERIOD INTERACTION OF AVERAGE DAILY TIME SPENT ON HOMEWORK ACTIVITIES (MINUTES). 275
TABLE D-118. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER X PERIOD INTERACTION OF AVERAGE DAILY TIME SPENT ON HOMEWORK ACTIVITIES (MINUTES). 275
TABLE D-119. ANOVA SUMMARY TABLE FOR AVERAGE DAILY TIME SPENT ON HOMEWORK ACTIVITIES.276
TABLE D-120. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER INTERACTION OF THE HOMEWORK BEHAVIOR CHECKLIST MEASURE. 276
TABLE D-121. SUMMARY OF NON-PARAMETRIC TESTS PREFORMED ON THE HOMEWORK PROBLEM CHECKLIST MEASURE. 276
TABLE D-122. MEANS AND STANDARD DEVIATIONS FOR THE CLASS EFFECT ON STUDENT COMPUTER TASK SCORES. 277
TABLE D-123. MEANS AND STANDARD DEVIATIONS FOR THE GENDER EFFECT ON STUDENT COMPUTER TASK SCORES. 277
TABLE D-124. MEANS AND STANDARD DEVIATIONS FOR THE CLASS X GENDER INTERACTION ON STUDENT COMPUTER TASK SCORES. 277
TABLE D-125. MANOVA RESULTS FOR THE EFFECT OF CLASS ON STUDENT COMPUTER TASK SCORES. 277
TABLE D-126. MANOVA RESULTS FOR THE EFFECT OF GENDER ON STUDENT COMPUTER TASK SCORES.278
TABLE D-127. MANOVA RESULTS FOR THE EFFECT OF CLASS X GENDER INTERACTION ON STUDENT COMPUTER TASK SCORES. 278
TABLE D-128. ANOVA SUMMARY TABLE FOR STUDENT TRAINING SKILLS SCORE. 278
TABLE D-129. ANOVA SUMMARY TABLE FOR STUDENT TYPING ACCURACY. 278
TABLE D-130. ANOVA SUMMARY TABLE FOR STUDENT TYPING SPEED. 278
TABLE D-131. MEANS AND STANDARD DEVIATIONS FOR THE CLASS EFFECT OF SOL COMPUTER / TECHNOLOGY CATEGORY SCALED SCORES. 279
TABLE D-132. MEANS AND STANDARD DEVIATIONS FOR THE GENDER EFFECT OF SOL COMPUTER / TECHNOLOGY CATEGORY SCALED SCORES. 279
TABLE D-133. MEANS AND STANDARD DEVIATIONS FOR THE CLASS X GENDER INTERACTION OF SOL COMPUTER / TECHNOLOGY CATEGORY SCALED SCORES. 279
TABLE D-134. MANOVA RESULTS FOR THE EFFECT OF CLASS ON SCALED SCORES FROM THE SOL COMPUTER / TECHNOLOGY CATEGORY. 279
TABLE D-135. MANOVA RESULTS FOR THE EFFECT OF GENDER ON SCALED SCORES FROM THE SOL COMPUTER / TECHNOLOGY CATEGORY. 279
TABLE D-136. MANOVA RESULTS FOR THE EFFECT OF CLASS X GENDER INTERACTION ON SCALED SCORES FROM THE SOL COMPUTER / TECHNOLOGY CATEGORY. 280
TABLE D-137. DESCRIPTIVE INFORMATION FOR PERIOD EFFECT OF PARENT RATINGS OF HOME-SCHOOL COMMUNICATION. 280
TABLE D-138. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION ON PARENT RATINGS OF HOME-SCHOOL COMMUNICATION. 280
TABLE D-139. ANOVA SUMMARY TABLE FOR PARENT RATINGS OF HOME-SCHOOL COMMUNICATION. 281
TABLE D-140. DESCRIPTIVE INFORMATION FOR PERIOD EFFECT OF AVERAGE WEEKLY PARENTAL SCHOOL CONTACTS. 281
TABLE D-141. DESCRIPTIVE INFORMATION FOR THE PERIOD X MODE INTERACTION OF AVERAGE WEEKLY PARENTAL SCHOOL CONTACTS. 281
TABLE D-142. DESCRIPTIVE INFORMATION FOR THE CLASS X MODE INTERACTION OF AVERAGE WEEKLY PARENTAL SCHOOL CONTACTS. 281
TABLE D-143. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION OF AVERAGE WEEKLY PARENTAL SCHOOL CONTACTS. 282
TABLE D-144. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD X MODE INTERACTION OF AVERAGE WEEKLY PARENTAL SCHOOL CONTACTS. 282
TABLE D-145. ANOVA SUMMARY TABLE FOR THE RANKS OF THE AVERAGE WEEKLY PARENTAL SCHOOL CONTACTS. 282

TABLE D-146. DESCRIPTIVE INFORMATION FOR THE DIRECT X ROLE INTERACTION OF PARENT-TEACHER E-MAIL COMMUNICATION AMONG PCF PARTICIPANTS. 283
TABLE D-147. ANOVA OF RANKS SUMMARY TABLE FOR PARENT-TEACHER E-MAIL COMMUNICATION AMONG PCF PARTICIPANTS. 283
TABLE D-148. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER INTERACTION OF AVERAGE DAILY PARENTAL HOMEWORK TIME (MINUTES). 283
TABLE D-149. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION OF AVERAGE DAILY PARENTAL HOMEWORK TIME (MINUTES). 284
TABLE D-150. DESCRIPTIVE INFORMATION FOR THE GENDER X PERIOD INTERACTION OF AVERAGE DAILY PARENTAL HOMEWORK TIME (MINUTES). 284
TABLE D-151. DESCRIPTIVE INFORMATION FOR THE CLASS X GENDER X PERIOD INTERACTION OF AVERAGE DAILY PARENTAL HOMEWORK TIME (MINUTES). 284
TABLE D-152. ANOVA SUMMARY TABLE FOR OF AVERAGE DAILY PARENTAL HOMEWORK TIME. 284
TABLE D-153. DESCRIPTIVE INFORMATION FOR PERIOD EFFECT ON PARENT SELF-REPORTS OF TIME SPENT SUPPORTING SCHOOL ACTIVITIES. 285
TABLE D-154. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION ON PARENT SELF-REPORTS OF TIME SPENT SUPPORTING SCHOOL ACTIVITIES. 285
TABLE D-155. ANOVA SUMMARY TABLE FOR THE RANKS OF PARENTAL SELF-REPORTS OF TIME SPENT SUPPORTING SCHOOL ACTIVITIES. 285
TABLE D-156. DESCRIPTIVE STATISTICS FOR CLASSROOM WEEKLY INTERNET APPLICATION USE BY 12-WEEK PERIOD. MINUTES ARE THE UNIT OF MEASUREMENT. 286
TABLE D-157. DESCRIPTIVE STATISTICS FOR CLASSROOM WEEKLY PRODUCTION APPLICATION USE BY 12-WEEK PERIOD. MINUTES ARE THE UNIT OF MEASUREMENT 286
TABLE D-158. DESCRIPTIVE STATISTICS FOR CLASSROOM WEEKLY APPLICATION USE IN THE OTHER CATEGORY BY 12-WEEK PERIOD. MINUTES ARE THE UNIT OF MEASUREMENT. 286
TABLE D-159. ANCOVA OF RANKS SUMMARY TABLE FOR CLASSROOM APPLICATION USE BY CATEGORY. 286
TABLE D-160. DESCRIPTIVE STATISTICS FOR THE CLASSROOM BREADTH OF APPLICATION USE MEASURE BY 12-WEEK PERIOD. 287
TABLE D-161. ANCOVA SUMMARY TABLE FOR CLASSROOM APPLICATION BREADTH MEASURE. 287
TABLE D-162. DESCRIPTIVE STATISTICS FOR WEEKLY CLASSROOM WEB USAGE BY 12-WEEK PERIOD. 287
TABLE D-163. ANCOVA SUMMARY TABLE FOR CLASSROOM WEB USAGE. 287
TABLE D-164. DESCRIPTIVE INFORMATION FOR PERIOD EFFECT OF TIME SPENT USING HOME COMPUTER. 288
TABLE D-165. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION ON TIME SPENT USING HOME COMPUTER. 288
TABLE D-166. DESCRIPTIVE INFORMATION FOR PERIOD EFFECT OF TIME SPENT PLAYING GAMES ON HOME COMPUTER. 288
TABLE D-167. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION ON TIME SPENT PLAYING GAMES ON HOME COMPUTER. 288
TABLE D-168. ANOVA SUMMARY TABLE FOR THE RANKS OF TIME SPENT PLAYING GAMES ON HOME COMPUTER. 289
TABLE D-169. DESCRIPTIVE INFORMATION FOR PERIOD EFFECT OF TIME CONNECTED TO THE INTERNET FROM HOME. 289
TABLE D-170. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION ON TIME CONNECTED TO THE INTERNET FROM HOME. 289
TABLE D-171. ANOVA SUMMARY TABLE FOR RANKS OF TIME CONNECTED TO THE INTERNET FROM HOME. 290
TABLE D-172. DESCRIPTIVE INFORMATION FOR THE CLASS X PERIOD INTERACTION OF DAILY AVERAGE HOMEWORK-RELATED COMPUTER USAGE (MINUTES). 290
TABLE D-173. ANOVA OF RANKS SUMMARY TABLE FOR DAILY AVERAGE HOMEWORK-RELATED COMPUTER USAGE. 290
TABLE D-174. DESCRIPTIVE INFORMATION FOR THE GENDER X MEDIUM INTERACTION OF TECHNOLOGY UTILIZATION PERCENTAGE BY PCF STUDENTS. 291
TABLE D-175. ANOVA SUMMARY TABLE FOR THE RANKS OF TECHNOLOGY UTILIZATION PERCENTAGE BY PCF STUDENTS. 291

TABLE D-176. DESCRIPTIVE INFORMATION FOR MEDIUM EFFECT ON THE PERCENTAGE OF DAYS EACH MONTH PCF STUDENTS USED INTERNET TECHNOLOGIES. ... 291
TABLE D-177. DESCRIPTIVE INFORMATION FOR MONTH EFFECT ON THE PERCENTAGE OF DAYS EACH MONTH PCF STUDENTS USED INTERNET TECHNOLOGIES. ... 292
TABLE D-178. DESCRIPTIVE INFORMATION FOR THE MONTH X GENDER INTERACTION OF THE PERCENTAGE OF DAYS EACH MONTH PCF STUDENTS USED INTERNET TECHNOLOGIES. ... 292
TABLE D-179. DESCRIPTIVE INFORMATION FOR THE GENDER X MEDIUM INTERACTION OF THE PERCENTAGE OF DAYS EACH MONTH PCF STUDENTS USED INTERNET TECHNOLOGIES. ... 292
TABLE D-180. DESCRIPTIVE INFORMATION FOR THE MEDIUM X MONTH INTERACTION OF THE PERCENTAGE OF DAYS EACH MONTH PCF STUDENTS USED INTERNET TECHNOLOGIES. ... 293
TABLE D-181. ANOVA SUMMARY TABLE FOR THE RANKS OF THE PERCENTAGE OF DAYS EACH MONTH PCF STUDENTS USED INTERNET TECHNOLOGIES. ... 293
TABLE D-182. FIT STATISTICS FOR FAMILY WWW USAGE MODEL. ... 294
TABLE F-183. FIT STATISTICS FOR STUDENT EMAIL USAGE MODEL. ... 294
TABLE D-184. ANOVA SUMMARY TABLE FOR THE RANKS OF CHAT USAGE MODEL. ... 294
TABLE D-185. DESCRIPTIVE INFORMATION FOR THE CATEGORY MAIN EFFECT OF THE CHAT CATEGORIES OF USE ANALYSIS. ... 294
TABLE D-186. DESCRIPTIVE INFORMATION FOR THE GENDER X CATEGORY INTERACTION OF THE CHAT CATEGORIES OF USE ANALYSIS. ... 295
TABLE D-187. ANOVA SUMMARY TABLE FOR THE CHAT CATEGORIES OF USE. ... 295
TABLE D-188. ANOVA SUMMARY TABLE FOR THE RANKS OF EMAIL CENTRALITY MODEL. ... 295
TABLE D-189. ANOVA SUMMARY TABLE FOR THE RANKS OF EMAIL PRESTIGE MODEL. ... 295
TABLE D-190. ANOVA SUMMARY TABLE FOR CHAT CENTRALITY MODEL. ... 296
TABLE D-191. DESCRIPTIVE INFORMATION FOR THE PERIOD MAIN EFFECT OF THE STUDENT DISCOMFORT MEASURE. ... 296
TABLE D-192. DESCRIPTIVE INFORMATION FOR THE GENDER X PERIOD INTERACTION OF THE STUDENT DISCOMFORT MEASURE. ... 296
TABLE D-193. ANOVA OF RANKS SUMMARY TABLE FOR STUDENT DISCOMFORT MEASURE. ... 296
TABLE D-194. ANOVA SUMMARY TABLE FOR OF DEA ACADEMIC EFFICIENCY SCORES. ... 297
TABLE D-195. REGRESSION SUMMARY TABLE FOR DEA EFFICIENCY SCORES OF PCF STUDENTS. ... 297
TABLE D-196. STANDARDIZED CANONICAL COEFFICIENTS FOR TECHNOLOGY USE, TECHNOLOGY USE - QWL CANONICAL ANALYSIS. ... 297
TABLE D-197. STANDARDIZED CANONICAL COEFFICIENTS FOR QWL, TECHNOLOGY USE - QWL CANONICAL ANALYSIS. ... 297
TABLE D-198. STANDARDIZED CANONICAL COEFFICIENTS FOR TECHNOLOGY USE, TECHNOLOGY USE - STUDENT PERFORMANCE CANONICAL ANALYSIS. ... 298
TABLE D-199. STANDARDIZED CANONICAL COEFFICIENTS FOR STUDENT PERFORMANCE, TECHNOLOGY USE - STUDENT PERFORMANCE CANONICAL ANALYSIS. ... 298
TABLE D-200. STANDARDIZED CANONICAL COEFFICIENTS FOR QWL, QWL - STUDENT PERFORMANCE CANONICAL ANALYSIS. ... 298
TABLE D-201. STANDARDIZED CANONICAL COEFFICIENTS FOR STUDENT PERFORMANCE, QWL - STUDENT PERFORMANCE CANONICAL ANALYSIS. ... 298
TABLE D-202. MEASURE SET USED FOR R-ANALYSIS OF OUTCOME MEASURES. * INDICATES MEASURES THAT WERE CONVERTED TO RANK DATA PRIOR TO ANALYSIS. ... 299
TABLE D-203. RESEMBLENCE MATRIX FOR R-ANALYSIS OF OUTCOME MEASURES. NUMBERS CORRESPOND TO SPECIFIC MEASURES IN THE PREVIOUS TABLE. ... 300
TABLE D-204. STANDARDIZED CANONICAL COEFFICIENTS FOR GROUP1, GROUP1 - GROUP 3 CANONICAL ANALYSIS. ... 301
TABLE D-205. STANDARDIZED CANONICAL COEFFICIENTS FOR GROUP 3, GROUP1 - GROUP 3 CANONICAL ANALYSIS. ... 301
TABLE D-206. REGRESSION SUMMARY TABLE FOR GPA CHANGES OF PCF STUDENTS. ... 301
TABLE D-207. REGRESSION SUMMARY TABLE FOR THE AVERAGE WEEKLY PERCENTAGE OF HOMEWORK ASSIGNMENTS DELIVERED ON-TIME BY PCF STUDENTS. ... 302
TABLE D-208. REGRESSION SUMMARY TABLE FOR SOL READING SS OF PCF STUDENTS. ... 302

TABLE D-209. REGRESSION SUMMARY TABLE FOR SOL WRITING SS OF PCF STUDENTS. 302
TABLE D-210. REGRESSION SUMMARY TABLE FOR SOL SCIENCE SS OF PCF STUDENTS. 302
TABLE D-211. REGRESSION SUMMARY TABLE FOR SOL MATHEMATICS SS OF PCF STUDENTS. 302
TABLE D-212. REGRESSION SUMMARY TABLE FOR SOL TECHNOLOGY SS OF PCF STUDENTS. 303
TABLE D-213. REGRESSION SUMMARY TABLE FOR ABSENCE CHANGE OF PCF STUDENTS. 303
TABLE D-214. REGRESSION SUMMARY TABLE FOR SAM NP CHANGE OF PCF STUDENTS. 303
TABLE D-215. REGRESSION SUMMARY TABLE FOR KNUDSON WRITING SURVEY CHANGE OF PCF STUDENTS. 303
TABLE E-1. SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR THE COMPUTER TASK PERFORMANCE MEASURES. 305
TABLE E-2. SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR THE SOL TECHNOLOGY MEASURES. ... 306
TABLE E-3. SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR STUDENT SELF-REPORTS OF HOME COMPUTER USE. 308
TABLE E-4. SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR PCF STUDENT NETWORK USAGE. 309
TABLE E-5. SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR THE STUDENT ATTITUDE SURVEY CHANGES. 310
TABLE E-6. SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR THE ATTENDANCE CHANGES. 311
TABLE E-7. SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR THE SOL SUBJECT SCALED SCORES. ... 312
TABLE E-8. SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR STUDENT GRADE GAINS. 314
TABLE E-9. SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR THE SOL HOMEWORK PROCESS MEASURES. 316

LIST OF ACRONYMS

ANOVA	Analysis of Variance
ANCOVA	Analysis of Covariance
CAI	Computer-assisted-instruction
GLM	General Linear Model
i.i.d.	Independent and identically distributed data.
IRB	Institutional Review Board
MANOVA	Multivariate Analysis of Variance
MANCOVA	Multivariate Analysis of Covariance
MMPI	Murphy-Meisgeiner Type Indicator
PCF	PCs for Families Project
RGLM	Rank General Linear Model
SAM	School Attitude Measure
SOL	Standards of Learning
STD	Standard Deviation
STS	Sociotechnical Systems

CHAPTER 1. INTRODUCTION

Chapter Table of Contents

1.1 PROBLEM STATEMENT......2
1.2 FRAMEWORK FOR STUDYING CLASSROOM TECHNOLOGY......2
1.3 RESEARCH GOALS......3
1.4 RESEARCH SETTING......3
1.5 ORGANIZATION OF THIS DOCUMENT......4

1.1 Problem Statement

Recent investments by U.S. educators have put a wide range of computer technology in the hands of students and teachers. In 1999, the U.S. Department of Education reported 89 percent of schools and 51 percent of all instructional rooms were connected to the Internet. During the 1995-1996 school year alone, U.S. schools spent somewhere between $3.5 and $4 billion on K-12 educational technology (President's Panel on Educational Technology, 1997), with spending increasing in subsequent years. Given the magnitude of these investments, the public might expect that educators and researchers have a clear understanding of how computers can best be used to maximize educational benefits and what the long-term impact of computers will be on educational productivity. However, despite extensive anecdotal evidence as to the value of this recent influx of classroom computer technology, the available empirical studies provide no conclusive evidence of its value (Coley, 1997; Conte, 1998; Oppenheimer, 1997; President’s Panel on Educational Technology, 1997; Trotter, 1997; Viadero, 1997). Results from existing studies are often difficult to generalize due to methodological issues such as non-random assignment of subjects, lack of control groups, and small sample sizes (Glennan and Melmed, 1996; Madinach and Cline, 1997; President’s Panel on Educational Technology, 1997). Additional empirical studies are needed to determine the merit of recent investments in classroom technology (President’s Panel on Educational Technology, 1997).

1.2 Framework For Studying Classroom Technology

Frameworks used for studies investigating the impact of classroom technology generally examine the classroom in either a piecemeal fashion or from a more systematic perspective, but lack mechanisms for integrating the two perspectives. The first perspective is a “micro” approach that focuses on the qualities of the technology and its interface with individual students. The other is a “macro” approach that views the classroom as an organization, where the qualities of students, teachers, and the classroom, along with those of the technology, influence learning outcomes. Both the “micro” and “macro” approaches have their limitations. Even the most ergonomic and pedagogically advanced educational software can be rendered ineffective when coupled with inappropriate teaching strategies (Pea, 1996). Similarly, an exceptional technology-rich learning environment may prove ineffectual if students cannot easily manipulate computer controls. An analysis approach that considers both the “micro” and “macro” elements of the classroom is needed.

One approach that incorporates both the “macro” and “micro” aspects of systems in the analysis process is macroergonomics. A systems-based approach, macroergonomics combines sociotechnical system methodology with traditional ergonomic methods and techniques. It is a “top-down sociotechnical system approach to organization and work system design, and the design of related human-machine, user, and human-environment interfaces.” (Hendrick, 1986, 1991). Macroergonomic studies of technology interventions in adult organizations have repeatedly found that overall performance of a system is optimized only when the “macro” and “micro” elements of a system have been ergonomically designed and are in alignment with each other (Beekun, 1989; Hendrick, 1991; Kleiner, 1996; Livari and Hirschheim, 1996).

Within the macroergonomic framework, the classroom can be viewed as a learning system comprised of four interdependent elements: social, technical, organizational, and environmental. This breakdown is especially appropriate when the goal of researchers is to understand how classroom computer technology impacts other elements of the system, namely the students, teachers, and overall learning process. Macroergonomic methodologies for analysis and design of work systems are expected to be extensible to classroom systems, and should provide a robust framework for examining issues related to the introduction of classroom computing technology.

1.3 Research Goals

This research focused on developing a better understanding of the effects of constructivist, technology-rich learning environments on the learning performance and behaviors of elementary students. In particular, this research attempted to

1. Empirically determine the effect of one such environment, specifically the PCs for Families network classroom, on student performance and behaviors.

2. Provide insights into patterns and predictors of Internet usage among elementary students and their families, as well as the relationship between student usage patterns and student changes.

3. Explore the “fit” of the theoretical model underlying the PCs for Families project.

4. Investigate the efficacy of macroergonomic methods and techniques for evaluating the impact of classroom and home technology on students.

Such information should provide valuable guidance to educators or designers seeking to determine how computers can best be used to maximize educational benefits or what the long-term impact of computers will be on educational productivity.

1.4 Research Setting

The context for this research was the PCs For Families Project (PCF), a three-year program sponsored by the U.S. Department of Education, which examines the effect of network computer technology on rural students and their families. During the fifth grade, students in the program were to experience a constructivist approach to learning[1] combined with ubiquitous network computer technology, in both the school and the home. The project sent a computer home with each child and teacher, and provided as much support as necessary to all program participants, including parents. Students, along with their parents, received training in using the technology to facilitate the learning process. After a year in the PCF classroom, students returned to a normal classroom but kept their home computer technology and Internet access. Throughout the course of the project, teachers, students, and families in the program had access to on-call computer system support in both the classroom and home. The research described here focuses on the in-depth assessment of the third cohort of students to enter the program and is limited to the students' first year in the PCF program.

1.5 Organization of this Document

This document is organized as follows.

Chapter 1 provides a brief introduction to this research.

Chapter 2, *Computers and Classrooms*, summarizes previous research on technology-rich classrooms.

Chapter 3, *Macroergonomics as a Framework For Studying Classroom Technology*, provides a brief introduction to macroergonomic methodology, presents issues related to its application in classroom settings, and discusses the role macroergonomics played in this research.

Chapter 4, *A Model for Evaluating the PCs for Families Project*, summarizes the research strategy at the "macro" and "micro" levels, discusses the underlying research model, and presents research hypotheses.

Chapter 5, *Field Evaluation Methodology*, describes the experimental design and procedures for the year-long field study used to empirically evaluate the effect of the PCF intervention on the third cohort of PCF students during the 1998-1999 school year.

Chapter 6, *Analysis of Field Evaluation Results*, summarizes the results for the field experiment discussed in the previous chapter.

Chapter 7, *A Participatory Study of the PCF Classroom Workstations*, describes a micro-level study involving PCF students, parents, and

[1] The basic assumption behind constructivism is that all knowledge is actively constructed by individuals performing meaningful activities (Mahoney, 1991). Constructivist learning practices include reflective thinking, consideration of multiple perspectives, project based learning, student collaboration, and student access to domain experts (Grabe and Grabe, 1998). Within this framework, the teacher serves as the coach and facilitator of the learning process (Bruer, 1993; Grabe and Grabe, 1998).

teachers that focused on the evaluation and re-design of the shared student workstations in the PCF network classroom.

Chapter 8, *Discussion,* discusses the implications of the field experiment and participatory study, including conclusions and future research implications.

Following these chapters are supporting appendices that provide more detailed information and subject materials. The appendices are organized as follows.

Appendix A, *PCF IRB Materials,* presents the PCF Institutional Review Board (IRB) submittal. The research described here represents a subset of the PCF research and is covered by the PCF submittal.

Appendix B, *Evaluation Instruments,* contains the surveys and checklists developed or modified for the field experiment.

Appendix C, *Procedures Used For Preliminary Testing of Data*, summarizes the underlying assumptions of analysis techniques and the procedures used to verify the data satisfied those assumptions.

Appendix D, *Descriptive Information and Detailed Analysis Results for Individual Evaluation Measures*, contains individual data descriptions and detailed analysis results for the field experiment.

Appendix E, *Summary Tables of Significant Correlations Between Evaluation Measures,* summarizes the significant Spearman's Rank Correlations between field experiment measures.

Appendix F, *Workstation Designs From the Participatory Sessions,* contains materials for the participatory study and detailed information about each design produced by teams participating in the study.

CHAPTER 2. COMPUTERS AND CLASSROOMS

Chapter Table of Contents

2.1 INTRODUCTION 7
2.2 CHANGES IN THE CLASSROOM 7
2.2.1 Teaching Pedagogies 8
2.2.2 Communication Patterns 9
2.2.3 Authority Structures 10
2.2.4 Physical Setting 11
2.2.5 Classroom Efficiency 12
2.2.6 Factors Mediating the Effects of Technology in the Classroom 12
2.3 CHANGES IN STUDENTS 14
2.3.1 Attitudes Towards Self 14
2.3.2 Attitudes Towards Learning 15
2.3.3 Perceptions of Classroom Life 16
2.3.4 Engagement in Learning 16
2.3.5 Academic Skills 17
2.3.6 Learning Outcomes 18
2.3.7 Factors Mediating the Effects of Technology on Students 19
2.3.7.1 Social Influences 20
2.3.7.2 Individual Differences 20
2.3.7.3 Effects of Time on Technology Use 22
2.4 CHANGES IN THE HOME 22
2.5 LOOKING FORWARD 23

2.1 Introduction

Today’s classrooms and homes are part of an on-going and immense technological “experiment” fueled by public dollars and parental enthusiasm. This “experiment” involves introducing computers into the classroom and home in hopes of improving student learning and the quality of educational experiences. Extensive anecdotal evidence can be found supporting the value of educational uses of computer technology, and a variety of research studies have examined the effects of technology in the classroom and home. However, the mere presence of computers in the classroom does not guarantee educational improvements. This chapter summarizes previous research on technology-rich settings and briefly discusses factors mediating the effects of classroom technology.

Earlier research provides evidence that the effects of classroom technology can go far beyond that of the technology itself. Classroom computer technology has been linked to improved attitudes and motivation towards school on the part of the students (*e.g.*, Follansbee, 1996), changes in student-teacher interactions (*e.g.*, Collins, 1991), shifts from didactic to constructivist teaching practices (*e.g.*, Schofield and Verban, 1988), gains on learning measures by students (*e.g.*, Honey and Henriquez, 1996), increased student collaboration (*e.g.*, David, 1992), changes to the physical classroom (*e.g.*, McCreary, Reaux, Ehrich, Rowland, and Hood., 1998), and even changes in family-school involvement (*e.g.*, Rockman, 1995). As the primary aim of this research was investigating the impact of network technology on students in the classroom and home, this section focuses on technology-related changes in the classroom, students, and home environment.

2.2 Changes in the Classroom

In many classrooms, learning is largely dependent on tools, practices, and techniques that for the most part have not changed greatly in the last century (Papert, 1992). Adding computer technology, by and of itself, does little to change classroom functioning (Coley, 1997). Rather, change results from what is done with the technology. Ideally, students and teachers see the technology as a tool for facilitating learning rather than as an end into itself (Campoy, 1992; Conte, 1998; Shaw, 1996; Trotter, 1997; Viadero, 1997). Typically, computers serve primarily as 1) tools for carrying out classroom tasks, 2) integrated learning systems, and 3) educational simulations or games (Collins, 1991).

Available evidence suggests that the nature of classroom changes is directly related to the manner in which the technology is integrated into the curriculum and the “richness” of technology (Coley, 1997; Shaw, 1996). The ratio of students to computers is the usual measure of “richness” (Coley, 1997; Shaw, 1996), while usage is often categorized as either a replacement use, *e.g.*, electronic workbooks, or an emergent use, *e.g.*, exploratory use of video-conferencing (Caporael and Thorngate, 1984; McInerney, 1989).

2.2.1 *Teaching Pedagogies*

After technology is introduced, teachers often transition from traditional, didactic teaching methods to more constructivist[2] and collaborative approaches to learning (Gearhart, Herman, Baker, Whittaker, and Novak, 1990; Schofield and Verban, 1988) resulting in more student-centered classrooms (Collins, 1991; Gayle and Thompson, 1995; Gutherie and Richardson, 1995; Honey and Henriquez, 1996; Rockman, 1995; Sandholtz, Ringstaff, and Dwyer, 1990; Swan and Mitrani, 1993). Teachers in student-centered classrooms facilitate learning activities and set learning objectives, but do not specify how students must go about fulfilling those objectives (Bryson, 1992; Collins, 1991; David, 1992; Gearhart *et al.*, 1990; Means and Olson, 1995a; Schofield and Verban, 1988; Strommen and Lincoln, 1992; Van Dusen and Worthen, 1995). Studies suggest on the order of a 60% decrease in teacher-led activities in student-centered classrooms (Gearhart, *et al.*, 1990). Teachers lecture less and students talk more (Collins, 1991; David, 1992; Honey and Henriquez, 1996; Means and Olson, 1995a). This is very different from traditional classrooms where teachers generally do most of the talking from the front of the classroom (Adams, 1970). With less emphasis on lecturing, teachers also circulate more throughout the classroom (Collins, 1991; David, 1992; Means and Olson, 1995a).

Collaborative and cooperative learning activities are more common in technology-rich classrooms (Collins, 1991; David, 1992; Dwyer, Ringstaff, and Sandholtz, 1991; Gayle and Thompson, 1995; Herman, 1988; Honey and Henriquez, 1996; Swan and Mitrani, 1993; Rockman, 1995; Tierney, Kieffer, Stowell, Desai, Whalin, and Moss, 1995; Wilson and Peterson, 1995). Students collaborate and cooperate more when working on computer tasks than when working on non-computer ones (Hawkins, Homolsky, and Heide, 1984), with 66% of students working with others on computer assignments (Becker, 1991). Much of the increase in collaboration is simple economics; pairing children cuts technology costs by 50 percent. However, students who are assigned individual computers will often work with other students on learning activities (Watson, 1991). Computer displays make student work public and increase the likelihood that students will become involved in the activities of others (Hawkins *et al.*, 1984; Means and Olson, 1995).

Numerous benefits have been attributed to collaborative learning including increased motivation, increased student autonomy, and improved attitudes toward self, school and other students (Blaney, Stephan, Rosenfield, Aronson, and Sikes, 1977; Cooper, Johnson, Johnson, and Wilderson, 1980; Johnson and Johnson, 1987; Sharan, 1980). Meta-analyses of collaborative learning indicate students perform achievement-wise no worse and often better than in working individually (Johnson and Johnson, 1989; Johnson, Maruyama, Johnson, Nelson, and Skon,

[2] The basic assumption behind constructivism is that all knowledge is actively constructed by individuals performing meaningful activities (Mahoney, 1991). Constructivist learning practices include reflective thinking, consideration of multiple perspectives, project based learning, student collaboration, and student access to domain experts (Grabe and Grabe, 1998).

1981; Slavin, 1980). Similar benefits occur when students share a classroom computer (Hawkins, *et al.*, 1984; Inkpen, Booth, Gribble, and Klawa, 1995; McLellan, 1994; Peters, 1996). For instance, studies indicate children who work in groups on Computer-Assisted Instruction (CAI) [3] programs perform no worse (Carrier and Sales, 1987; Schlechter, 1990) and often better than those working individually (Dalton, Hannafin, and Hooper, 1989, Johnson, Johnson, and Stanne, 1986). Teasley (1995) found students working in pairs both on or off the computer were found to reason more effectively than students working individually. Inkpen *et al.* (1995) found that children playing a problem-solving game together on a single computer scored higher than children playing alone. Similarly, Blaye *et al.* (1991) found pairs of students performed better than individuals on a complex computer-based planning task. Performance and learning improvements are thought to result from increases in giving versus merely receiving information (Webb, 1988); increased student verbalizations (Hooper, 1992, King, 1990), and Vygotsky's (1978) theory of proximal development[4].

While shifts to student-centered or collaborative teaching practices do not require technology, computers, especially networked ones, can support these innovations in many ways, making the techniques more feasible in a range of educational settings. Technology can facilitate application of these approaches by providing new forums for student collaboration, fostering critical inquiry by facilitating access to new information, facilitating student communication with the outside world, and providing tools for storing and presenting information in ways that support student knowledge construction. Technology also offers opportunities for shared creation, *e.g.*, the joint virtual world building at the Human Interface Technology Laboratory (Bricken and Byrne, 1993) and negotiation of joint decision-making, *e.g.*, group decision support systems. Technology also provides a framework for shared collective understanding. Schrange (1990) found the technologies that were most beneficial for collaborative learning were the ones that establish a shared space for participants. Examples of these technologies include computer conferencing tools, electronic whiteboards, and collaborative notebooks such as the Collaboratory. Such tools encourage the negotiation of meaning among participants and promote the development of a distributed, collective intelligence for virtual learning communities.

2.2.2 Communication Patterns

Once the classroom was a fairly isolated unit, where communication was primarily synchronous and the teacher acted as the gatekeeper to the outside

[3] Unlike the technology-rich approach to classroom computing which puts general purpose computer technology in the hands of students, the CAI approach focuses on the student gaining specific knowledge or skills using specially designed instructional software, *e.g.*, drill and practice software.
[4] Vtgotsky defined the zone of proximal development as "the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." In practical terms, it means that the techniques individuals learn while collaborating will be used independently by the student the next time a similar situation is encountered.

world. Computer technology and network communications can change the nature of classroom interactions and enlarge classroom communication networks for both students and teachers. Classroom technology can diversify both student and teacher communications and simplify asynchronous communication for classroom members.

Network technology has been credited with expanding student communication networks (Ehrich and Kavanaugh, 2000; Honey and Henriquez, 1996; Matusevich, 2000; Wilson and Peterson, 1995), and despite critic predictions (*e.g.,* Langeveld, 1983), computers have not socially isolated students (David, 1992; Wilson and Peterson, 1995). Instead, the technology facilitates communication between classroom inhabitants and the larger world (Ehrich and Kavanaugh, 2000; Honey and Henriquez, 1996; Matusevich, 2000; Wilson and Peterson, 1995). Email, chat, teleconferencing and other network technologies provide a medium for interaction and collaboration outside classroom boundaries.

Computer technology is also credited with changing teacher perceptions of student classroom conversations. In traditional instructional settings, talk is regarded as noise that must be suppressed (Cazden, 1986). Most verbal interchanges in traditional classrooms are teacher-initiated with students generally controlling classroom conversation less than one quarter of the time (Dillon, 1988; Green, Harker, and Golden, 1987; Mehan, 1979; Mehan, 1985). However, in technology-rich classrooms, student verbalizations increase (Hawkins, Sheingold, Gearhart, and Berger, 1982; Means and Olson, 1995a; Sandholtz *et al.*, 1990). Verbal interaction between teachers and students also increases (David, 1992; Wilson and Peterson, 1995) and social interaction becomes a desired element of learning activities (Hertz-Lazarowitz and Shache, 1990). Teachers and students in networked computing projects which provide home access also report substantial increases in teacher-student out of classroom communication (Honey and Henriquez, 1996; Ehrich, McCreary, Reaux, Rowland, and Ramsey, 1998).

After computer technology is introduced in the classroom, teachers talk more with individual students or small groups of students rather than the class as a whole (Collins, 1991; David, 1992; Means and Olson, 1995a). Teachers also interact more with low achieving students (Collins, 1991). Researchers report low achievers receive two to four times more attention from the teacher than high achievers in technology-rich classrooms (Schofield and Verban, 1988; Collins, 1991). Teacher expectations of students may play a role in these changes. In technology-rich settings, teacher expectations of all students rise (Sandholtz, Ringstaff, and Dwyer, 1993), and in traditional settings, increased teacher expectations result in more numerous and more positive student-teacher interactions (Scileppi, 1984).

2.2.3 Authority Structures

In traditional classrooms, the teacher serves as supervisor with students working individually on learning tasks. Teachers generally control student activities and provide few opportunities for student decision-making. Classroom technology interventions often result in a shift from traditional authority-based structures to expertise structures, in which those with knowledge of the technology gain a degree of control (McInerney, 1989). Students frequently serve as technology experts for classmates, teachers, and family members (Hruskocy, Ertmer, Johnson, and Cennamo, 1997; Dwyer *et al.*, 1991; Herman, 1988; Sandholtz *et al.*, 1990). Students are typically allowed autonomy on computer-based learning tasks and make more decisions without teacher input (David, 1992; Means and Olson, 1995a; McInerney, 1989). As a result, students in technology-rich settings are believed to evolve from passive recipients of adult-provided knowledge into independent manipulators of information (Means and Olson, 1995a).

With the introduction of computer technology, students usually work more frequently in teams on learning tasks and student autonomy increases (David, 1992; Dwyer *et al.*, 1991; Gayle and Thompson, 1995; Herman, 1988; Honey and Henriquez, 1996). Partially a by-product of pedagogy shifts, this increase is also driven by the practical need to minimize equipment purchases and lower costs. Studies have found that such pairings enhance student learning (Cooper and Hall, 1991; Hawkins, *et al.*, 1984; Inkpen, *et al.*, 1995; McLellan, 1994; Peters, 1996) and increase performance (Hawkins, *et al.*, 1984; Inkpen *et al.*, 1995).

2.2.4 Physical Setting

The physical requirements of technology-rich learning environments differ from those of more traditional classrooms (McCreary *et al.*, 1998; Stuebing, Cousineau, and Giddings, 1992; Stuebing, Celsi, and Cousineau, 1994). For instance, space and storage needs are higher in a technology-rich classroom (McCreary *et al.*, 1998; Stuebing *et al.*, 1992; Stuebing *et al.*, 1994). Lighting is also more difficult; in the average classroom with traditional fixtures, lights must often be turned off and the classroom darkened in order to eliminate computer glare (Stuebing *et al.*, 1992; Stuebing *et al.*, 1994).

Student collaboration, while often having a positive effect on student achievement, can also increase the ambient noise levels in technology-rich classroom and surrounding areas. Additional soundproofing is required if noise levels are to return to their pre-technology levels (Stuebing *et al.*, 1992; Stuebing *et al.*, 1994). Reducing the ambient noise levels is especially important as Johansson (1983) found that noise negatively impacts children's performance on reading and mathematics tasks, with lower ability children experiencing the largest performance decrements. Several studies have found actual teaching time decreases in noisy classrooms and schools, with teachers in these classrooms reporting increased levels of fatigue and irritation (Bronzaft and McCarthy, 1975; Crook and Langdon, 1974).

The fit between students and classroom furniture is a more critical issue in computer classrooms, as poorly designed computer workstations can have a negative effect on both the health and performance of users (Bergqvist, Wolgast, Nilsson, and Voss, 1995; Carter and Banister, 1994; Kroemer, 1997). However, due to educational economics and the culture of the classroom, classroom furniture is often old and seldom properly sized for student computer users (Healy, 1998). Although occupational researchers have studied adult computer users extensively, no equivalent body of research exists for children. Further, classroom computer use, unlike that of the office, is not governed by myriad regulations aimed at minimizing the health risks to users. The result is classroom workstations that are often a poor fit for students.

2.2.5 Classroom Efficiency

All known studies of classroom efficiency relate to teachers. Some studies have found that classroom technology increases teacher work-hours as well as their overall productivity and efficiency (Rockman, 1995; Wilson and Peterson, 1995). The magnitude of this increase is on the order of 3 to 4 percent of the total hours worked (Wilson and Peterson, 1995). Generally, the increase is greatest right after the technology is introduced (Fulton, 1988; Wiske and Zodhiates, 1988). Teachers must spend time developing alternative lesson for when the technology fails thereby increasing their total hours (Sandholtz *et al.*, 1990; Ehrich *et al.*, 1998). However, computers have also been credited with simplifying lesson preparation (David, 1992), record keeping, and other administrative tasks (Sandholtz *et al.*, 1990) thereby increasing teacher overall effectiveness.

2.2.6 Factors Mediating the Effects of Technology in the Classroom

Success at integrating technology into a classroom is not merely a matter of having sufficient technological resources. Earlier research provides evidence of technology's potential to be an agent for change in the classroom. However, before technology can become an agent for change, the teacher, who effectively functions as the gatekeeper for the classroom, must accept it. Recent research provides evidence that the mere presence of computers in a classroom does not change either a teacher's belief systems or teaching style (*e.g.*, Coley, 1997; Hannafin and Savenye, 1992; Harris, 1997; Honey and Moeller, 1990). Typically, teachers will select software that supports their existing teaching style or simply ignore the technology (Honey and Moeller, 1990). If the technology is not aligned with the cultural and organizational goals of the teacher, the technology will not be utilized (Cuban, 1986; Hannafin and Savenye, 1992). Further to make effective use of the technology, teachers must be flexible enough (and willing) to adapt their approach when computer glitches occur.

The educational background of most teachers ill-prepares them to take a role in learning activities facilitated by technology (Zehr, 1997). Further, schools seldom provide teachers with the necessary training and support to effectively manage technology rich classrooms. To effectively utilize technology, teachers need the following kinds of support: help in technology planning, training, demonstrations and advice onto how to incorporate it in the curriculum, help with technology failures, and low-level system maintenance (Means and Olsen, 1995). Classroom technology failures can be particularly intimidating for teachers. Often, teachers plan two lessons, one with and one without technology, to ensure lesson continuity (Ehrich *et al.*, 1998; Means and Olsen, 1995; Sandholtz *et al.*, 1990).

The main driver for teacher engagement with educational computing is thought to be teacher perceptions that its usage will increase their authority, status, and advancement opportunities (McInerney, 1989). Classroom computer technology has been linked to increases in teacher motivation (Herman, 1988), improved attendance (Honey and Henriquez, 1996), increased job satisfaction (Pick, 1996; Wilson and Peterson, 1995), and better teacher self-esteem (Herman, 1988). These reports are primarily anecdotal, with extremely limited use of objective data (*e.g.,* decrease in teacher sick days) to substantiate the anecdotes. Some researchers report that teacher changes are not sustained past 5 or 6 years (*e.g.,* Means and Olson, 1995a), with the theory being either the novelty wears off after that period or the expected gains for teachers fail to materialize thereby reducing teacher motivation.

Teachers with more years of teaching experience make significantly greater use of network computing resources (Grandgenett and Harris, 1994). Teacher take-home programs also increase usage in classroom (Means and Olson, 1995a; Wilson and Peterson, 1995). Sufficient time, training, support, and opportunities to become familiar with the technology also improve teacher attitudes towards computers (Dupagne and Krendl, 1992; McQuarrie and Iwamoto, 1990; Savenye, 1993). At first, teachers focus on the negative aspects of computers such as the time required to keep the technology functioning (Dupagne and Krendl, 1992; McQuarrie and Iwamoto, 1990; Sandholtz *et al.*, 1990). As the investment begins yielding benefits, teacher attitudes improve (Dupagne and Krendl, 1992; Sandholtz *et al.,* 1990). Not unexpectedly, well-trained teachers with positive computer attitudes have positive effects on student computer attitudes, while badly trained or negative teachers have a negative impact (Gardner, Dukes, and Discenza, 1993; Weil, Rosen, and Wugalter, 1990).

Without school level support, particularly that of the principal, classroom technology innovations are unlikely to become the norm in the larger school community (Coley, 1997; Means and Olson, 1995a; Sandholtz, Ringstaff, and Dwyer, 1990; ‘Yaghi, 1996). Principal support is needed for schools to acquire computer training, obtain network support, and foster innovative teaching practices (Coley, 1997; ‘Yaghi, 1996). Equipping only one class or a small number of classes with technology is often not effective as it segregates classes participating in the intervention from the larger educational community (David, 1992; Sheingold and Hadley, 1990).

2.3 Changes in Students

Classroom computer technology has been linked to a variety of changes in students, including spending longer on academic tasks (Means and Olson, 1995a), and improvements in academic achievement (*e.g.*, Honey and Henriquez, 1996). More positive student attitudes towards learning and self are often reported after the introduction of classroom technology. These changes may be difficult to sustain. Several longitudinal studies have found that the attitudes of students in technology interventions towards learning with computers declines significantly over time suggesting such improvements may be transitory (King, 1993; Krendl and Brohier, 1992; Proctor and Burnett, 1996).

2.3.1 Attitudes Towards Self

The literature often indicates that students in technology-rich classrooms have increased self-esteem (*e.g.* Follansbee, 1996; Herman, 1988; Means and Olson, 1995a; Rockman, 1995; Wilson and Peterson, 1995; 'Yaghi, 1996). Students are proud of their technical skills, and frequently rush to share computer products with visitors (Means and Olson, 1995b). Additionally, technology gives classroom non-achievers a new forum for excelling (Means and Olson, 1995a; Ehrich *et al.*, 1998). Herman (1988) and others have found that educational computing interventions increase student self-efficacy. Similar to self-esteem, self-efficacy is one's self-appraisal of the one's ability to excel at an activity.

Increases in student self-esteem and self-efficacy are generally associated with higher achievement (*e.g.,* Scileppi, 1984). Whether improved self-beliefs result from increased achievement or improved self-beliefs result in increased achievement is not clear. Additionally, some evidence suggests that the strength of the relationship between self-esteem and achievement diminishes as children age. For example, Newman (1984) found that student self-perception did not have a significant causal influence on later achievement during grades 5-10.

Computers are believed to facilitate student control of the learning environment, thereby increasing student perceptions of control and shifting them towards the intrinsic both in terms of motivation and locus of control (Dirkes, 1985; Louie, Luick, and Louie, 1986). Intrinsic motivation refers to "the degree in which a student perceives himself or herself engaging in an activity for reasons such as challenge, mastery, or curiosity; participation is itself motivating as opposed participation as a means to an end (*e.g.,* grades), as in the case for extrinsic motivation" (Velayo and McKeachie, 1994). A closely related concept is locus of control, which relates to the student's perceived casual relationship between actions and the events that follow. Students with an internal locus of control see events as being the result of their own actions and thus under their control, while externals see events as unrelated to their own actions (Rotter, Seeman, and Liverant, 1962). Louie *et al.* (1986) reported a shift towards intrinsic control in elementary school students (p=.03) after 16 hours of word-processing and LOGO programming as measured by the Nowicki-Strickland Locus of Control Scale for

Children (1973). Similarly, Bernhard and Siegel (1994) reported a shift towards intrinsic in lower elementary schoolchildren who experienced a six-week LOGO intervention. Similar shifts are expected in longer classroom computer interventions.

This shift towards the intrinsic is considered significant as studies have found that individuals who are intrinsically motivated and believe events are under personal control make greater learning gains (Atkinson and Feather, 1966; Johnson, 1970; Coleman, Campbell, Hobson, McPartland, Mood, Weinfeld, and York, 1966; Malone, 1981). Coleman *et al.* (1990) found that a student's sense of control of environment is the attitudinal factor most related to achievement. These characteristics are also positively correlated with many positive learner behaviors, such a student's ability to delay gratification, stay on task, increased social maturity, and positive social interactions (Louie *et al.*, 1986). The degree to which students are intrinsically motivated also impacts how they respond to new methods of instruction. Intrinsically motivated students are more accepting of new educational methods than those who are highly extrinsically motivated (Malone, 1981; Velayo and McKeachie, 1994). For example, students with high extrinsic motivation tend to view emergent uses of classroom technology more negatively than those who are more intrinsically motivated, possibly because they see the mastery and use of the technology as an added work (Velayo and McKeachie, 1994).

2.3.2 Attitudes Towards Learning

Studies of technology-rich classrooms often report improved attitudes toward school and increased motivation on the part of students (*e.g.* Follansbee, 1996; Herman, 1988; Means and Olson, 1995a; McKinnon, Nolan, and Sinclair, 1996; Wilson and Peterson, 1995; 'Yaghi, 1996). Researchers have found that learners who construct and manipulate their own worlds find student-guided learning easier and more motivating. For instance, Malone and Lepper (1987) found that computer activities motivated the students by allowing them to control the learning experience and by providing immediate feedback. Also motivating is the "real-life" feel of classroom activities involving technology (Means and Olson, 1995). These improvements are considered significant as "taken alone ... attitudinal variables account for more of the variation in achievement than any other set of variables (all family background variables together, or all school variables together)" (Coleman, Campbell, Hobson, McPartland, Mood, Weinfeld, and York, 1990).

Evidence of students' improved attitudes toward school comes from a variety of sources including students' self-reports and interviews (Herman, 1988; Follansbee, 1996; Kitabchi, 1987; Sandholtz *et al.*, 1993), decreased absenteeism (Honey and Henriquez, 1996), higher transfer rates into technology-rich classrooms (Honey and Henriquez, 1996), and decreases in transfers out of technology-rich classrooms (Honey and Henriquez, 1996). The introduction of technology often improves teacher perceptions of students which may drive improvements in student attitudes; in a long-term ACOT interventions, teachers perceived students as being more enthusiastic when working with computers and more positive toward school (Sandholtz *et al.*, 1993).

Classroom technology has also been credited with changing student attitudes towards specific academic activities. Following the introduction of computer technology in the home and the classroom, students have less interest in reading print material as evidenced by a decrease in book buying (Australian Council (1990) as cited in Russell and Russell, 1996). At the same time, student computer users were more motivated to write (David, 1992) and often believed they were more capable writers as the result of using the computer (Tierney *et al.*, 1992).

Drivers for these improvements include student perceptions that the work is authentic and important (Follansbee, 1996; Herman, 1988; Means and Olson, 1995a; Wilson and Peterson, 1995; ‘Yaghi, 1996), increased pride in learning products (Herman, 1988; Honey and Henriquez, 1996; Means and Olson, 1995a; McKinnon, *et al.*, 1996), and increased teacher expectations (Follansbee, 1996; Herman, 1988; Means and Olson, 1995a; Wilson and Peterson, 1995). Teacher expectations are thought to be especially significant (Herman, 1988) as the greater the increase in teacher expectancy, the greater the corresponding increase in student learning (Johnson, 1970, Scileppi, 1984).

2.3.3 Perceptions of Classroom Life

Classroom teaching and learning strategies are the primary shapers of student perceptions of classroom life (Getzels and Thelen, 1960). Few studies have considered the impact of computer interventions on student perceptions of classroom life. Of the few studies who examined the issue, most involved high school students. These studies did indicate computer interventions improve student perceptions of classroom life (Levine, 1994; Maor and Fraser, 1993; Teh and Frazier, 1995). However, after leaving enriched classrooms and returning to traditional classrooms, many students felt deprived and experienced a sharp decrease in their ratings of the classroom environment (Herman, 1988).

2.3.4 Engagement in Learning

Numerous studies have indicated student engagement increases during technology-intensive learning activities (Carver, 1990; Collins, 1991; Rockman, 1995; Sandholtz *et al.*, 1990; Scardamalia, Bereiter, McLean, Swallow, and Woodruff, 1989; Schofield and Verban, 1988). By definition, “students are engaged when they devote large amounts of time and effort to a learning activity, when they care about the quality of their work, and when they commit themselves because it has significance beyond its personal instrumental value” (Newmann, 1986). Student engagement is linked to both achievement and quality of learning outcomes (Capie and Tobin, 1981; Fisher, Berliner, Filby, Marliave, Cahen, and Dishaw, 1980; McGarity and Buttws, 1984). Student engagement is difficult to operationalize but indicators include: time on task, or the time students spend actively attending to the appropriate instructional object or person (Wilson, 1987); and academic learning time, or the "amount of time a student spends successfully performing relevant and appropriate learning activities" (Vockell, 1987), with academic learning time being positively related to basic skills achievement in elementary school children (Far West Laboratory, 1979; Vockell, 1987).

Technology-rich interventions have been credited with increasing the time students spend on a task (Means and Olson, 1995a; Van Dusen and Worther, 1995). Teachers in long-term Apple Classrooms of Tomorrow (ACOT) interventions found that as students became engaged in computer activities, they spent more time on class assignments and often did more than required by the teacher (Sandholtz *et al.*, 1993). Student "over-engagement" in computer work sometimes creates time management problems for students (Sandholtz *et al.*, 1993). Sandholtz *et al.* (1993) report students persisting on computer tasks when they should have been working on non-computer activities or listening to the teacher as does Ehrich *et al.* (1998). Teachers also reported increased student distractibility (Sandholtz *et al.*, 1993). As one teacher put it, a "... child who is off task with pencil and paper is off task on the computer and may be more so because of the many distractions going on around him with technology ... " (Sandholtz *et al.*, 1993).

Teachers in technology-rich classrooms have greater difficulty in determining if students were on-task during computer work (McCreary *et al.*, 1998; Roberson, 1997; Sandholtz *et al.*, 1990). For instance, the teacher for the PCF classroom found that students with short attention spans would sometimes hide behind the monitor and distract themselves, either with the computer or with other material, (McCreary *et al.*, 1998). The computer also expands the range of student misbehaviors and makes many misbehaviors easier (Sandholtz *et al.*, 1990). Many kinds of student ethics violations, *e.g.*, copying someone else's work, are simplified in a computer environment (Sandholtz *et al.*, 1990), and students often blame the technology when they fail to complete work (Robertson, Calder, Fung, Jones, and O'Shea, 1997; Sandholtz *et al.*, 1990). For instance, in one ACOT home technology intervention, home computer problems were a common excuse for not completing homework (Sandholtz *et al.*, 1990).

2.3.5 Academic Skills

Educators and researchers have attributed student improvements on a variety of academic skills to classroom technology. Among the most commonly cited changes are improved learning and study skills, improved writing skills, improved research skills, and increased higher-order cognitive thinking on the part of the students. However, many questions remain as to the exact nature of these changes (Shultz and Higginbotham, 1991). Much of the evidence supporting these claims is anecdotal, with the exact nature of the changes often not well defined.

Classroom technology interventions are considered to have a positive impact on learning skills (Kitabchi, 1987; Roberson *et al.*, 1997). Some researchers advocate repeated applications of learning process inventories as a means of evaluating changes in learning skills (Kember, Charlesworth, Davies, McKay, and Stott, 1997). Learning inventories are considered direct descriptions of learning processes used by students and an appropriate means of evaluating educational interventions (Watkins, 1996). Results from learning inventories indicate students shifting towards deeper approaches to learning after successful educational interventions (Gibbs, 1992; Kember *et al.*, 1997).

Classroom computer interventions are also linked to improvements in writing strategies (e.g., Honey and Hendriquez, 1996; Means and Olson, 1995a; Rockman, 1995). These improvements may result from students being more willing, and more able, to repeatedly edit and refine writing products on the computer (Means and Olson, 1995b). Students in technology rich settings have access to productivity tools, such as word processors or spreadsheets, that facilitate student management of intermediate data and the production of professional appearing artifacts.

Internet technologies can be somewhat of a mixed blessing to student researchers. With the computer, students have access to a larger number of information sources which are often more up-to-date than those traditionally available in the schools (David, 1992). The massive amount of information available increases the use of outside sources of information and prompts greater consideration of multiple perspectives (David, 1992; Means and Olson, 1995). However, students have been found to lack the skills needed to perform effective searches (Solloway and Wallace, 1997), and even under the best conditions, on-line searches can be very time-consuming. Studies with databases and library catalogs indicate that students are not adept at using Boolean logic, and that many students do not fully understand the research process (Borgman, Krieger, Gallagener, and Bower, 1990; Jacobson, 1995, Kuhltahau, 1993; Kuhltahau, 1996; Pitts, 1994, Walter, Borgman and Hirsch, 1996). In web searching studies, elementary students paid little attention to the quality of an information source and instead focused on whether the source gave them the desired answer (Wallace and Kupperman, 1997).

Technology interventions are also linked to increases in higher-order cognitive thinking on the part of students (Tierney *et al.*, 1992). However, the evidence is anecdotal and the actual changes are often not well defined (Bagley and Hunter, 1992; Herman, 1988). In general, the computer is seen as facilitating the completion of more complex tasks by carrying out the overly boring or difficult parts of a learning activity thereby promoting higher-order thinking (Means and Olson, 1995b).

2.3.6 Learning Outcomes

Although the literature has well documented the effectiveness of computer-assisted-instruction (CAI) at raising student achievement scores (Becker, 1989; President's Panel on Educational Technology, 1997), the value of less focused infusions of computer technology into the classroom is less clear. Some researchers found that standardized test results improve in technology-rich classrooms (Dwyer, *et al.*, 1991; Gearhart *et al.*, 1990; Honey and Henriquez, 1996; Kitabchi, 1987; Kromhout and Butzin, 1993; Means and Olson, 1995a; Wilson and Peterson, 1995), while others report mixed results (Pick, 1996; Rockman *et al.*, 1995) or found no effect (Baker, 1989; Baker, Gearhart, and Herman, 1990; Franks, DeVaney, Weerakkody, and Katayama, 1996). Other studies found no change in math scores, but net increases in reading and language arts scores (Pick, 1996; Riel, 1990; Rockman *et al.*, 1995). The variability in these results is believed to have more to do with the manner in which the technology is used than the characteristics of the technology itself (David, 1992; Oppenheimer, 1997). Other changes noted by researchers include increased honors eligibility of students (Honey and Henriquez, 1996), increases in the number of students passing standardized tests (Honey and Henriquez, 1996), and increased computer skills (Herman, 1988; Rockman *et al.*, 1995).

Some researchers and educators believe that standardized tests cannot assess the improvements in higher order cognitive skills that many attribute to more constructivist teaching practices (Coley, 1997; President's Panel on Educational Technology, 1997). These researchers advocate the use of project-based assessment methods to assess technology-enriched classrooms (Collins, 1991; David, 1992; Honey and Henriquez, 1996; Means and Olson, 1995a). Some researchers using project-based assessment report improved writing quality in technology-intensive classrooms (Bangert-Downs, 1993; Cochran-Smith, 1991; Follansbee, 1996; Gayle and Thompson, 1995; Herman, 1988; Owenstein, Murphy, and Wideman, 1992), while others report mixed results (Baker, 1989). The improvements in writing quality are attributed to the introduction of network technology and the resulting enlargement of audiences for student writing (Allen and Thompson, 1995; Riel, 1985). In these environments, the length (Herman, 1988; Von Holzen, 1996) as well as the creativity (Means and Olson, 1995a; Wilson and Peterson, 1995) of student writing improves.

2.3.7 Factors Mediating the Effects of Technology on Students

The extent to which classroom students adopt technology mediates any potential benefits of the technology. Studies with adults have found a user's attitudes towards electronic communication applications to be the strongest predictor of computer usage (Grantham and Vaske, 1985; Komsky, 1991; Schmitz and Fulk, 1991) and indeed positive correlations have been found between a student's attitude towards computers and the student's frequency of using computers (Bracey, 1988; Francis and Evans, 1995; Loyd and Loyd, 1985; Koohang, 1989; Martin, 1991; Mohamedali, Messer, and Fletcher, 1987; Woodrow, 1992). Student attitude has been shown to be a critical factor in the success or failure of technology-based classroom interventions (Loyd and Gressard, 1984), with the importance of its measurement often emphasized in the literature (Koohang, 1989; Loyd and Gressard, 1984; Martin, 1991; Reece and Gable, 1982; Woodrow, 1991). Anecdotal evidence suggests that not all students like computers, but most students view them positively (Wilson and Peterson, 1995; Ehrich *et al.*, 1998b).

The main indicators of student computer attitudes are student direct time expenditures, self-reports, and interviews. Most evidence of direct time expenditures is anecdotal, with reports of students considering computers so enjoyable that they request additional work involving the computer (Sandholtz *et al.*, 1990). When access to classroom computers is unrestricted, students typically spend 30 percent of the school day using computers (Dwyer, 1994). When given the choice, students reportedly choose the computer over pencil and paper for assignments (Means and Olson, 1995b; Sandholtz, *et al.* 1993). Further during free periods, students chose the computer over other activities and frequently volunteered to stay after school to work on the computer (Means and Olson, 1995b; Sandholtz, *et al.* 1993).

Among the other factors shown to influence student technology use are social variables (*e.g.,* teacher attitudes), student individual differences (*e.g.,* cognitive style), and the length of technology availability.

2.3.7.1 Social Influences

Social factors, such the extent to which the technology was adopted by other students and teachers, can be expected to influence classroom technology use and, as a result, student outcomes. Critical mass theory suggests that the value of the technology to students and teachers will increase if others important to them use it and, similarly, would decrease if those individuals ceased using it (Markus, 1990). Studies of technology adoption in adult organizations provide support for this theory (*e.g.,* Kraut, Cool, Rice, and Fish, 1994). No such studies have been done with children, but a large portion of variability in student attitudes towards computers can be accounted for by the attitudes of their teachers (Todman and Dick, 1993).

2.3.7.2 Individual Differences

The impact of individual differences on student technology use has been explored in the educational computing literature. The ones more commonly discussed include gender, cognitive styles, previous achievement, and social economic status (SES). These factors are expected to also influence student outcomes for any technology-based, classroom intervention.

The individual difference most addressed in educational computing literature is gender. Some researchers report that girls spend less time with classroom technology and are less assertive in claiming computer time and controls, *e.g.,* mouse, (Mohamedali *et al.,* 1987; Sutton, 1991); others report that with ubiquitous classroom technology, usage by both sexes is comparable (Means and Olson, 1995a). Girls typically have less interest in computer games and greater interest in using computers to communicate and create, whereas with boys this pattern is reversed (Means and Olson, 1995a; Mohamedali, *et al.,* 1987; Ross, Smith, Morrison, Ericson, and Kitabchi, 1989). In general, boys report more positive attitudes toward computers than girls (Krendl and Broihier, 1992).

Student cognitive style is also a factor in computer use. Most evidence for cognitive style comes from the CAI literature, with little attention being paid to individual differences in non-CAI, educational computing literature. In recent years, researchers have called for it also to be considered in non-CAI settings (Kitabchi, 1987; Partridge, 1993). The CAI literature suggests that learning style will be significant factor for students (Enochs, Handley, and Wollenberg, 1986), with some indication that highly visual and abstract individuals use email with greater ease (Sein and Bostrom, 1989). Personality type, as measured by the Murphy-Meisgeiner Type Indicator (MMPI) (Myers and McCaulley, 1985), also appears significant with adults having perceptive attitudes, rather than judging attitudes, favoring use of "rich media" (Schmitz and Fulk, 1991) like electronic mail (Trevino, Lengel, Bodensteiner, Gerloff, and Muir, 1990). All known studies linking cognitive style to computer use involved adults, not children; however, a similar effect is expected with children.

Not unexpectedly, previous student achievement also plays a role. High achievers use a plan in computer use and monitor their own computer performance to a greater degree (Bowen, Shore, and Cartwright, 1992), much as they do in other academic areas. Lower achievers are often attracted by lots of graphics and animation, while higher achievers prefer more open-ended problem solving software (Clements, 1993). Additionally, high achieving elementary students prefer instructional methods that emphasize independence, while medium and low ability students prefer more structured methods (Stewart, 1981) and may be less comfortable with constructivist learning practices[5] such as those associated with classroom computer technology.

Family income is also thought to influence student computer use. Several researchers have remarked on the tendency of children whose families cannot afford computers to withdraw from activities (Means and Olson, 1995a; Sutton, 1991), while others report significant differences between high and low SES students in their perceptions of the computer function and frequency of use (Shashaani, 1994). The student's home computer experiences have been shown to account for a large of portion of the variability in student computer attitudes (Hughes, Brackenridge, and MacLeod, 1987). Students with computer experience believe that computers can improve the learning process significantly more frequently than students with no experience (Mohamedali, *et al.*, 1987). However, some students so strongly identify the computer with playing games that when compelled to use computers at school for other purposes, they find the computer activities dull or unpleasant (King, 1993).

[5] Constructivist learning practices require the student to take greater responsibility for their own learning under the assumption that all knowledge is actively constructed by individuals performing meaningful activities (Mahoney, 1991). In constructivist classrooms, the teacher serves not as the dispenser of information but rather as the facilitator of the learning process (Bruer, 1993; Grabe and Grabe, 1998).

2.3.7.3 Effects of Time on Technology Use

Several earlier studies, as well as exploratory analyses of PCF data, suggest that student use will change over time. For instance in a study with palmtop computers, Robertson *et al.* (1997) found that heaviest computer use was initially when students were trying to see how the technology worked, with use dropping off 30 to 40 percent over the course of five months. While personal use remained relatively constant, self-reports of computer use for homework or school purposes peaked at around five months and dropped off sharply by eight months. However, the Robertson *et al.* study (1997) depended solely on student self-reports, which is not the most reliable metric. For example, self-reports of computer usage can be impacted by group composition, with boys in mixed gender groups inflating self-reports of usage and girls deflating self-reports (Cooper and Stone, 1996).

Interestingly, after a yearlong computer project in a middle school, students liked computers more at the start of the year than they did at the end (Proctor and Burnett, 1996), with similar decreases over time seen by King (1993) and Krendl and Brohier (1992). This research suggests that a novelty effect may be at work in computer interventions and raises the possibly of decreased benefits over time. Surprisingly, student perceptions of the difficulty of computer use remained constant over a three-year period (Krendl and Brohier, 1992).

2.4 Changes in the Home

Parents have a profound impact on student attitudes towards learning activities and learning in general (Henderson, 1987; Stevenson, Lee, Chen and Lummis, 1990). Most parents are uncritical of classroom technology interventions and are generally positive that classroom computers benefit students (Baker, *et al.*, 1990; Pick, 1996), with many parents believing that classroom technology will increase achievement scores (Visser, 1987). Although pleased by the technology, parents are not always pleased by the constructivist teaching practices that often accompanies it (Wentworth and Connel, 1995), and generally prefer standard didactic practice over less structured approaches (Cobb, 1988; Wentworth and Connel, 1995).

Parents are usually enthusiastic about computer technology in the home (Rockman, 1995), especially when supplied by researchers (Kitabchi, 1987). Parents often assume that a computer is automatically more educational than a television, and monitor its use less closely (Healy, 1998). Parents frequently report using computers to help children with homework, which increases their overall involvement in the learning process (Rockman *et al.*, 1995). Network technology can also be an effective tool for increasing home-school communication (Herman, 1988; Pick, 1996; Rockman *et al.*, 1995). Anecdotal evidence also suggests family communication improves when computers are sent home with students (Rockman, 1995) and some family self-reports indicated students watching less television due to spending time on the computer (Rockman, 1995). Of the families who had a networked computer at home, 80 percent of the parents were on-line daily (Rockman, 1995), with male family members spending more time on-line (Mohamedali, *et al.*, 1987).

Students are often the family computer expert (Ringstaff *et al.*, 1991) and frequently teach fellow family members about the technology (Rockman, 1995). Both the extent and type of school computer use are affected by home computer access (Mohamedali, *et al.*, 1987). The student's home computer experiences have been shown to account for a large of portion of the variability in student computer attitudes (Hughes *et al.*, 1987). Students with computer experience believe that computers can improve the learning process significantly more frequently than students with no experience (Mohamedali, *et al.*, 1987). However, school computer use is not always an indication of home use. ACOT teachers report some students would do minimal work on their computers at home despite being engaged at school (Sandholtz *et al.*, 1993).

Among fourth and eighth graders, 50 percent of students report having a computer at home (Coley, 1997). The study also found only nine percent of fourth graders and ten percent of eighth graders were using the computer for schoolwork on a daily basis (Coley, 1997). In fact, 60 percent of the fourth graders with computers in the home and 51 percent of the eight graders never used the computer for schoolwork (Coley, 1997). Students in the study most frequently use the computer for playing games, with learning things and writing only slightly less frequent (Coley, 1997). However, the popularity of using the computer for learning decreased as students aged (Coley, 1997). A larger percentage of girls than boys report using educational games or software; however, the boys who use educational software report spending more time using it (Mohamedali, *et al.*, 1987). In another study which sent networked computers home with students, researchers reported that students spend about four hours a week on the computer, doing homework or playing educational games, with the boys more likely to play non-educational games and the girls more likely to spend their time on-line (Rockman, 1995).

Anecdotal evidence from several family computing projects suggests that computer training has tangible benefits for parents' professional lives, especially in families from lower socioeconomic (SES) neighborhoods (Honey and Henriquez, 1996). Additionally, when parents are given computer training in conjunction with home computer technology, parents look at student's work more critically and expect more from students (Honey and Henriquez, 1996). However, even after training, parents generally rated themselves slightly lower on computer skills than students (Honey and Henriquez, 1996; Rockman, 1995).

2.5 Looking Forward

Despite extensive anecdotal evidence as to the benefits of this recent influx of classroom computer technology on students and education, empirical research does not consistently substantiate its value or effects (Coley, 1997; Conte, 1998; Healy, 1998, Oppenheimer, 1997; President's Panel on Educational Technology, 1997; Trotter, 1997; Viadero, 1997). Although educational dollars continue to be spent on classroom technology, researchers remain divided as to the educational merit of computers in the classroom and home. Studies often cover only a short period (Madinach and Cline, 1996; Healy, 1998), making the long-term impact of the technology unclear. Many studies fail to fully consider how the characteristics of students, teachers, and larger school interact with the characteristics of the technology in determining outcomes (Healy, 1998). Well-controlled research on computer effects on students, teachers, and the learning process are therefore needed. In particular, research is needed which considers how the characteristics of the technology, students, and teachers affect the outcomes of technological interventions.

CHAPTER 3. MACROERGONOMICS AS A FRAMEWORK FOR STUDYING CLASSROOM TECHNOLOGY

Chapter Table of Contents

3.1 INTRODUCTION....26
3.2 SOCIOTECHNICAL SYSTEMS MODEL OF THE CLASSROOM....27
3.3 "MACRO" ELEMENTS OF THE CLASSROOM....29
3.3.1 Organizational Design....29
3.3.2 Technical Subsystem....30
3.3.3 Social Subsystem....31
3.3.4 Environment....32
3.4 "MICRO" ELEMENTS OF THE CLASSROOM....32
3.5 MACROERGONOMIC ANALYSIS PROCESS....33
3.5.1 Initial Scanning....33
3.5.2 Technical Subsystem Analysis....34
3.5.3 Technical Work Process Analysis....34
3.5.4 Variance Data Collection and Analysis....35
3.5.5 Social Analysis....36
3.5.6 Organizational, Joint, and Function Design....38
3.5.7 Roles and Responsibility Perception Analysis....38
3.5.8 Support System and Interface Design....38
3.5.9 Implement, iterate, and improve....38
3.6 ROLE OF MACROERGONOMICS IN THIS RESEARCH....39

3.1 Introduction

Researchers and educators need analytical frameworks to help them understand how the characteristics of classroom technology, students, and teachers affect the outcomes of technological interventions. Frameworks commonly used for research studying the impact of classroom technology generally examine the classroom in either a piecemeal fashion or from a more systematic perspective, but lack mechanisms for integrating the two perspectives. The first perspective is a "micro" approach that focuses on the qualities of the technology and its interface with individual students. The other is a "macro" approach that views the classroom as an organization, where the qualities of students, teachers, and the classroom, along with those of the technology, influence learning outcomes. Both the "micro" and "macro" approaches have their limitations. Even the most ergonomic and pedagogically advanced educational software can be rendered ineffective when coupled with incompatible teaching strategies (Pea, 1996). Similarly, an exceptional technology-rich learning environment may prove ineffectual if students cannot easily manipulate computer controls. An analysis approach that considers both the "micro" and "macro" elements of the classroom is needed.

One approach that incorporates both the "macro" and "micro" aspects of systems in the analysis process is macroergonomics. A sub-discipline of human factors engineering, macroergonomics combines sociotechnical system methodology with traditional ergonomic methods and techniques. It is concerned with the interface between a system's organizational design and system technology to ensure ergonomic compatibility of system elements with the system's overall structure (Hendrick, 1991). Macroergonomic models and methodologies define the "macro" qualities of a system and specify many of the "micro" qualities that should be designed into a system (Hendrick and Kleiner, 2000).

In recent years, there has been rapid growth both in the development of macroergonomic methods and in the number of macroergonomic interventions. Macroergonomics has been used in a variety of industries including airline, manufacturing, service, information technology, health care, and public administration (Hendrick, 1991; Kleiner, 1996). Macroergonomic studies of technology interventions in adult organizations have repeatedly found that overall performance of a system is optimized only when the "macro" and "micro" elements of a system have been ergonomically designed and are in alignment with each other (Beekun, 1989; Hendrick, 1991; Kleiner, 1996; Livari and Hirschheim, 1996). Other lessons learned from such efforts include the need for multi-disciplinary assessment by teams that are viewed as objective and unbiased, the value of a participatory approach, the need for evaluation and feedback, the importance of autonomous work teams, the moderating effect of pay incentives, the importance of organizational commitment to the intervention, and the need for follow-up assessments (Beekun, 1989; Kleiner, 1996).

Macroergonomics was expected to provide an appropriate framework for examining issues related to the introduction of educational computing technology. Within the macroergonomic framework, the classroom can be viewed as a learning system comprised of four interdependent elements: social, technical, organizational, and environmental. This breakdown is especially appropriate when the goal of researchers is to understand how the characteristics of classroom technology impact other elements of the system, namely the students, teachers, and overall learning process. Macroergonomic methodologies for analysis and design of work systems are expected to be extensible to classroom systems, and should provide a robust framework for examining issues related to the introduction of classroom computing technology.

3.2 Sociotechnical Systems Model of the Classroom

A key component of the macroergonomic approach is sociotechnical systems (STS) methodology. STS regards organizations as open systems with porous boundaries that convert inputs into products (Hendrick, 1991). Organizations are thought to be composed of three elements: the technical subsystem, the social subsystem, and the organizational design (Trist, 1978, 1981; Hendrick, 1991). These three elements along with the organization’s environment comprise the sociotechnical system. The organizational design specifies the contours of formal communication and how authority will be shared among individuals and groups in the system. This “sharing” of authority results in specific areas of responsibility for individuals and groups. The conversion of inputs into products or services is accomplished through the combined efforts of the technical and social subsystems. The technical subsystem specifies the tasks to be performed while the social subsystem specifies the manner in which tasks are performed (Hendrick, 1986, 1991).

Within the STS framework, the social and technical subsystems are considered interdependent and are thought to react jointly to events in the environment. That is, they operate under joint causation. As the subsystems react jointly to events, optimization of one subsystem without consideration of the other results in suboptimization of the overall system. Joint optimization is thought to be achieved only through the joint analysis and design of the subsystems. Macroergonomic and STS techniques take into consideration the joint nature of the subsystems and attempt to optimize the overall functioning of the system by maximizing alignment between system elements. As a result, systems undergoing such interventions typically experience increased productivity and increased quality of work life while experiencing a reduction in employee absenteeism and turnover (Doukmak and Huber, 1996; DuBrin, 1984; Trist, 1978).

Thus, the classroom can be viewed as a learning system comprised of the following interdependent elements:

- The social subsystem, which is concerned with classroom personnel, *i.e.*, students and teachers, and their interactions.
- The technical subsystem includes general educational practices and processes, as well as computer technologies.
- The organizational subsystem, which can be characterized in terms of its complexity and the degree to which classroom decision-making is vested in the teachers.
- The environmental subsystem, with the key elements being students' families, the community, and the academic and administrative climate of the school.

A high-level representation of this system can be found in Figure 2-1. This breakdown is especially appropriate when the goal of researchers is to understand (a) how classroom computer technology impacts other elements of the system or (b) how the characteristics of the system and its environment affect technology integration. This model was expected to provide an effective framework for researchers and educators wishing to understand such issues as how the addition of a particular technology to the classroom will affect the efficacy of the learning process, interactions between students and teachers, classroom-decision making, and family involvement. The model was expected to be equally useful to those seeking to understand how the characteristics of students, teachers, and classroom processes facilitate or hinder the effective utilization of a particular classroom technology.

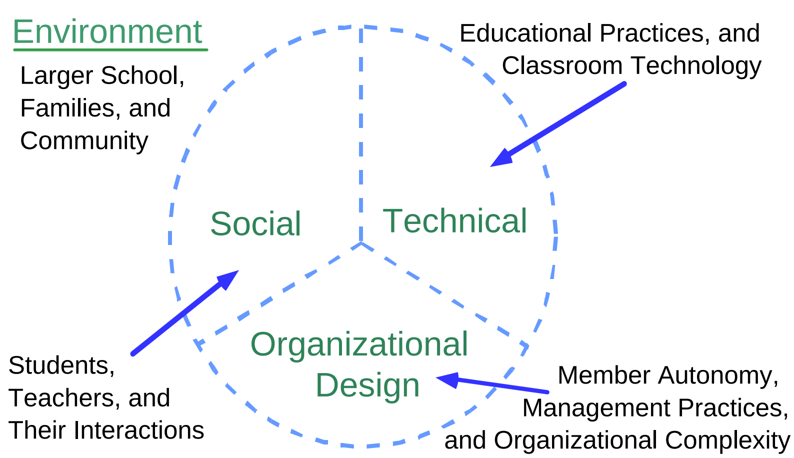

Figure 3-1. The sociotechnical system model of the classroom is comprised of four, interdependent subsystems: social, technical, organizational, and environmental.

Within the STS model, classroom technical and social subsystems would react jointly to events such as the introduction of network technologies. The introduction of technology to a classroom would be expected to change the roles of students and teachers as well as the nature of student and teacher interactions with both the larger school environment and the family. Existing studies of classroom computer use provide evidence of the interrelated nature of classroom subsystems. Classroom computer technology has been linked to improved attitudes and motivation towards school on the part of the students (*e.g.*, Follansbee, 1996), increased student self-esteem (*e.g.*, Means and Olson, 1995a), changes in student-teacher interactions (*e.g.*, Collins, 1991), shifts from didactic to constructivist teaching practices (*e.g.*, Schofield and Verban, 1988), gains on learning measures by students (*e.g.*, Honey and Henriquez, 1996), increased student collaboration (*e.g.*, David, 1992), increased student autonomy (*e.g.*, Means and Olson, 1995b), changes to the physical classroom (*e.g.*, McCreary *et al.*, 1998), and even changes in family-school involvement (*e.g.*, Rockman, 1995).

As classroom subsystems react jointly to events with the framework of STS, optimization of one subsystem without consideration of the other would be expected to result in suboptimization of the overall system. Thus no one "optimal" method for introducing classroom technology exists. Instead, the successful utilization of classroom technology must take into account the characteristics and roles of students and teachers, as well as the nature of student and teacher interactions with both families and the larger school organization. Similarly, joint optimization means that the measurement of classroom performance must take into consideration variables from the technological, social, and organizational subsystem. These variables provide metrics for evaluating the effectiveness of the current system and for evaluating the long-term impact of system interventions. Technical variables typically used to assess the effectiveness of an STS intervention include overtime, operational efficiency, customer satisfaction, the number of failure reports, and production volume. Social variables typically measured include turnover, absences without reason, sickness, accidents, employee satisfaction, and the number of grievances. (Beekun, 1989; Trist, 1978).

3.3 "Macro" Elements of the Classroom

At the "macro" level, classroom researchers and designers are concerned primarily with the characteristics of classroom subsystems and how the qualities of these subsystems, along with those of the technology, influence learning outcomes. Each of the "macro" elements of the STS model has been studied in relation to its effects on the other elements, and models have been derived that can be used to categorize the salient features of the classroom and consider their effect on the efficacy of educational technologies. This section provides an overview of these models and briefly discusses their application to educational settings.

3.3.1 Organizational Design

Within the STS framework, an organizational design is generally specified in terms of three attributes: formalization, centralization, and complexity (Hendrick, 1984b, 1991; Robbins, 1983). Formalization is the degree to which work operations are standardized in an organization; centralization refers to the degree that formal decision-making is vested in individual or work unit in an organization; and complexity relates to the number of differentiated elements, *e.g.*, groups or levels, in an organization and the extent to which integrative mechanisms for facilitating communication and coordination across the differentiated elements in the system have been designed into the organization's structure.

With the primary technical work of schools, namely teaching and learning, separate from the formal school organizational structure, classroom internal functions are controlled by the teachers who informally establish classroom processes (Meyer and Rowan, 1983; Bidwell, 1965). Within a classroom, formalization and centralization are traditionally high with teachers controlling most decision-making and classroom tasks designed to allow students little discretion over how, or when, learning tasks are performed (Jackson, 1968). Some forms of learning, *e.g.*, collaborative, promote greater student involvement in decision-making and result in a less formal learning environment (David, 1992). Computer technology can provide new forums for student decision-making resulting in increased student autonomy and satisfaction (Means and Olson, 1995a), along with decreased formalization and centralization in the classroom. With all elements of the classroom traditionally co-located, classrooms depend heavily on standard integrative mechanisms, such as direct supervision, for facilitating communication and control within the classroom processes (Meyer and Rowan, 1983). Teams are a rarity in traditional, teacher-centered classrooms, with other more modern integrative mechanisms such as electronic communication possible in networked learning environments.

3.3.2 Technical Subsystem

The classroom technical subsystem includes general educational practices and processes, as well as computer technologies. The average classroom remains largely dependent on tools, practices, and techniques that for the most part have not changed greatly in the last century (Papert, 1992). Classroom technology is considered an intensive technology (Thompson, 1967) that brings about changes in students through specialized techniques. Educational technologies are knowledge-based technologies, which can be classified based on their task analyzability (*i.e.*, number of exceptional cases encountered and the nature of the search process in dealing with the exception cases) and task variability (*i.e.*, the stability or variability of raw inputs and the extent to which inputs can be handled in a standardized fashion) (Perrow, 1967).

- Routine technologies have few exceptions and well-defined problems;
- Non-routine technologies have many exceptions and are difficult to analyze;
- Engineering technologies have many exceptions but can be handled using well-defined processes; and

- Craft technologies have relatively well defined tasks but problem solving relies heavily on worker experiences, judgment, and intuition.

Traditional classroom technology can be categorized as either routine or craft (Keckley, 1988), with task variability accounting for 55% of the variance in teacher motivation and satisfaction (Keckley, 1988). In most classrooms, the technology is best categorized as a craft technology that involves relatively routine tasks but problems rely heavily on experience, judgment, and intuition (Keckley, 1988). The addition of computer technology to a classroom increases the complexity of classroom processes and decreases the routine nature of classroom tasks.

3.3.3 Social Subsystem

Students and teachers comprise the social subsystem of the classroom. Teachers are responsible for (a) presenting learning materials and mediating between students and the coursework, (b) creating a classroom environment that optimizes classroom functioning, and (c) performing classroom administrative functions such as record-keeping (Johnson, 1970). In traditional classrooms, activities generally involve students attending to teachers while ignoring others and delaying gratification (Jackson, 1968). Without network technology, communication in the classroom is generally limited by physical proximity, with classroom communication primarily synchronous.

Within the STS framework, the characteristics of the social system which are considered to most impact the effectiveness of organizational and work system designs are the degree of professionalism and the psycho-social characteristics of the personnel (Hendrick, 1984a, 1991).

- The degree of professionalism refers to the training and education required for a given job; teachers exhibit the highest degree of professionalism in the classroom with student professionalism related to their educational level.
- Psycho-social characteristics are typically divided into 1) cultural alignment, or the degree to which personnel values are aligned with the organizational culture, and 2) cognitive factors which encompass the cognitive styles, motivation, and attitudes of system personnel.

The introduction of classroom computer technology raises the levels of professionalism required by both students and teachers. It also decreases the routine nature of classroom tasks, which is thought to trigger increases in motivation and quality of work life for students and teachers. In general, personnel interacting with more complex technology have been found to be more satisfied and more highly motivated than those interacting with highly routine technology (Hendrick, 1984a; Rousseau, 1978). However, in keeping with STS theory, when classroom technology is not deployed in a manner well aligned with classroom culture and processes, the technology has little effect on educational processes (Cuban, 1986; Tyack and Cuban, 1996).

3.3.4 Environment

Of all the sociotechnical system factors which impact the effectiveness of an organizational design, environmental uncertainty is thought to be the most influential (*e.g.*, Burns and Stalker, 1961; Lawrence and Lorsch, 1967). It is a function of the degree of complexity and change in an organization's external environment (Lawrence and Lorsch, 1967). The degree of change relates to the stability of the task environment over time, while the degree of complexity relates to the number of relevant task environments (Hendrick, 1991). In general, the greater the degree of environmental uncertainty, the greater the need to minimize the number of levels in the organization, decrease the extent to which formal decision-making is vested in a single individual or group, increase the professionalism of organizational members, and decrease the extent to which daily operations are standardized in the organization (Hendrick, 1991).

For classroom systems, the task environments of most concern are the larger school, the families, and the community. Classrooms typically experience low environmental uncertainty; they are part of larger school systems with mandated public funding and thus are insulated from many external forces of change (Chubb and Moe, 1990; Hodas, 1993). However for classroom technology interventions to succeed, school level support, especially that of the principal, is needed for computer training, computer system support, and the fostering of educational innovation (Coley, 1997; 'Yaghi, 1996). Without school level support, innovations in the use of classroom computer technology seldom diffuse into the larger organization (Means and Olson, 1995).

3.4 "Micro" Elements of the Classroom

At the "micro" level, classroom researchers and designers are concerned primarily with learner capabilities, limitations, and other characteristics and how they affect the efficacy of learning tasks and specific technology interfaces. The "micro" elements are generally considered as relating to 1) human-machine interface (*e.g.*, student workstation design), 2) human-environment interface (*e.g.*, classroom lighting), 3) human-software interface (*e.g.*, computer-assisted-instruction program interface), or 4) human-job interface (*e.g.*, curriculum units) (Hendrick and Kleiner, 2000). Although STS methodology provides an appropriate framework for considering how the "micro" elements of learning systems affect other system elements, it provides classroom practitioners with no direct instruction on how to analyze or design these elements (Hendrick and Kleiner, 2000). Classroom practitioners must look to methodologies from the domains of education, traditional ergonomics, human-computer interaction, instructional technology, and related fields for guidance at the "micro" level.

3.5 Macroergonomic Analysis Process

This section provides a brief overview of the general macroergonomic process and a discussion of methods commonly used in macroergonomics. The macroergonomic design and analysis process combines sociotechnical system methodology with traditional ergonomic methods and techniques. At both the “macro” and “micro” level, the aim of this process is to maximize the fit between system components. Participation by system stakeholders throughout this process is considered essential (Hendrick and Kleiner, 2000). Several variants of this process can be found in the literature (*e.g.,* Hanna, 1988; Hendrick and Kleiner, 2000) with most being based on the Emery and Trist (1978) sociotechnical analytical model. Typically, the analysis process includes the following activities:

1. Initial Scanning
2. Technical Subsystem Analysis
3. Technical Work Process Analysis
4. Variance Data Collection and Analysis
5. Social Analysis
6. Organizational, Joint, and Function Design
7. Role and Responsibility Perception Analysis
8. Support System and Interface Design
9. Implement, iterate, and improve

This process is generally not performed in a fixed sequential manner or in its entirety (Hendrick and Kleiner, 2000). Application of the complete process is most practical when creating a new system or making major modifications to an existing system (Hendrick and Kleiner, 2000). A brief discussion of each of the stages is presented in the following sections. The process models of Emery and Trist (1978) along with Hendrick and Kleiner (2000) form the basis of this discussion.

3.5.1 Initial Scanning

In this stage, the analyst identifies the main characteristics of the system including the system boundaries, major system processes, feedback mechanisms, inputs and outputs, existing organization structure, interactions with environment, primary stakeholders, and main objectives. Often this information is presented in graphical form, such as the classroom diagram shown in Figure 2-2 . Differences between the system’s stated goals and its actual behavior are noted; these differences are viewed as “opportunities” for system enhancement (Hendrick and Kleiner, 2000). Based on this initial assessment, a preliminary “ideal” system is proposed. For instance, if a school district provides home tutors to seriously ill students in order to minimize school re-entry difficulties but finds that returning students often have difficulty re-establishing classroom ties, the district might propose using network technology to allow home-bound students to actively participate in classroom activities and maintain social ties.

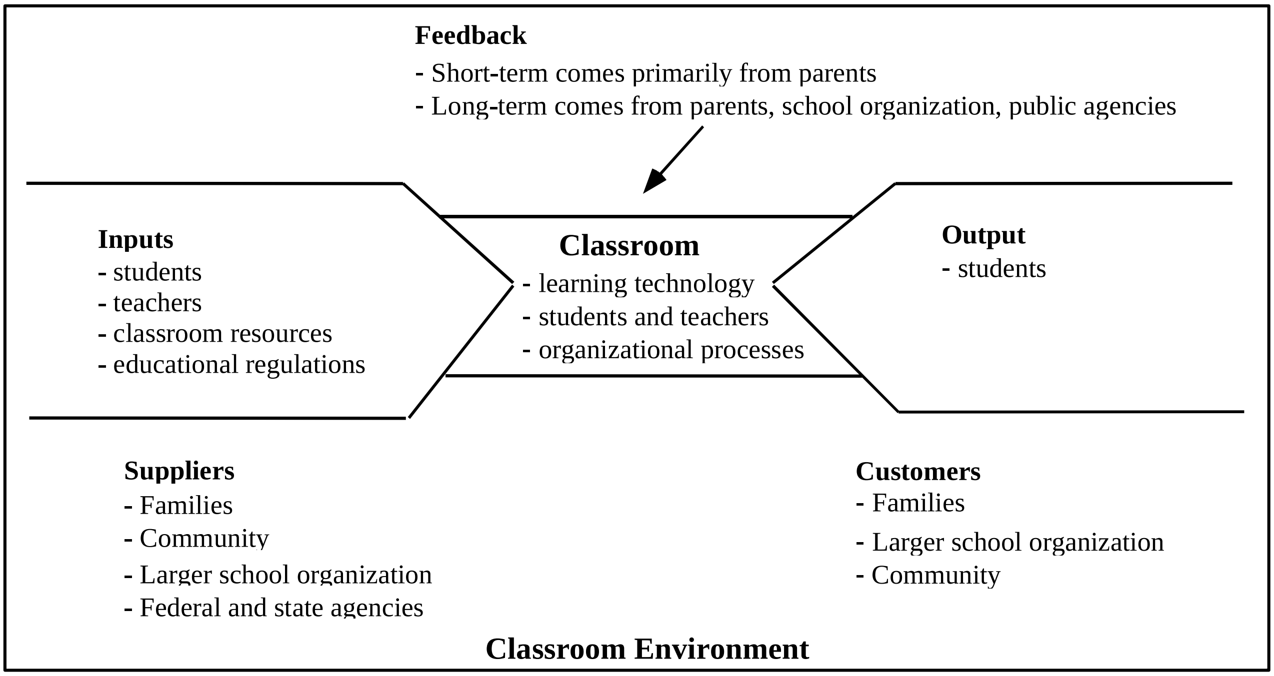

Figure 3-2. High-level classroom process model developed for the PCs for Families (PCF) project.

3.5.2 Technical Subsystem Analysis

Here, the analyst determines the nature of the system technology (*e.g.*, routine vs. craft), defines performance expectations for the system, and identifies performance criteria. These criteria then serve as guides for the development of specific measures, both objective and subjective, for assessing system effectiveness. Sink and Tuttle (1988) performance criteria (effectiveness, efficiency, quality, productivity, quality of work life, innovation, and budgetability) are commonly used to ensure a balanced scorecard approach to system measurement. Using information from this stage, the original "ideal" system can be revised.

3.5.3 Technical Work Process Analysis

During this phase, the analyst flowcharts system processes and identifies unit operations, or major phases, in the process that converts inputs to outputs. In non-linear systems like the classroom, these processes may occur in parallel as well as sequentially (Hendrick and Kleiner, 2000). Unit operations can be determined by natural breaks in the process, and are often related to a particular sub-product or changes in system inputs. For example, a teaching process might be divided into planning, actual teaching, and assessment. Objectives, inputs, transformations, and outputs should be defined for each unit operation; this information will be used to establish the function and sub-functions for the system.

3.5.4 Variance Data Collection and Analysis

A variance is an unexpected departure from normal procedures or an unanticipated violation of system expectations (Pasmore, 1988). Variances can be 1) input variances which are the result of the environment, 2) throughput variances which result from the normal conversion process, or 3) output variances in the final products (Hanna, 1988). For instance, differences in students' entry knowledge would be an input variance but differences in students' exit knowledge would be an output variance, while differences in teaching practices would be a throughput variance. System variances may be identified based on actual system performance or on performance expectations for a proposed system.

A grid is created with the variances serving as titles for the rows and columns of the grid; variances should appear in the order that they occur in the system, *i.e.* input variances would come before throughput variables. Next an X is placed in any grid cell where the variances used to label the column and the row are related; alternatively, numbers can be placed in a cell to indicate the variance's importance. Empty cells mean that no relationship exists between the two variances. Figure 2-3 presents a portion of the variance matrix for the PCF project. Once the matrix has been created, the analyst can identify the key variances, which are those variances that significantly impact system performance or have numerous relationships with other variances.

	Student Learning Styles	Student Previous Achievement	Student Family Involvement	Teacher Pedagogic Beliefs	Availability of Classroom Technology
Classroom Input Variances					
Student Learning Styles					
Student Previous Achievement	X				
Student Family Involvement		X			
Teacher Pedagogic Beliefs					
Availability of Classroom Technology				X	
Classroom Throughput Variances					
Student Grades		X	X	X	X
Student Absences			X	X	X
Innovative Uses of Technology	X	X		X	X

Figure 3-3. A portion of the PCF variance matrix.

3.5.5 Social Analysis

The first step in this phase is the construction of a key variance control table. For each key variance, the table contains the following information: (a) unit operation in which the variance can be controlled or corrected, (b) who is responsible, (c) current control activities, (d) what knowledge or information is necessary to support control, and (e) what technology is necessary to support control (Hendrick and Kleiner, 2000). The next step is to construct a network of roles for the system (or sub-system if the system is complex). As shown in Figure 2-4, lines are used to link roles that must communicate with arrows indicating the direction of communication and width indicating the frequency of communication. Discrepancies between actual and needed communication patterns can be uncovered, and the “ideal” system modified to support the needed communication patterns.

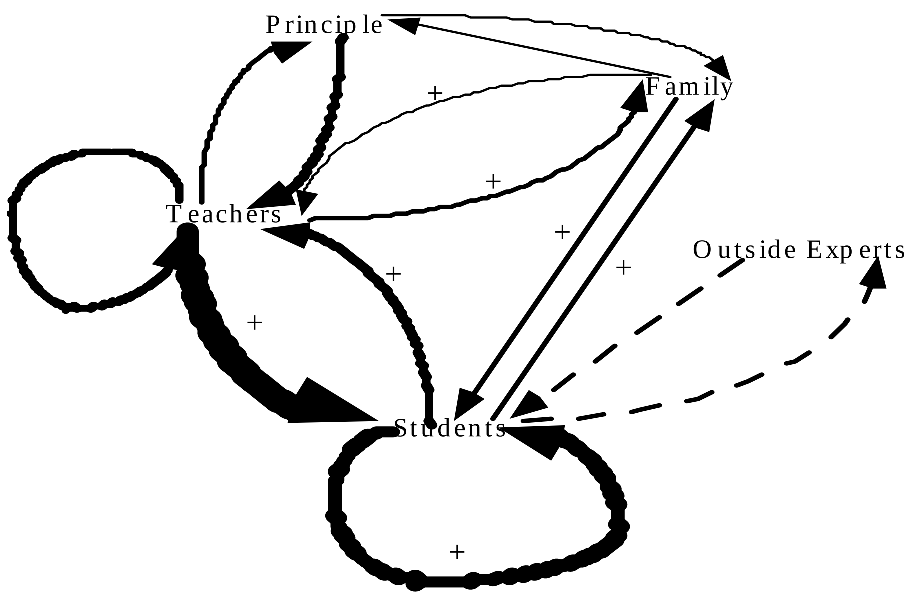

Figure 3-4. High-level role network developed for the PCF classroom. Solid lines represent actual patterns, dashed lines represent desired patterns, and + indicates those relationships where the PCF intervention was expected to result in more frequent communication.

Social network analysis provides a methodology for studying changes in role networks. Social network analysis has been used extensively to explore relationships between individuals in organizations as well as relationships between organizations. In keeping with macroergonomic theory, social network methods and techniques are based on the assumption that the behavior of an individual is influenced by both the characteristics of the individual and by the patterns of relationships the individual has with others. Using social network techniques, a researcher can find clusters of individuals who share similar patterns of relationships with others, evaluate the importance of a particular person to group communication, or examine the strength of relationships between individuals with certain attributes.

Social networks are defined by sets of ties or relations between actors, where an actor is an individual or social unit (Wasserman and Faust, 1997). The ties between actors can vary in frequency, strength, and type. Graphs are often used to represent social networks, which are akin to the role networks commonly used in macroergonomic analyses. Nodes in the graph represent individual actors, while the lines represent ties between actors. The patterns of relationships between actors can be operationalized as structural variables. Structural variables commonly used to examine on-line networks include *density* which measures the proportion of all possible ties which actually exist, *boundedness* which assesses the extent to which member ties remain within the boundaries of their social group, *centrality* which measures a member's prominence in the social network, and *tie strength* which assesses closeness or frequency of contact between members (Wasserman and Faust, 1997; Wellman, 1996).

3.5.6 Organizational, Joint, and Function Design

The major focus at this stage is to control key variances through the introduction of additional technology (*e.g.,* a chat facility to increase after-school collaboration among isolated, rural students), refinement of the social subsystem (*e.g.*, addition of a school system administrator to increase network uptime), or modification of the organizational design (*e.g.,* teaming teachers). At this point, system designers determine which functions are best performed by humans and which are best performed by the technology using human-centered techniques. "Micro" elements of the system are also designed or refined during this stage. Next keeping in mind the previous changes, the proposed social subsystem is refined with the primary considerations being personnel skills and knowledge, system communication requirements, personnel information needs, and elimination of redundancies.

3.5.7 Roles and Responsibility Perception Analysis

The views of students, teachers, and others in the classroom may be different from those doing the preceding analysis. Using the previously defined roles and feedback from classroom stakeholders, differences between defined roles and perceived roles can be discovered. Technology or training may be required to align stakeholder role perceptions with defined roles. For instance, a teacher might see herself only as a consumer of classroom technology. If her defined role includes responsibility for maintaining classroom technology, she may need further training or a technical support role may be needed for the classroom to function smoothly.

3.5.8 Support System and Interface Design

Support systems for a classroom system may be added or re-designed after system technology is re-designed. For example, computer technical support may be necessary after collaborative Internet technologies have been added to a classroom system. Additionally, technology interfaces and the internal physical setting may need to be modified. For example, classroom lighting may be modified to reduce computer glare.

3.5.9 Implement, iterate, and improve

"Implementation" of the proposed system may take the shape of a proposal, a prototype, or even an actual system (Hendrick and Kleiner, 2000). Evaluation of the proposed system is critical. Care should be taken to include the appropriate stakeholders and experts in the evaluation process. Evaluation can take many forms including field study, laboratory study, surveys, and focus groups. Using evaluation feedback, the proposed system can be further refined.

3.6 Role of Macroergonomics in this Research

In the fall of 1996, the Computer Science Department at Virginia Tech initiated a joint project, called PCs for Families (PCF), with the Montgomery County Public Schools in Virginia, to determine how ready access to networked computing in the fifth-grade would affect long-term student achievement. This research was undertaken to explore the effects of the PCF intervention on *the third cohort* of students and families participating in the project. Macroergonomics served as the theoretical framework for this research, which focused on the in-depth, systematic assessment of those changes that resulted from exposure to the PCF fifth grade network classroom. Table 3-1 summarizes the PCF intervention in terms of the previously discussed STS conceptual model.

Investigations of the effects of the PCF intervention on the earlier cohorts of students and families had highlighted the limitations of traditional evaluation methodology. Traditional approaches to project evaluation (*e.g.*, comparison of standardized test scores and survey research) by themselves proved too limiting and provided little insight into the complicated relationships between home and school and the effect of network technology on students and families. Project researchers identified the need for an evaluation approach that provided 1) a mechanism for systematically identifying the key differences between a standard classroom and the PCF classroom, 2) a theoretical framework for relating student and family changes to elements of the PCF intervention, and 3) a process for exploring both the “micro” and “macro” aspects of the PCF classroom.

One approach that satisfied the previous criteria was macroergonomics. Although macroergonomics is frequently used to successfully design technology interventions and study their effects in adult organizations, it had not been used before as a framework for examining issues related to the introduction of computing technology in elementary schools. Macroergonomic methodologies for analysis and design of work systems were expected to be extensible to classroom systems and to provide a robust framework for examining issues related to the PCF intervention. Within this framework, the PCF classroom can be viewed in terms of four interdependent elements: social, technical, organizational, and environmental. This breakdown was especially appropriate as the primary goal of this research was to understand how the elements of the PCF intervention affected students, teachers, families, and the learning process.

As the PCF project was already in place, macroergonomics was used mainly as a framework for modeling the expected impact of PCF intervention elements and for developing evaluation criteria for the intervention. Macroergonomics guided research efforts at both the “macro” and “micro” levels, with the primary focus being

- Development of a high-level classroom model during system scanning as shown in Figure 3-2.

- Identification of variances for the PCF classroom based on the expected results of the intervention, a comprehensive literature review, and detailed STS analyses of a standard and the PCF classroom.

- Selection of an initial set of key variances based on the strength of their linkage with PCF intervention elements. This set was further refined using project evaluation priorities. A portion of the resulting variance matrix is shown in Figure 3-3.

- Development of role networks for the standard classroom and identification of changes that were expected to occur as the result of the network technology.

- Interviews with students, families, and teaching staff were used to verify researcher perceptions of responsibilities in the system.

Based on the previous analyses, a research model was developed and performance criteria created for the third year of the project. As the set of criteria was so large as to be infeasible to implement, a subset was selected based on input from school personnel and further definition of research priorities. The resulting research model and performance criteria will be discussed in greater detail in the remaining chapters. Additionally, participatory ergonomics were used to involve classroom stakeholders in the design of “micro’ elements of the classroom, with output from “macro” level analyses guiding investigation of classroom “micro” elements.

Table 3-1. The PCF intervention in terms of the STS conceptual model.

Grade	Technological	Social	Organizational	Environmental
5	• Teacher instruction on constructivist learning practices • Classroom network technology • Classroom, computer support	• Mandatory student computer training	• Student pairing for learning activities	• Free home network technology • Free home Internet access • Home computer system support • Optional parent computer training
6, 7	n/a	• Optional student computer training	n/a	• Free home network technology • Free home network accounts • Home computer system support

CHAPTER 4. A MODEL FOR EVALUATING THE PCS FOR FAMILIES PROJECT

Chapter Table of Contents

4.1 INTRODUCTION.......42
4.2 RESEARCH MODEL.......42
4.3 RESEARCH HYPOTHESES.......44

4.1 Introduction

In the fall of 1996, the Computer Science Department at Virginia Tech initiated a joint project, called PCs for Families (PCF), with a rural elementary school, to determine how ready access to networked computing in the fifth grade would affect long-term student achievement. During the fifth grade, students in the program were to experience constructivist teaching practices combined with ubiquitous network computer technology, in both the school and the home. The project sent a computer home with each child and teacher, and provided as much support as necessary to all program participants, including parents. Students, along with their parents, received training in using the technology to facilitate the learning process. Throughout the project, teachers, students, and families in the program had access to on-call computer system support in both the classroom and home.

The original goal of project evaluation was very specific: to see whether in a 3 to 5 year period researchers would find changes in standardized test scores between PCF children and those in a matched control group selected anonymously from children across the school district. However, the original approach to evaluation proved too limiting and provided little insight into the complicated relationships between home and school and the effect of network technology on students and families. A decision was made in the second year of the project to transition to a macroergonomic approach to evaluation.

The research discussed here is limited to the third year of the project and focused on the in-depth assessment of the last cohort of students to enter the program. The primary vehicle for this research was a yearlong field experiment that explored the "macro" effects of the PCF intervention on the last cohort of students participating in the project. Participatory methods were used to further evaluate the design of "micro' elements of the classroom, with results from the field experiment guiding investigation of classroom "micro" elements.

4.2 Research Model

This research focused on the systematic assessment of quantitative changes that occurred in the third cohort of PCF students as the result of exposure to the networked, technology-rich classroom during the 1998-1999 academic year. The conceptual model for this research is shown in Figure 3-1. The model shows the expected interactions between changes in computer technology accessibility and support, teaching practices, and changes in classroom processes and outcomes. An interaction was also expected between the classroom performance and the measurable effects of technology access and teaching practices on student and family involvement in learning. Classroom performance includes common outcome measures, both objective and subjective, related to both the social and technical aspects of the classroom as well as environmental factors.

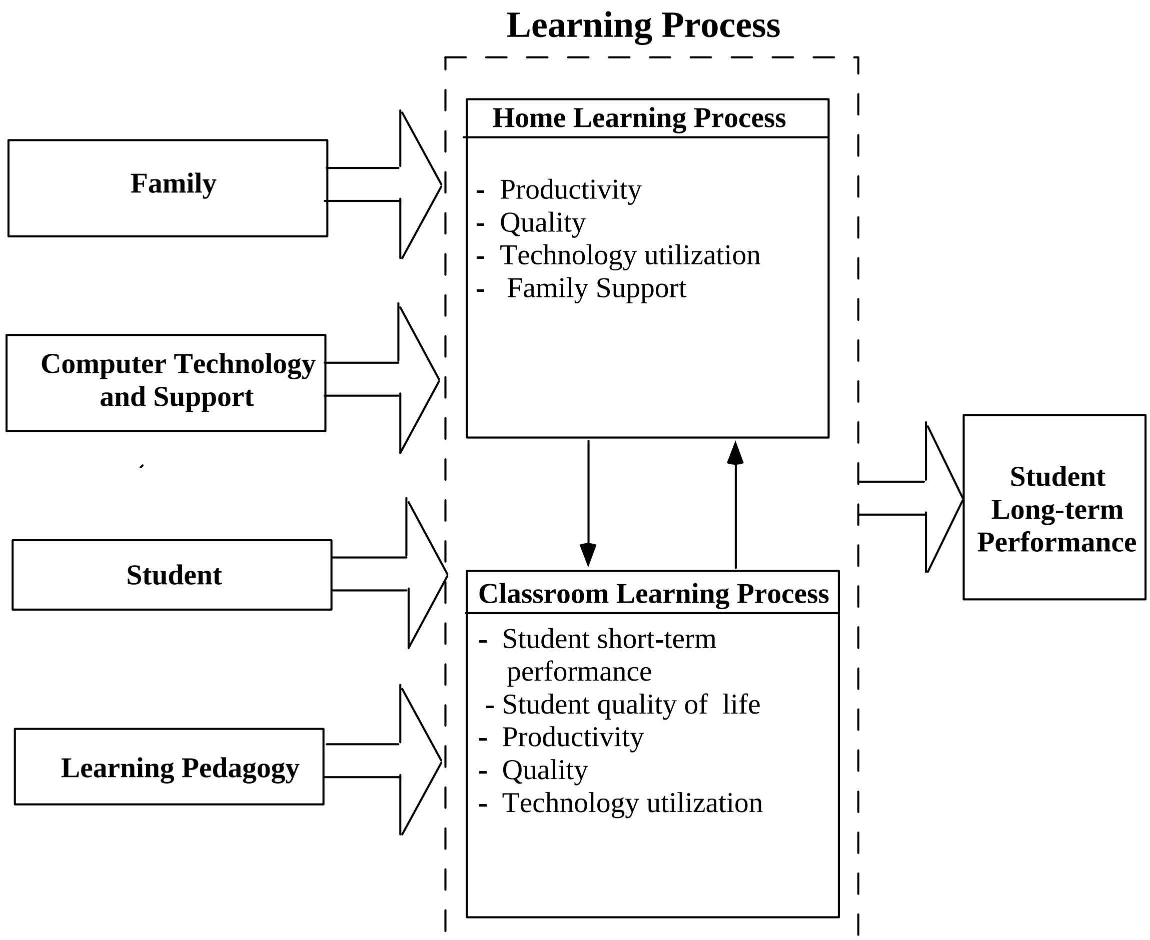

Figure 4-1. Conceptual model for PCF intervention.

The factors affecting student achievement and their anticipated interactions are shown in greater detail in Figure 3-2. As student performance and quality of work life (QWL) were expected to be related to student entry values, the associated measures were formulated to assess changes occurring over the course fifth grade. Technology use and classroom pedagogy were expected to affect student QWL and achievement, as was the effectiveness of the home-school partnership. Student technology use was expected to be largely explained by technology availability (*e.g.*, home computer technology), participant entry characteristics (*e.g.*, cognitive style or SES), and social influences on technology use (*e.g.*, classroom technology use). Student technology use is expected to mediate the impact of these factors, which were not expected to directly influence the magnitude or direction of student gains on outcome measures.

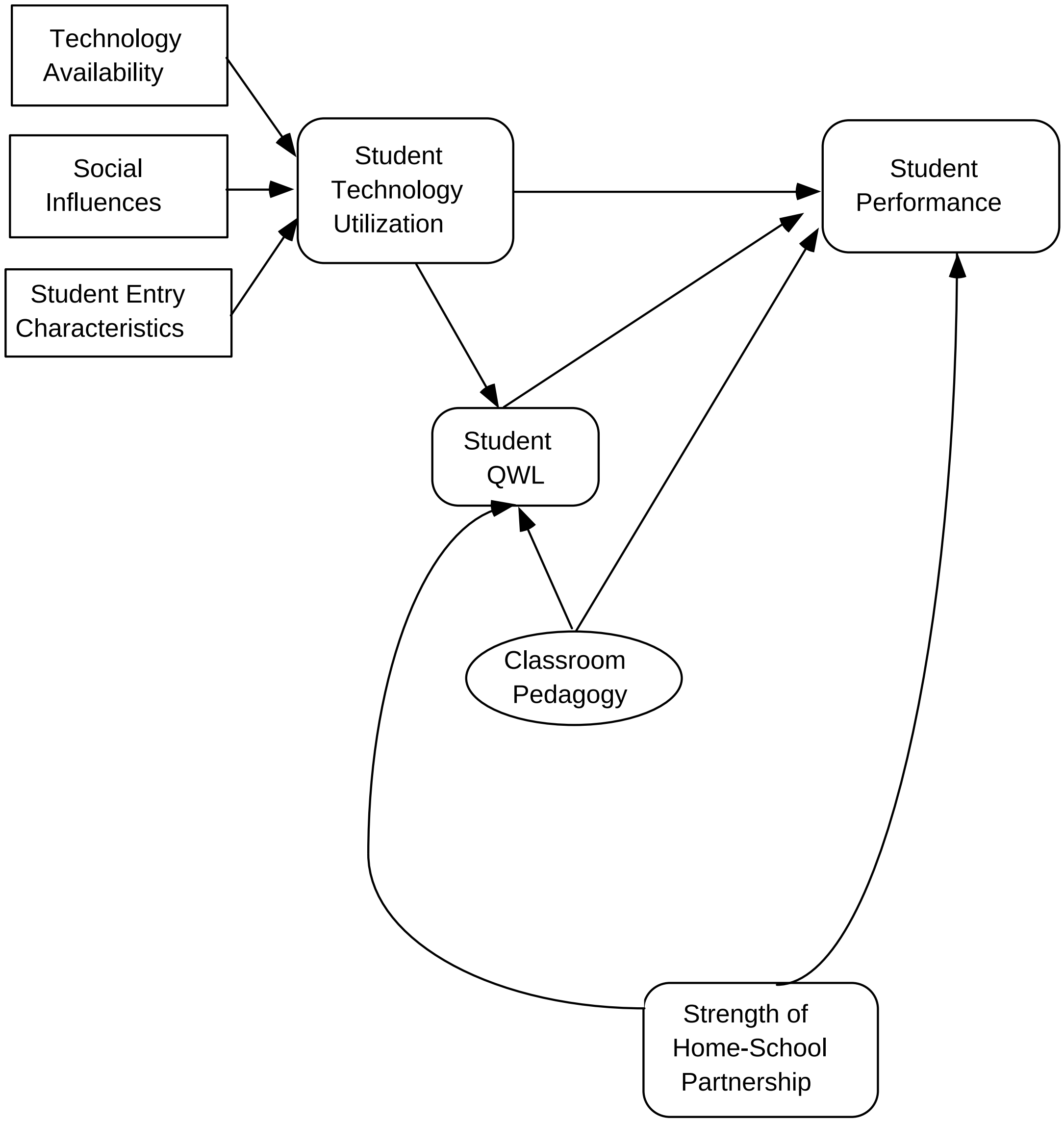

Figure 4-2. Factors affecting changes in student achievement and QWL during fifth grade.

4.3 Research Hypotheses

The general hypothesis of this research was that, when compared to a traditional fifth grade classroom, the enriched PCF learning environment would result in significantly greater improvements in student performance, the learning process, and family involvement. Based on the general hypothesis and the nature of the proposed study, the following specific hypotheses were formulated.

- ***Hypothesis 1.*** The learning process of the PCF class will be significantly more productive and make greater use of computer technology than that of the control class. In particular, when compared to the control class, the learning process in the experimental class will

    a) make greater gains on student standardized test scores, learning process inventory scores, and student grades;

    b) involve less time spent doing homework and significantly better homework reliability as measured by homework delivery metrics and behavior checklists;

    c) result in higher levels of student computer knowledge as measured by the number of target computer skills students can successfully demonstrate and technology scores from standardized tests; and

    d) involve greater use of computer technology to support learning activities, both in the school and in the home, as measured by computer logs, computer laboratory use metrics, and self-reports.

- ***Hypothesis 2.*** During the fifth grade, students in the PCF class will make greater gains in learning motivation, and will have more positive perceptions of their ability to learn and academic activities than students in the control class. In particular, when compared to students in the control class, students in the experimental class will

    a) make more positive gains in their attitudes towards school as measured by student surveys and student school attendance;

    b) have more positive attitudes towards computers as indicated by student surveys.

- ***Hypothesis 3.*** During the fifth grade, parents of students in the PCF class will be more supportive of learning activities and will use computer technology more often to support learning activities than parents in the control classroom. In particular, when compared to parents of students in the control class, parents of students in the experimental class will

    a) spend more time helping students with homework and supporting school activities based on family self-reports;

    b) make more contacts with school personnel based on family self-reports; and

    c) use computer technology more often to support home learning activities and to communicate with school personnel based on family self-reports.

- ***Hypothesis 4.*** Home computer use, as measured by computer logs and self-reports, will increase as the year progresses for the PCF class with student performance related to home computer use, student QWL, and family involvement.

    a) Student home use of computer technology will increase as the school year progresses.

    b) Parents will increase their use of computer technology to support home learning activities and to communicate with school personnel as the school year progresses.

    c) A relationship will exist between student cognitive styles and student home use of network technology.

    d) A positive relationship will exist between student home network usage and changes in student achievement and QWL.

    e) A positive relationship will exist between student musculoskeletal complaints and student home computer use. Further, a positive relationship will exist between student musculoskeletal complaints and the degree of mismatch between student anthropometric dimensions and student workstation dimensions.

CHAPTER 5. "MACRO" EVALUATION METHODOLOGY

Chapter Table of Contents

5.1 INTRODUCTION 48
5.2 EXPERIMENTAL DESIGN 48
5.3 DEPENDENT VARIABLES 50
5.3.1 Learning Variables 50
5.3.1.1 Student Performance Variables 50
5.3.1.2 Student Overtime Variables 51
5.3.2 Student Attitudinal Variables 52
5.3.3 Family Support Variables 53
5.3.4 Computer Technology Variables 54
5.3.4.1 Attitudes Towards Technology 54
5.3.4.2 Technology Usage 55
5.3.4.3 Technology "Fit" 57
5.4 PARTICIPANTS 57
5.4.1 Protection of Participant Rights 58
5.5 MATERIALS AND APPARATUS 58
5.5.1 Experimental Instruments 58
5.5.2 Computer Usage Logging 58
5.5.3 Classroom Video Taping 59
5.6 PROCEDURE 59
5.6.1 Pilot Testing 59
5.6.2 Data Collection Procedures 59
5.6.2.1 Administration of Experimental Instruments 59
5.6.2.2 Measurement of Student Anthropometric Dimensions 60
5.6.2.3 Computer Logs 60
5.6.2.4 School Records 61
5.6.2.5 Classroom Videotaping and Analysis 61

5.1 Introduction

This section presents methodology for the yearlong field experiment used to evaluate the “macro” effects of the PCs for Families (PCF) intervention. The main objective of this field experiment was to investigate the quantitative effects of constructivist teaching practices combined with ubiquitous network computer technology, in both the classroom and home, on student achievement and behaviors, learning processes, and family involvement over the course of a school year. Macroergonomics served as the theoretical framework for the field experiment, with dependent variables formulated to measure key aspects of the technological, social, and organizational subsystems of the classroom.

5.2 Experimental Design

The mixed-factor, longitudinal field experiment shown in Figure 5-1 factorially combined classroom type (CLASS), the time period under consideration (PERIOD), and student gender (GENDER).

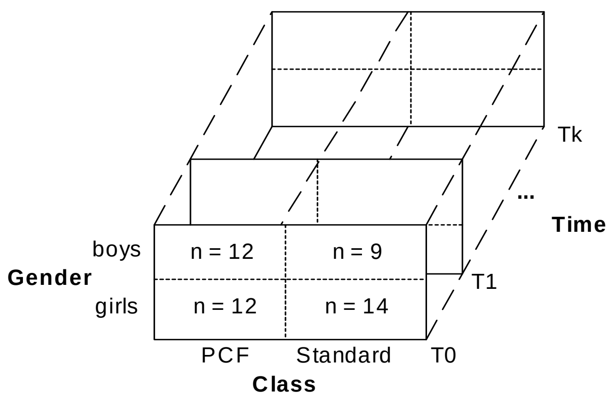

Figure 5-1. Experimental design for year-long field experiment.

The between-subject factor CLASS had two levels (PCF classroom, Standard classroom). Differences between the two levels of CLASS can be categorized by the following variables.

- **Technical variances**
    1. Teacher trained on constructivist learning practices (PCF = Yes, Standard = No).
    2. Classroom Network Technology (PCF = ubiquitous, Standard = limited).
    3. Classroom computer support infrastructure, *i.e.*, classroom technology specialist and on-call classroom computer system administrator (PCF = Yes, Standard = No).

- **Social variances**
    1. Student Computer Training
       (PCF = Weekly-Mandatory, Standard = Biweekly-Optional).

- **Organizational variances**
    1. Student Pairings (PCF = Yes, Standard = No).

- **Environmental variances**
    1. Free Home Network Technology (PCF = Yes, Standard = No).
    2. Home Computer System Support (PCF = Yes, Standard = No).
    3. Parent Computer Training
        a) Optional Computer Training
           (PCF = Weekly, Standard = Monthly).
        b) Parent training on how to more effectively support student using network technology (PCF = Yes, Standard = No).

Students under the two conditions had different homeroom teachers. As the two classes were part of a fifth-grade pod where each teacher was responsible for a specific subject, students from both conditions were taught most subjects by the same teachers. Generally, students changed classrooms for each subject. However, because of the field experiment, the PCF students stayed in the technology-rich classroom, and teachers were the ones to change classrooms.

The number of levels for the within-subject factor PERIOD depends on the frequency of data collection for a particular variable.

- In general, most variables have two or three levels of PERIOD resulting in measurement periods of 12 or 18 weeks given a 36-week school year.

- Additionally, cumulative changes across the school year may be analyzed for some dependent measures to better gauge the overall impact of the intervention.

The frequency of data collection for dependent measures is explicitly marked in the *Dependent Variables* section of this section. Note, regardless of data collection frequency, the time between data collections for a particular measure was approximately equivalent across the year.

The between-subject variable GENDER has two levels (Male, Female). Gender was selected as an experimental variable as studies have shown that gender can be a factor in student attitudes towards computers and in determining student computer activity patterns (Krendl and Broihier, 1992; Mohamedali *et al.*, 1987; Ross *et al.*, 1989; Sutton, 1991).

5.3 Dependent Variables

The dependent variables described here were formulated to fulfill the research objectives and to measure the key variances that were identified based on experimental hypotheses, a comprehensive literature review, and detailed sociotechnical (STS) analyses of a standard and the PCF classroom. Both objective and subjective variables were gathered with objective preferred. In general, subjective variables were paired with objective ones, as minimal objective data would be collected by the PCF project once the students leave fifth grade. Individual dependent variables can be categorized as follows:

- learning variables
- student attitudinal variables
- family support variables
- computer technology variables

In terms of the previously discussed STS conceptual model, learning variables measure the classroom technological subsystem, student attitudinal variables measure the social subsystem, and family support variables measure the environmental subsystem. Computer technology variables can be sub-divided into those related to computer usage which measure the technological subsystem, and those related to attitudes towards computers, which measure the social subsystem.

A detailed discussion of each variable, including its scoring method, can be found in the *Procedure* section of this chapter. Simple dependent variables, *e.g.*, survey scores, may be used to formulate a set of evaluation measures. From a single variable, multiple measures may be formed that relate to the changes in the variable score across the course of the year or that relate variable changes to costs. The resulting measure set was then be used for analysis purposes. Both the simple dependent variables and associated composite measures are given in this section. Due to the nature of the proposed experiment, some dependent variables were not applicable to the control classroom. Such variables are explicitly noted in this section.

5.3.1 Learning Variables

These variables assess changes in learning performance during the fifth grade, including changes in student performance (*e.g.*, grades) and work habits (*e.g.*, homework effort).

5.3.1.1 Student Performance Variables

These variables assess changes in learning performance during the fifth grade. As previous student achievement is a strong predictor of future learning performance (Scileppi, 1988), learning performance variables are formulated to assess the size of the gains in learning performance relative to earlier grades and are not based solely on fifth grade performance. Table 5-1 summarizes these variables.

Table 5-1. Alternative Dependent Variables for Learning Performance.

Group	Associated Measures	Details
Standardized Test Performance	fifth grade Standards of Learning (SOL) Scaled Scores	Scaled scores are available for the following categories: reading, writing, social sciences, mathematics, and science.
	3rd grade Stanford 9 Scaled Scores	The scores serve as covariates during the analysis of the SOL scores in order to remove the variance in scores due to previous achievement.
Grades	Subject Grade	Fifth grade moving ranges for a given subject - those of 4th grade.
	Overall GPA	Fifth grade moving ranges for overall GPA
Technology Skills and Knowledge	Training Skills Checklist Score	A maximum score of 52 was possible with a point was given for each task component successfully completed from the *Training Skills Checklist* found in the appendix titled *Evaluation Instruments.*
	Typing Speed	Average number of characters typed per minutes
	Typing Accuracy	Percentage of characters typed correctly
	Technology SOL Scaled Scores	The technology category was comprised of the following sections: 1) basic understanding of computer technology, 2) basic operational skills, and 3) using technology to solve problems. Scores on the sections could range from 0 to 50.

5.3.1.2 Student Overtime Variables

These variables focus on student overtime, *i.e.*, homework activities. Unless otherwise noted, variables have three 12-week measurement periods. Table 5-2 summarizes these variables.

Table 5-2. Alternative Dependent Variables for Homework Process.

Measures	Details
Homework Duration	Average amount of time spent on homework each day (self-report).
Homework Process Measure	Assessed by the *Homework Problem Checklist*, which is taken at the start and end of the school year.
Homework Reliability	Percentage homework assignments completed on time.

5.3.2 Student Attitudinal Variables

These variables assess changes in students' motivators, self-perceptions, and attitudes towards school activities across the course of the year. Attitudinal and motivational differences between students account for more of the variation in achievement than family or school variances (Coleman, *et al.*, 1990), with computer-rich learning environments shown to improve self-perceptions, increase student motivation, and result in more positive attitudes towards learning (Follansbee, 1996; Herman, 1988; Means and Olson, 1995a; McKinnon *et al.*, 1996; Wilson and Peterson, 1995; 'Yaghi, 1996). As with learning performance variables, these variables are formulated to assess attitudinal and motivational changes across the school year. Table 5-3 summarizes these variables.

Table 5-3. Student Attitudinal Dependent Variables.

Group	Measure	Details
School Attitudes	School Attitude Measure	Measured by School Attitude Measure (SAM), Second Edition, Level G/H yearly moving ranges for national percentile. Component scales include (a) *Motivation for Schooling*, (b) *Academic Self-concept -- Performance-based*, (c) *Academic Self-concept -- Reference-based*, (d) *Student's Sense of Control over Performance*, and (e) *Student's Instructional Mastery*.
	Attendance	Available every six weeks. Δ (4th-5th) days absent / tardies serve as measures.
	Knudson Writing	Attitudes towards writing were assessed by student scores on the *Knudson Writing Survey*.
Cognitive Style	Learning Style	Percentiles for verbal, visual, and kinesthetic learning. Covariate or regressor variable.
	MMPI Scores	Scores for MMPI Thinking-Feeling, Judging-Perceiving, Extroversion-Introversion, and Sensing-Intuition scales. Covariate or regressor variable.

5.3.3 Family Support Variables

These variables measure the amount of support families provides students and the family's level of satisfaction with the school organization. Unless otherwise noted, these variables have three 12-week measurement periods. Table 5-4 summarizes these variables.

Table 5-4. Family Support Dependent Variables.

Group	Measures	Details
Home-School Communication	Perceived Quality Rating Ranking of Communication Modes	Self-report data Self-report data
	Number of Contacts Per Week	Self-report data
	Number of Parent-Teacher Email Contacts	Extracted from proxy server data.
Parental Support for School Activities	Time parents spent helping students with homework	Self-report data
	Time parents spent at school	Self-report data

5.3.4 Computer Technology Variables

These variables assess the degree to which computer technology has become a part of the learning process along with student attitudes towards technology. In order to minimize data collection demands on the family, only variables related to computer use for schoolwork are collected from the families. For the most part, these variables focus on information that can be collected without direct parent input. Unless otherwise noted, these variables have three 12-week measurement periods.

5.3.4.1 Attitudes Towards Technology

These variables assess student attitudes towards computers and their use in learning. Table 5-5 summarizes these variables.

Table 5-5. Computer Attitude Dependent Variables.

Measures	Details
Computer Attitude Measure	Assessed by *How Do You Feel About Computers Scale* (Todman and File, 1990), which is taken three times during the school year**.** The maximum score for this measure was 80; scores for individual items ranged from zero to four where zero signified never and four signified always.
Computer Writing Attitude Measure	Assessed by *Attitudes Toward Writing With the Computer Scale* (Shaver, 1990), which is taken three times during the school year. The maximum score for this measure was 45. Scores for individual items ranged from one to five where one signified strongly disagree and five signified strongly agree

5.3.4.2 Technology Usage

These variables assess the degree to which computer technology has become a part of the learning process in the classroom and in the home. These variables explore how the computer is used and the extent to which the computer is incorporated into the learning process. Table 5-6 summarizes these variables.

Table 5-6. Technology Usage Dependent Variables.

Group	Measures	Details
Classroom Usage	Average number of hours per week of use in the technology-rich classroom	Measured by Historian logging software for machines in the PCF classroom
	Average amount of time spent using each category of software in the technology-rich classroom	Applications was categorized as either 1) Internet-related, *e.g.,* web browsers and ftp applications, 2) production-related, *e.g.,* word-processors and drawing programs, or 3) other which related primarily to computer assisted instruction and non-educational games, *e.g.,* solitaire. Measured by Historian logging software.
	Average number of different applications used each week technology-rich classroom	Measured by Historian logging software.
	Average number of World Wide Web accesses in the technology-rich classroom	Measured by Historian logging software.
	Number of hours per week the school computer laboratory was used by the control class	The number of hours spent in the computer laboratory as reported by the teacher.
Self-reports of Home Computer Use	Daily average for home computer use	Self-report data (minutes).
	Daily average for computer game playing	
	Daily average for home Internet use	
	Daily average for home computer use for homework. purposes	
	Daily average for home Internet use for homework. purposes	
Network Utilization by PCF Families	Number of web pages accessed during a given time period	Extracted from PCF proxy server logs.
	Email use	Number of email messages sent to individual
		Number of email messages sent from individual
		Number of email account accesses
		Email ties between individuals
	Chat use	Number of lines entered in project chat room.

5.3.4.3 Technology "Fit"

These variables assess the extent to which technology in the PCF classroom "fit" students and the effect of long-term technology usage on students.

Table 5-7. Technology "fit" Dependent Variables.

Group	Measures	Details
Musculoskeletal Discomfort	Child Musculoskeletal Discomfort	Assessed *by Child Discomfort Survey*, which is taken three times during the school year.
Anthropometric Workstation Fit	seat pan height - student sitting height	These variables are measured once at the end of the school year (only technology-rich students).
	work surface height - student elbow height	
	height of upper display surface - student eye height	

5.4 Participants

Both classrooms were to contain 24 fifth grade students (12 females and 12 males). In the spring of 1998, a total of 48 students were chosen to participate in the field experiment. Participation was limited to those students from the local elementary school that had

1. Parents who were willing to have them participate in the experiment,
2. Completed a short initial survey on their attitudes toward school and computer technology,[6]
3. Been in the local school district since the beginning of third grade, and
4. Would be starting fifth grade in the fall of 1998.

A total of 67 students met these criteria. From this population, students were randomly selected for the two classrooms. A double-blind procedure was used for selecting the students. First, a random number generator created two ordered lists of numbers, one for each gender. Then, students and their families attended a meeting to select students for the two treatment conditions. At the meeting, students picked a number from one of two containers, depending on gender. Students then matched their numbers against the computer-generated lists. The students' position on the lists determined which treatment condition they were assigned to. For each gender, the first 12 matches on the associated list were assigned to the PCF condition, with the next 12 matches assigned to the control classroom. Students not assigned to either treatment condition were made alternates.

[6] This constraint was an artifact of the previous two years of research, where many participants frequently did not complete research surveys.

Only 47 of these students were available when school began in the fall of 1998. Of those students, 24 (12 boys, 12 girls) were assigned to the PCF classroom and 23 (9 boys, 14 girls) to the control classroom. Students under the PCF condition received title to their computer at the end of the experiment, while students under the control condition received fifty dollars for their participation.

5.4.1 Protection of Participant Rights

Only a participant number assigned by the experimenter connected participants to their experimental data. All written accounts of this study identify data only by number.

5.5 Materials and Apparatus

5.5.1 Experimental Instruments

The data collection instruments used for this research fall into two categories: (1) surveys which gather information about participant attitudes and beliefs, and (2) self-report forms which are used to gather information about an individual's behavior over a short period of time. Whenever possible, standardized survey instruments were utilized. The self-report forms are primarily PCF specific. The set of experimental instruments was comprised of the following survey instruments

- Attitudes Toward Writing With the Computer Scale (Shaver, 1990)
- Child Murphy-Meisgeiner Type Indicator
- Child Musculoskeletal Discomfort Survey
- Homework Problem Checklist
- How Do You Feel About Computers Scale (Todman and File, 1990)
- Learning Styles Inventory
- School Attitude Measure, Level G/H (American College Testing)

and the following forms

- Family Homework Effort | Homework Delivery Tracking Form (self-reports)
- Parental Involvement Form (self-report)
- Training Skills Checklist (behavior checklist)

These instruments can be found in the appendix titled *Evaluation Instruments*.

5.5.2 Computer Usage Logging

In-class computer usage by the technology-rich class was tracked with Historian logging software, which tracks local and network use. Usage of the two computers found in the control classroom could not be logged due to the configuration of the computers.

Home network use for PCF families was tracked by the PCF server, with UNIX scripts available for extracting the target data.

5.5.3 Classroom Video Taping

The Parker Vision autotracking camera was used for videotaping. The primary advantage of the system is that it allows teachers or individual students to be tracked as they move around the classroom.

5.6 Procedure

5.6.1 Pilot Testing

PCF specific data collection instruments were developed in an iterative, participatory manner with teachers and families from the second year of the PCF program. The suitability of the proposed experimental procedures and dependent measures was also assessed the summer before the field experiment began. The preliminary instrument set was perused for duplication of information and redundant instruments eliminated. Usability testing was used to assess the suitability of the proposed instruments with students and parents from the second year of the PCF project serving as usability subjects. A preliminary schedule for data collection was developed by PCF researchers and teaching staff with principal input. Researchers and the class technologist reviewed the data collection schedule to ensure that data collection would not be overly disruptive to classroom processes.

5.6.2 Data Collection Procedures

5.6.2.1 Administration of Experimental Instruments

In order to minimize classroom disruptions, instruments were completed in the home whenever possible. Scheduling of surveys was arranged so periods between administrations were approximately even. PCF self-report forms, *e.g.* Family Homework Effort Form, were scheduled on days randomly selected during the measurement period, with form return and completion verified by the PCF technologist.

In the following list, the number in parentheses following the form name indicates the number of times during the school year the form is administered to participants, **S** indicates instrument completion was the responsibility of the students, **P** indicates instrument completion was the responsibility of the parents, **F** indicates instrument completion is the joint responsibility of students and parents, and **T** indicates instrument completion was the responsibility of the teaching staff.

- Attitudes Toward Writing With the Computer Scale (**S** = 3/year)
- Child Murphy-Meisgeiner Type Indicator (**S** = 1/year)
- Child Musculoskeletal Discomfort Survey (**S** = 3/year)
- Family Homework Effort (**F =** 2 / 6 weeks)
- Homework Delivery Tracking Form (**T** = 1/6 weeks)
- Homework Problem Checklist (**P** = 3/year)
- How Do You Feel About Computers Scale (**S, P** = 3/year)
- Learning Styles Inventory (**S** = 1/year)
- Parental Involvement Form (**P** = 1/6 weeks)
- School Attitude Measure, Level G/H (**S** = 3/year)
- Training Skills Checklist (**S** = 2/year)

5.6.2.2 Measurement of Student Anthropometric Dimensions

The body dimensions of PCF students were measured at the end of the year. In particular, the following measurements were taken.

- **Sitting height** : vertical distance from floor to the horizontal midsection of the back of the thigh of a subject sitting with the thigh in contact with the seat, with a knee flexion angle of 90 degrees and feet flat on the floor (NASA, 1978).
- **Elbow Height**: Vertical distance from the floor to the posterior tip of the olecrannon when the arm is flexed to 90 degrees at the elbow and the shoulder is in the 0 position. (NASA, 1978).
- **Eye height**: vertical distance from the floor to the orbit when sitting with the spine straight (NASA, 1978).

5.6.2.3 Computer Logs

The Historian application software was installed on two randomly selected student machines plus the teacher machine in the technology-rich class. Due to school security concerns, Historian was not installed on the machines in the school computer laboratory. The following items were extracted from Historian logs

- Hours per measurement period of active computer use.
- Name of application and hours of use per period.
- Pages printed per period.
- Web pages examined per period.

with the following information extracted from PCF server logs

- frequency of network use
- frequency of email usage.
- Email role networks

5.6.2.4 School Records

Those portions of the individual student records relating to the experiment were copied at the end of fifth grade. In particular, the following data were collected from student records

- Family information.
- Grades.
- Standardized test scores.
- Attendance statistics.

5.6.2.5 Classroom Videotaping and Analysis

Classroom videotaping was used to supplement quantitative data collection and provide insights into how

1. The teaching process in the classrooms differ,
2. Computer technology is used to support learning,
3. Student collaboration patterns differ between the classes, and
4. Students are interacting with specific software packages.

The researchers were not in the classroom during taping, as the teacher found their presence disruptive. Timing of videotaping was at the discretion of the technologist. An automatic timer, set by the project technologist, was used to control video equipment.

No formal procedure was used to analyze the videotapes. Rather, qualitative and contextual information was extracted from the tapes. Additionally, the videotapes were used for remotely gathering critical incident information about the technology-rich classroom. A master teacher, the classroom technologist, and the experimenter reviewed video segments.

CHAPTER 6. ANALYSIS OF "MACRO" EVALUATION RESULTS

Chapter Table of Contents

6.1 OVERVIEW 64
6.2 ANALYSIS OF INDIVIDUAL MEASURES 64
6.2.1 Changes in Student Attitudes and Motivation 65
6.2.1.1 Student Overall Attitudes and Motivation for School 65
6.2.1.1.1 School Attendance 65
6.2.1.1.2 School Attitude Measure 66
6.2.1.2 Student Writing Attitudes 69
6.2.1.3 Student Attitudes Towards Computers 70
6.2.2 Changes in Student Performance 70
6.2.2.1 Academic Performance 71
6.2.2.1.1 Standardized Test Performance 71
6.2.2.1.2 Grade Point Average 72
6.2.2.2 Homework Performance 73
6.2.2.2.1 Homework Reliability 73
6.2.2.2.2 Time Spent on Homework Activities 75
6.2.2.2.3 Incidence of Problem Behaviors 76
6.2.2.3 Technical Skills and Knowledge 76
6.2.2.3.1 Computer Task Performance 77
6.2.2.3.2 Technology Standards of Learning Scores 78
6.2.3 Changes in Family Support 79
6.2.3.1 Home-School Communication 80
6.2.3.1.1 Perceived Quality of Home-School Communication 80
6.2.3.1.2 Parent-School Contacts 81
6.2.3.1.3 Email as a Medium for Parent-Teacher Communication Among PCF Families 83
6.2.3.2 Homework Help 85
6.2.3.3 Support For School Activities 86
6.3 PATTERNS AND PREDICTORS OF COMPUTER USAGE 87
6.3.1 Classroom Computer Usage 87
6.3.1.1 Total Time Spent Using the Computer 87
6.3.1.2 Nature of PCF Classroom Usage 89
6.3.1.2.1 Category of Application Use 89
6.3.1.2.2 Breadth of Application Use 91
6.3.1.2.3 Classroom World Wide Web Usage 91
6.3.2 Student Self-Reports of Home Computer Usage 91
6.3.2.1 Overall Patterns of Home Computer Use 92
6.3.2.1.1 Time Spent Using Home Computer 92
6.3.2.1.2 Time Spent Playing Computer Games 92
6.3.2.1.3 Time Connected to the Internet 93
6.3.2.2 Homework-related Computer Use 93
6.3.3 Home Internet Usage By PCF Students 94
6.3.3.1 Dispersion of Internet Technologies 94
6.3.3.2 Relative Importance of Different Internet Technologies 95
6.3.3.3 Interrelationships Between Internet Usage Measures 97
6.3.3.4 Factors Influencing Internet Usage 97
6.3.3.4.1 Influences on WWW Usage 99
6.3.3.4.2 Influences on Email Usage 100
6.3.3.4.3 Influences on Chat Usage 103
6.3.3.4.4 Nature of Chat Interactions 104
6.3.4 Evolution of Electronic Social Networks 106
6.3.4.1 Factors Influencing Network Density 108
6.3.4.1.1 Effect of Communication Medium 108

6.3.4.1.2 Centrality of the Teaching Staff....109
6.3.4.1.3 Effect of Leaving the Network Classroom....110
6.3.4.2 Differences in Student Network Characteristics....110
6.3.4.2.1 Factors Influencing Student Centrality....111
6.3.4.2.1.1 Influences on Email Centrality....111
6.3.4.2.1.2 Influences on Chat Centrality....112
6.3.4.2.2 Factors Influencing Student Prestige....113
6.3.4.3 Social Roles and Communication....114
6.3.5 Musculoskeletal Effects of PCF Student Computer Use....115
6.3.5.1.1 Relationship to Classroom Workstation Dimensions....116
6.4 PATTERNS AND PREDICTORS OF STUDENT CHANGES....117
6.4.1 Differences in Student Academic Efficiency....118
6.4.1.1 Factors Associated With Academic Efficiency....119
6.4.2 Patterns of Relationships Among Experimental Measures....121
6.4.2.1 Relationships Between Model Constructs....122
6.4.2.1.1 Relationship Between Technology Usage and QWL Measures....123
6.4.2.1.2 Relationship Between Technology Usage and Achievement Measures....123
6.4.2.1.3 Relationship Between Home-School Partnership and QWL Measures....124
6.4.2.1.4 Relationship Between Home-school Partnership and Achievement Measures....124
6.4.2.1.5 Relationship between QWL and Achievement Measures....125
6.4.2.2 Similarities Among Outcome Measures....125
6.4.2.3 Factors Influencing Student Outcomes....129
6.4.2.3.1 Influences on Student Achievement....129
6.4.2.3.1.1 Classroom Performance....129
6.4.2.3.1.1.1 Factors Influencing Student GPA....129
6.4.2.3.1.1.2 Factors Influencing On-time Completion of Homework Assignments....130
6.4.2.3.1.2 Standardized Test Performance....131
6.4.2.3.1.2.1 Factors Influencing Reading Performance....131
6.4.2.3.1.2.2 Factors Influencing Writing Performance....131
6.4.2.3.1.2.3 Factors Influencing Social Studies Performance....132
6.4.2.3.1.2.4 Factors Influencing Science Performance....132
6.4.2.3.1.2.5 Factors Influencing Mathematics Performance....133
6.4.2.3.1.2.6 Factors Influencing Technology Performance....133
6.4.2.3.2 Influences on Student QWL....134
6.4.2.3.2.1 Factors Influencing School Attendance....134
6.4.2.3.2.2 Factors Influencing SAM Score....134
6.4.2.3.2.3 Factors Influencing Knudson Score....135
6.5 BRIEF SUMMARY....136

6.1 Overview

This section presents results from the yearlong field experiment used to evaluate the “macro” effects of the PCF intervention. The main goal of these analyses was to examine the relationship between ubiquitous computer access and student outcomes. A variety of methods were used to analyze experimental data, with the primary focus being those techniques that allowed the experimenter to explore the relationships between experimental outcomes and participant characteristics. When the data failed to satisfy the underlying assumptions of a planned analysis technique, a different technique was selected based on the characteristics of the underlying distribution of the data. The procedures used for preliminary testing of data sets are summarized in the appendix titled *Procedures Used For Preliminary Testing of Data*. In order to control inflated Type 1 error rates, post-hoc tests were performed only on significant effects and interactions ($0 \leq p < 0.05$).

This chapter is comprised of the following sections.

Section 6.1, *Analysis of Individual Measures,* summarizes the results for the individual outcome measures.

Section 6.2, *Patterns and Predictors of Computer Usage,* explores differences in technology usage between the two classes and presents an in-depth analysis of network usage among families in the PCF program.

Section 6.3, *Patterns and Predictors of Student Changes,* presents the multi-dimensional analyses that were undertaken to better understand the relationships among system variables.

More detailed information for these analyses can be found in the appendix titled *Descriptive Information and Detailed Analysis Results.* A summary of the significant correlations between individual measures ($p < 0.05$) can be found in the appendix titled *Summary Tables of Significant Correlations Between Evaluation Measures.*

6.2 Analysis of Individual Measures

This section summarizes the results for the individual outcome measures. Outcome measures were grouped in terms of student attitudes and motivation, student performance, and family support. More detailed information for these analyses can be found in the appendix titled *Descriptive Information and Detailed Analysis Results.* As the analyses presented here pertain to the students’ first-year of what was intended to be a three-year intervention, pairwise comparisons were done using the Least Significant Difference (LSD) Test, one of the least conservative post-hoc tests (Winer, Brown, and Michels,1991).

A summary of the significant correlations between individual measures ($p < 0.05$) can be found in the appendix titled *Summary Tables of Significant Correlations Between Evaluation Measures*. Due to the mixed nature of the experimental data (*e.g.*, normal vs. non-normal), Spearman's rank correlation procedures were used to initially explore the relationship between individual experimental measures.[7]

6.2.1 Changes in Student Attitudes and Motivation

Student attitudes and motivations were analyzed in terms of their overall attitudes towards school, their attitudes towards writing, and their attitudes towards computer activities.

6.2.1.1 Student Overall Attitudes and Motivation for School

Analysis of student attitudes towards school and learning activities was based upon student attendance patterns and *School Attitude Measure* (SAM), Second Edition, Level G/H results.

6.2.1.1.1 School Attendance

Attendance was analyzed in terms of 1) changes in student absences and 2) changes in student tardies. As a student's attendance history is a strong predictor of future attendance, (Scileppi, 1988), the two measures were formulated to assess changes in student attendance relative to the fourth grade and are not based solely on fifth grade values. The basic unit of analysis for both measures was a student's fifth grade value minus the student's fourth grade value. A negative change indicated improved attendance. Full attendance data were available for all 47 students participating in the field experiment. Table 6-1 summarizes the descriptive information for these measures.

A Multivariate Analysis of Variance (MANOVA) for this pair of related measures found no significant main effects or interactions ($p > 0.05$). Spearman's rank correlations (r_s) indicated a significant linear relationship between a student's absence gain and their homework reliability ($r_s = -0.335$, $p < 0.05$) as well as family WWW usage ($r_s = 0.441$, $p < 0.05$).

Table 6-1. Summary descriptive information for the CLASS x GENDER interaction of the school attendance measures. A negative value indicates improved attendance.

	PCF Students		Control Students	
Males	*Mean*	*std*	*Mean*	*std*
• Days Absent (5^{th} - 4^{th})	1.83	2.82	-1.11	5.97
• Days Tardy (5^{th} - 4^{th})	3.67	7.76	-0.89	1.83
Females				
• Days Absent (5^{th} - 4^{th})	1.42	4.44	1.42	4.89
• Days Tardy (5^{th} - 4^{th})	0.58	3.15	0.21	2.69

[7] Spearman's rank correlation procedures require only that the data be independent and ordinal.

6.2.1.1.2 School Attitude Measure

The *School Attitude Measure* (SAM), Second Edition, Level G/H was used to evaluate changes in several dimensions of student attitudes towards school. This survey examined students' views of their academic setting and their ability to successfully perform their academic responsibilities. SAM is comprised of five attitudinal scales:

1. *Motivation for Schooling* scale, which focused on students' motivation for working hard at school. This scale included statements about the meaningfulness of school to the student, the importance of doing well academically, and the relationship of schooling to achievement of long-term goals.
2. *Academic Self-Concept -- Performance-based* scale which focused on students' perceptions of their academic abilities and performance.
3. *Academic Self-Concept -- Reference-based* scale which focused students' beliefs about other people's perceptions of their academic abilities and performance.
4. *Student's Sense of Control over Performance* scale, which measured student's academic self-efficacy. This scale included statements about the relationship between actions and outcomes in school settings, academic independence, and the student's sense of responsibility for academic outcomes.
5. *Student's Instructional Mastery* scale, which had students report on their learning strategies and behaviors. The scale included statements about the students' persistence on learning tasks, ability to effectively solicit and process feedback, and skill at maximizing the learning potential of activities.

Students completed the survey at the start and end of the school year. SAM data were available for all 47 students participating in the field experiment. SAM was analyzed both in terms of the overall score and the composite scales. The basic unit of analysis was the cumulative gain (loss) for the student's national percentile rank[8] (NP) for the year. A positive change indicated improvement. Table 6-2 summarizes the CLASS x GENDER interaction for this data.

[8] National percentile ranks are given relative to a student's current grade level, or in this case, the fifth grade.

Table 6-2. Summary descriptive information for the CLASS x GENDER interaction of changes in SAM scores over the course of fifth grade. A positive value indicates improvement.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
Males				
• Overall SAM Score	9.25	22.64	-9.89	17.46
• Motivation for Schooling Scale	2.25	27.86	-23.44	25.48
• Academic Self-Concept -- Performance Based Scale	11.5	34.71	-17.33	25.94
• Academic Self-Concept -- Reference Based Scale	16.75	25.13	-10.22	17.75
• Sense of Control over Performance Scale	3.55	23.91	19.11	29.04
• Instructional Mastery Scale	9.75	29.94	-19.89	32.80
Females				
• Overall SAM Score	-3.75	19.24	4.07	17.05
• Motivation for Schooling Scale	-10.00	27.80	0.00	25.18
• Academic Self-Concept -- Performance Based Scale	-5.33	17.42	5.43	22.25
• Academic Self-Concept -- Reference Based Scale	-6.42	20.38	3.79	19.48
• Sense of Control over Performance Scale	10.17	20.52	3.28	38.59
• Instructional Mastery Scale	-6.00	35.66	-0.42	24.86

To explore the overall impact of the experimental effects on SAM changes, an Analysis of Variance (ANOVA) was undertaken on the overall SAM change.[9] This analysis indicated only the CLASS x GENDER interaction was significant ($F[1,43] = 5.62$, $p < 0.05$). As shown in Figure 6-1, post-hoc tests provided evidence that boys from the PCF classroom made significantly greater improvements for this measure than boys in the standard classroom (LSD, $p < 0.05$).

[9] Like a MANOVA of changes on individual SAM scales, an ANOVA of the overall SAM change provided a measure of the overall impact of the experimental effects on changes in SAM.

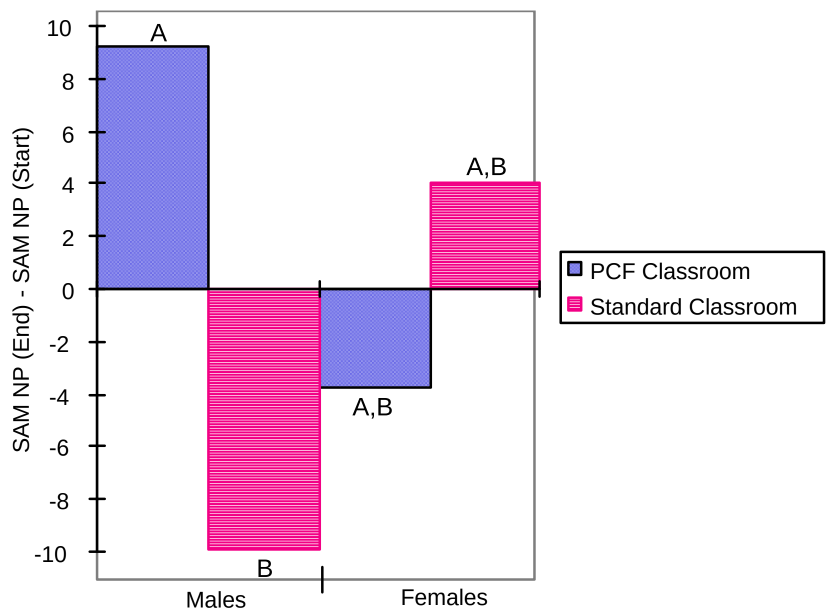

Figure 6-1. Effect of CLASS x GENDER interaction on School Attitude Measure. Means with the same label are not significantly different (LSD, p > 0.05). Positive values indicate improvement.

As significant results were obtained for the overall SAM measure ($p < 0.05$), additional analyses were undertaken which examined changes on the individual SAM scales. Analysis of individual SAM scales gave similar results, with the exception of the *Student's Sense of Control Over Performance* and *Instructional Mastery* scales for which no significant results were obtained ($p > 0.05$). Like the overall measure, only the CLASS x GENDER interaction was significant for the remaining scales (*Motivation for schooling*: $F[1,43] = 5.22$, $p < 0.05$; *Academic Self-Concept -- Performance Based*: $F[1,43] = 6.79$, $p < 0.05$; *Academic Self-Concept -- Reference Based:* $F[1,43] = 8.97$, $p < 0.01$); no other significant main effects or interactions were found for these scales. Means for the CLASS x GENDER interaction of the individual scale changes are found in Table 6-2.

Similarly, post-hoc tests of significant CLASS x GENDER interactions for the individual scales indicated boys from the PCF classroom made significantly greater improvements than boys in the standard classroom (LSD, $p < 0.05$). Further for the *Academic Self-Concept -- Reference Based* scale, post-hoc tests provided significant evidence that boys from the PCF classroom also made greater improvements for this measure than girls in the standard classroom (LSD, $p < 0.05$). Additionally post-hocs for the *Motivation for Schooling* scale indicated that boys in the standard classroom experienced significantly larger decreases in achievement motivation than girls in the standard classroom (LSD, $p < 0.05$).

Spearman's rank correlations indicated a significant linear relationship between entry SAM scores and the following computer usage variables: family WWW usage (r_s = 0.409, $p < 0.05$), total number of emails sent by student (r_s = 0.430, $p < 0.05$), and total number of emails received by student (r_s = 0.488, $p < 0.05$).

6.2.1.2 Student Writing Attitudes

The Knudson Writing Attitude Survey for Children (Knudson, 1991) was used to evaluate changes in several dimensions of student attitudes towards writing. This survey examined students' views of their ability to writing and of the extent to which they enjoyed writing. The survey was comprised of six attitudinal scales: 1) *Prefers Writing*, 2) *Positive View of Self as a Writer*, 3) *Competent Writer*, 4) *Writing Achievement*, 5) *Importance of Writing* and 6) *Letter / Note Writing*. Students completed the survey three times during the school year: start, middle, and end of the school year**.** If any survey value was missing for a student, the student was excluded from the reported analysis. Complete data were available for 34 students participating in the field study. Table 6-3 summarizes this data.

Table 6-3. Summary descriptive information for CLASS effect on changes in Knudson writing scores. A positive value indicates improvement.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
Overall Knudson Score	-2.47	8.23	4.98	8.73
Prefers Writing Scale	-0.59	3.85	2.48	3.74
Positive View of Self as Writer Scale	-0.71	1.98	0.27	1.69
Competent Writer Scale	-0.49	2.38	1.56	2.23
Writing Achievement Score	-0.21	1.79	0.38	1.81
Importance of Writing Scale	-0.43	1.62	0.21	2.18
Letter / Note Writing Scale	-0.04	1.89	0.09	2.84

Survey data were analyzed both in terms of the overall survey score and the scores for individual scales. Scores for individual items ranged from one to five where one signified almost never and five signified almost always. The basic unit of analysis was the cumulative change in the student's survey score at the time of measurement, *i.e.,* the difference between the student's score at the time minus the student's score at the beginning of the year. A positive change indicated improved attitudes towards writing.

An ANOVA indicated students in the standard classroom made significantly larger gains on the overall measure than students in the PCF classroom ($F[1,30] = 7.08$, $p < 0.05$). With the exception of the *Positive View of Self as a Writer*, *Writing Achievement, Letter/Note Writing,* and *Importance of Writing* scales, similar results were achieved on the remaining scales for the CLASS main effect (*Prefers Writing Scale*: $F[1, 30] = 6.77$, $p < 0.05$*; Competent Write Scale:* $F[1, 30] = 6.87$, $p < 0.05$). Additionally, girls made significantly larger gains on the *Writing Achievement* scale than boys ($F[1, 30] = 9.33$, $p < 0.01$). No other significant effects or interactions were found ($p > 0.05$).

6.2.1.3 Student Attitudes Towards Computers

The analyses in this section discuss changes in students' attitudes towards computers in terms of 1) their overall attitude and 2) their attitudes towards writing with the computer. Student computer attitudes were measured at the start, middle, and end of the school year. Students with incomplete data were excluded from the analyses. Multivariate methods were not used for this group of related variables as complete data were available for only a subset of the participating students. The members of this subset varied across measures. Restricting analysis to only those students with complete data for all variables in the group resulted in an overly small sample size. Table 6-4 summarizes the descriptive information for computer attitude measures.

Overall computer attitudes were measured by *How Do You Feel About Computers Scale* (Todman and File, 1990). Complete data were available for 38 students. The maximum score for this measure was 80; scores for individual items ranged from zero to four where zero signified never and four signified always. An ANOVA indicated no significant main effects or interactions for this measure ($p > 0.05$). A significant linear relationship was found between this measure and student self-reports of home computer use ($r_s = 0.353$, $p < 0.05$).

Computer writing attitudes were measured by *Attitudes Toward Writing With the Computer Scale* (Shaver, 1990). Complete data were available for 31 students; as complete data were available for only three boys in the control classroom, the effect of gender could not be included in the analysis. The maximum score for this measure was 45. Scores for individual items ranged from one to five where one signified strongly disagree and five signified strongly agree. An ANOVA indicated no significant main effects or interactions for this measure ($p > 0.05$). A significant linear relationship with this measure was found for the SOL History and Social Science SS ($r_s = 0.348$, $p < 0.05$), and the student's Science GPA gain ($r_s = 0.349$, $p < 0.05$).

Table 6-4. Summary descriptive information for the CLASS x PERIOD interaction of student computer attitude measures. Higher scores indicate better attitudes towards computers.

	Period					
	Start		Middle		End	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
PCF Classroom						
• Overall Computer Attitude	61.87	7.55	63.37	8.57	62.15	10.10
• Computer Writing Attitude	34.81	6.83	36.40	3.84	37.02	3.94
Standard Classroom						
• Overall Computer Attitude	61.56	9.11	59.10	10.03	56.33	10.49
• Computer Writing Attitude	34.44	5.41	33.95	5.14	33.68	3.88

6.2.2 Changes in Student Performance

Student performance was analyzed in terms of their academic performance, their homework reliability, and their technological skills and knowledge.

6.2.2.1 Academic Performance

Academic performance was analyzed in terms of standardized test performance and student grades.

6.2.2.1.1 Standardized Test Performance

Changes in student standardized test performance were assessed with scaled scores (SS) from categories of the *Virginia SOL Assessment Tests*, which are taken by all fifth grade students during the last month of school. Scores on individual sections could range from 0 to 50. Students who did not a) attempt all sections for an SOL category or b) have available third grade Standard 9 scores were excluded from the reported analyses. Full data were available for 44 of the 47 students participating in the field experiment.

Multivariate Analyses of Covariance (MANCOVAs) were performed on the scaled scores from each of the SOL Categories (Reading, Writing, Science, Mathematics, Social Science). Table 6-5 presents summary information for the scores. In order to control for the effect of pre-fifth grade academic performance on standardized test outcomes, the student's Stanford 9 standardized test scores were used as covariates for these analyses. The MANCOVAs provided significant evidence of a positive relationship between the SOL and the Stanford 9 scores for all measures ($p < 0.05$).

As the Writing MANCOVA indicated the main effect of CLASS was significant ($F[2,38] = 7.52$, $p < 0.01$), post-hoc Analysis of Covariances (ANCOVAs) were performed on each of the writing measures. An ANCOVA of the individual sections found the adjusted means for PCF students were significantly higher than those of the control students for both scales (*Composing Writing*: $F[1,39] = 15.02$, $p < 0.001$; the *Usage-Mechanics*: $F[1,39] = 4.67$, $p < 0.05$).[10] Means for this significant effect are given in Table 6-5.

The Social Studies MANCOVA indicated the main effect of GENDER was significant ($F[4,36] = 3.50$, $p < 0.05$) so post-hoc ANCOVAs were performed on each of the Social Studies measures. For the Geography SS, the adjusted mean for males on this score was found to be significantly higher than that of females ($F[1,39] = 5.79$, $p < 0.05$). For males, the mean Geography SS was 35.95, while for the females the mean was 31.96.

No other significant main effects or interactions were found for the standardized test measures ($p > 0.05$). However, several significant correlations were found for these measures. Social Science measures were significantly related to several self-report measures of computer use as well as student's entry writing with computers score ($p < 0.05$). Additionally, a significant linear relationship between a student's SOL Writing SS and their self-reports of home Internet use was indicated ($r_s = 0.442$, $p < 0.01$).

[10] Post-hoc tests for all ANCOVAs discussed in the *Results* chapter were done using adjusted means.

Table 6-5. Summary descriptive information for fifth grade SOL scaled scores.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
Reading				
• Use Word Analysis Strategies	40.87	10.32	39.05	9.22
• Understand a Variety of Printed Materials / Resource Materials	38.96	8.05	34.43	6.71
• Understand Elements of Literature	35.13	5.86	36.67	6.47
Writing				
• Composing Written Expression	40.52	7.35	33.76	5.29
• Usage-Mechanics	38.87	7.48	34.43	5.37
Mathematics				
• Number and Number Sense	34.43	11.83	32.95	8.55
• Computation and Estimation	39.00	10.18	35.33	8.27
• Measurement and Geometry	31.39	6.47	29.33	7.44
• Probability and Statistics	38.30	10.44	32.76	8.18
• Patterns, Functions, and Algebra	35.52	8.95	31.52	5.88
Science				
• Scientific Investigation	39.17	9.52	37.76	8.73
• Force, Motion, Energy, and Matter	36.13	9.16	36.76	9.27
• Life Processes and Living Systems	37.52	8.13	36.57	7.88
• Earth/Space Systems and Cycles	37.00	8.08	36.95	7.81
History and Social Science				
• History	34.22	5.63	30.90	7.62
• Geography	34.52	7.62	33.14	6.92
• Economics	32.83	9.11	32.24	5.58
• Civics	34.26	8.24	32.90	6.29

6.2.2.1.2 Grade Point Average

As a student's previous performance is a strong predictor of future performance, (Scileppi, 1988), the grade measures were formulated to assess changes in students' grade point average (GPA) since fourth grade and are not based solely on fifth grade performance. The basic unit of analysis for these measures was the fifth grade GPA for a particular subject minus the fourth grade GPA for the same subject. Full grade data were available for all 47 students participating in the field experiment. Table 6-6 summarizes descriptive information for GPA measures.

Table 6-6. Summary descriptive information for changes in student GPA. A positive value indicates improvement.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
Language arts GPA Changes	-0.20	0.32	-0.14	0.66
Mathematics GPA Changes	-0.28	0.76	-0.22	0.82
Science GPA Changes	-0.35	0.41	-0.21	0.56
Social Science GPA Changes	-0.24	0.36	-0.46	0.43

As a Multivariate Analysis of Variance (MANOVA) of student language arts, mathematics, science, and social studies GPA changes indicated the main effect of CLASS was significant ($F[4,40] = 2.95$, $p < 0.05$), post-hoc ANOVAs were performed on each of the dependent measures. The individual analyses indicated no significant effects or interactions for any of the subjects. However for PCF students, a significant positive correlation was found between a student's language arts GPA gain and the number of email received by the student ($r_s = 0.442$, $p < 0.002$) as well as between the student's science GPA gain and family WWW usage ($r_s = 0.442$, $p < 0.01$). Additionally, a significant positive correlation exists between family WWW usage and their overall grade point average gain ($r_s = 0.442$, $p < 0.01$).

6.2.2.2 Homework Performance

Student homework performance was assessed in terms of the following process metrics: reliability, time spent, and the incidence of problem behaviors. The mean change in parent reports of problem behaviors for students from the PCF classroom was 0.47 with a standard deviation of 8.10, while the mean change for student from the standard classroom was 0.79 with a standard deviation of 3.70. Table 6-7 summarizes descriptive information for the remaining measures.

Table 6-7. Summary descriptive information for CLASS x PERIOD interaction of the homework performance measures.

	Period					
	Start		Middle		End	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
PCF Classroom						
• Percent delivered on-time	83.25	14.37	92.38	21.26	90.00	10.22
• Increase in problem behaviors	n/a	n/a	n/a	n/a	0.47	8.10
• Time spent	72.16	26.61	*	*	58.95	26.38
Standard Classroom						
• Percent delivered on-time	84.52	10.44	95.87	11.93	92.61	22.20
• Increase in problem behaviors	n/a	n/a	n/a	n/a	0.79	3.10
• Time spent	56.30	28.57	*	*	32.61	18.81

* Insufficient data for analysis.

6.2.2.2.1 Homework Reliability

Homework reliability was assessed by the percentage of homework assignments that were delivered on-time. Information about homework completion was gathered from teachers using the *Homework Delivery Tracking Form*. Each form covered a week of homework activities, with a minimum of two forms completed for each 12-week period.

As preliminary tests indicated the data were non-normal ($p < 0.05$), a Rank General Linear Model (RGLM) analysis was undertaken. This analysis indicated girls were significantly more reliable at homework than boys ($F[1,43] = 5.59$, $p < 0.05$). Students were also significantly less reliable in the first period than the other periods ($F[2,86] = 45.04$, $p < 0.001$) as shown in Figure 6-2.

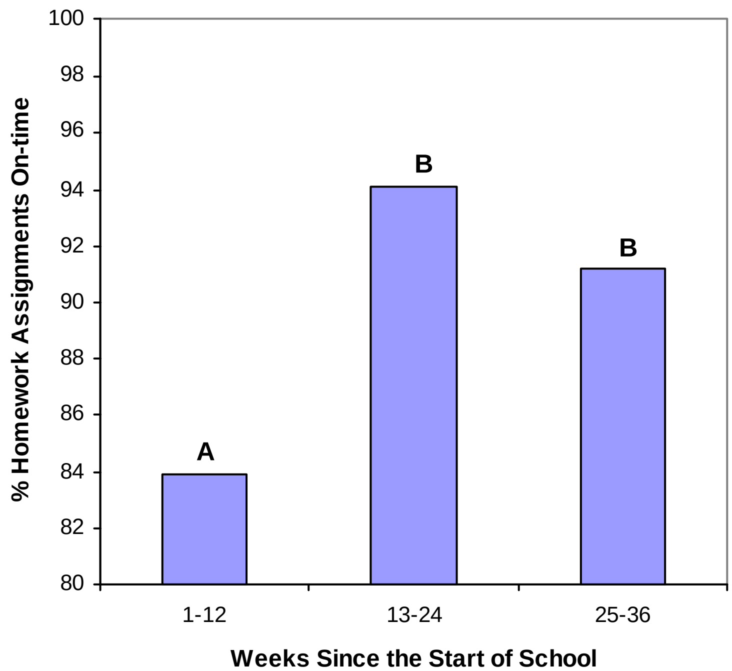

Figure 6-2. Effect of PERIOD main effect on the percentage of homework assignments delivered on-time. Means with the same label are not significantly different (LSD, $p > 0.05$).

The PERIOD x CLASS interaction was also significant ($F[2,86] = 4.10$, $p < 0.05$). As shown in Figure 6-3, post-hoc analysis on the data ranks indicated that control students in the middle period completed significantly more homework assignments on-time than they did in the first period or the PCF students did in the first and third periods (LSD, $p < 0.05$). Further control students in the third period completed significantly more homework assignments on-time than PCF students in the first period (LSD, $p < 0.05$). Finally, PCF students in the last two periods completed significantly more homework assignments on-time than they did in the first period (LSD, $p < 0.05$).

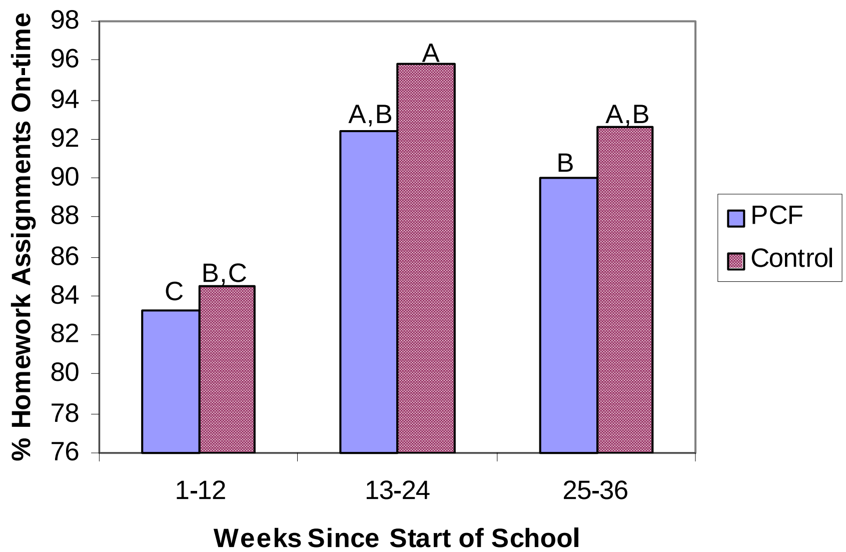

Figure 6-3. Effect of PERIOD x CLASS interaction on the percentage of homework assignments delivered on-time. Means with the same label are not significantly different (LSD, $p > 0.05$).

The percentage of homework assignments delivered on-time by a student was correlated with the student's MMPI Thinking-Feeling Score ($r_s = 0.342$, $p < 0.05$) along with family WWW usage ($r_s = -0.433$, $p < 0.05$).

6.2.2.2.2 Time Spent on Homework Activities

Information about the amount of time students spent on homework was gathered using the *Family Homework Effort* self-report form, with each form covering a single night. Self-report forms were distributed only on full school days; if weather caused school to be released early, the forms were distributed to students on the next full day of school. Data were collected on at most six randomly selected school days during each 12-week period.

Any student who did not return at least three self-report forms during each period was excluded from the reported analyses. In all, complete data were available for 37 of the students participating in the field experiment. As insufficient data were available for the second 12-week period in the school year, that period was excluded from the analyses reported here. As the number of self-report forms returned varied from student to student, the basic unit of analysis for this measure was the average number of minutes students reported doing homework each day.

An ANOVA of this variable indicated students in the PCF classroom spent significantly longer on homework than students in the standard classroom ($F[1,33] = 10.10$, $p < 0.01$). Additionally, students from both classes spent significantly longer on homework during the first 12 weeks of the school year than they did in the last 12 weeks ($F[1,33] = 10.49$, $p < 0.01$). No other significant main effects or interactions were found.

6.2.2.2.3 Incidence of Problem Behaviors

The Homework Problem Checklist assessed student homework-related behaviors. Originally, parents were to complete the checklist three times during the school year; however, in order to minimize the experimental demands on parents, the survey was administered only at the beginning and end of the school year. If any survey value was missing for a student, the student was excluded from the reported analysis. In all, data were available for 27 students participating in the field experiment. Scores for individual items ranged from zero to three where zero signified never and three signified very often. The maximum survey score was 60.

The basic unit of analysis was the difference between the student's checklist score at the end of the school year and the student's score at the beginning of the year. The Mann-Whitney-Wilcoxon tests and the Kruskal-Wallis One-Way Analysis of Variance by Ranks were used to analyze this non-parametric data. These analyses found no significant main effects or interactions for this measure ($p > 0.05$).

6.2.2.3 Technical Skills and Knowledge

Student technical skills and knowledge were assessed by a set of computer tasks and written SOL tests given to the students at the end of fifth grade. Table 6-8 presents summary descriptive information for these measures.

Table 6-8. Summary descriptive information for the student technical skills and knowledge measures.

	PCF Students		Control Students	
Males	*Mean*	*std*	*Mean*	*std*
Computer Tasks				
• Training Skills Score	36.00	5.24	13.69	7.49
• Typing Accuracy	93.27	5.88	91.88	4.91
• Typing Speed	13.55	5.72	10.88	4.52
Technology SOL Scores				
• Basic Understanding of Computer Technology	38.00	8.86	46.00	7.94
• Basic Operational Skills	39.33	7.61	36.44	4.90
• Using Technology to Solve Problems	40.42	7.60	38.78	7.68
Females	*Mean*	*std*	*Mean*	*std*
Computer Tasks				
• Training Skills Score	32.91	7.27	13.61	6.57
• Typing Accuracy	95.55	5.16	85.14	9.53
• Typing Speed	16.27	6.54	11.93	3.83
Technology SOL Scores				
• Basic Understanding of Computer Technology	42.26	11.30	44.00	8.86
• Basic Operational Skills	40.64	6.86	37.50	7.15
• Using Technology to Solve Problems	40.54	8.48	37.58	6.01

6.2.2.3.1 Computer Task Performance

Students were asked to demonstrate the extent of their computer knowledge by completing the *Training Skills Checklist* found in the appendix titled *Evaluation Instruments* and by a short typing task. For the *Training Skills Checklist*, a maximum score of 52 was possible with a point was given for each task component successfully completed from the checklist. Typing speed and accuracy was determined by the *Type to Learn* program using the following brief passage

```
A thousand is 1,000.
A million is 1,000,000.
A billion is 1,000,000,000.
A googal has 1 and 100 zeros.
Can you type it?
```

The program output the following metrics: a) percentage of characters which were correctly typed, and b) average number of words typed per minute. Full data were available for 44 of the students participating in the field experiment.

As the MANOVA undertaken for these measures indicated the main effect of CLASS was significant ($F[3,38] = 35.97$, $p < 0.001$), post-hoc ANOVAs were performed on each of the computer task measures. Post-hoc analyses indicated

- The CLASS main effect was significant for each of the measures (Training Skills Score: $F[1,40] = 104.23$, $p < 0.001$; Typing Speed: $F[1,40] = 4.78$, $p < 0.05$; Typing Accuracy: $F[1,40] = 4.78$, $p < 0.05$), with PCF students consistently out-performing control students on all computer tasks.

- The CLASS x GENDER interaction was also found to be significant for the typing accuracy measure ($F[1,40] = 4.37$, $p < 0.05$). As shown in Figure 6-4, post-hoc analysis indicated that girls from the control class had significantly lower typing accuracy than boys in the control class and students from the PCF class (LSD, $p < 0.05$).

No other significant main effects or interactions were found for these measures ($p > 0.05$).

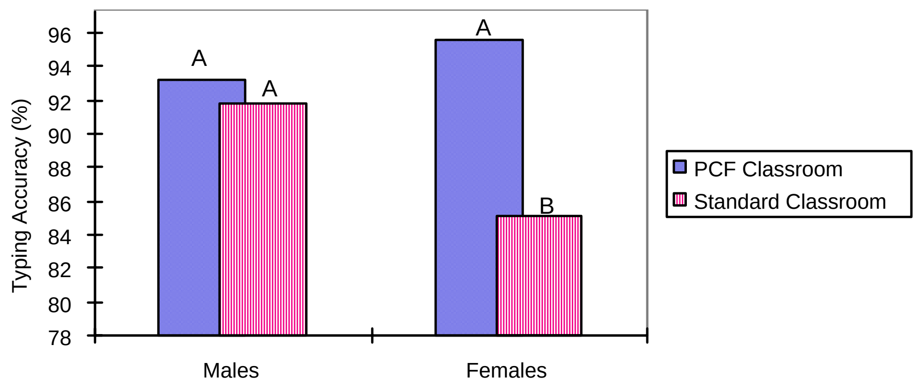

Figure 6-4. Effect of CLASS x GENDER interaction on student typing accuracy. Means with the same label are not significantly different (LSD, p > 0.05).

A number of significant correlations were found for these measures, with the majority pertaining to the training skills score and typing speed. They are summarized in Appendix E. Additionally, the magnitude of the training skills gain[11] made by PCF students over the course of the school year was positively related to the number of home residential computers ($r_s = 0.588$, $p < 0.01$).

6.2.2.3.2 Technology Standards of Learning Scores

Student technology skills were also assessed by the technology portion of the *Virginia SOL Assessment Tests.* Students who did not attempt all portions of the computer/technology sections were excluded from the reported analyses. The technology category was comprised of the following sections: 1) basic understanding of computer technology, 2) basic operational skills, and 3) using technology to solve problems. Scores on the sections could range from 0 to 50. Full data were available for 44 of the 47 students participating in the field experiment. A multivariate analysis found no significant main effects or

[11] Although not analyzed here, PCF students were given the *Training Skills Checklist* at both the start and end of the school year. Control students were given the checklist only once at the end of the year in order to minimize disruptions during school hours.

interactions for this group of related measures ($p > 0.05$). However, a number of significant correlations were found including

- Basic understanding of computer technology SS and the following variables: days tardy change ($r_s = -0.326$, $p < 0.05$); GPA gain ($r_s = 0.319$, $p < 0.05$); and various SOL SS scores.

- Basic operational skills SS and the following variables: Sensing - Intuitive MMPI score ($r_s = 0.334$, $p < 0.05$); entry SAM score ($r_s = 0.454$, $p < 0.002$); training skills score ($r_s = 0.442$, $p < 0.01$); and various SOL SS scores.

- Using technology to solve problems SS and the following variables: entry SAM score ($r_s = 0.361$, $p < 0.05$); training skills score ($r_s = 0.363$, $p < 0.05$); and various SOL SS scores.

Additional significant correlations for these measures can be found in Appendix E.

6.2.3 Changes in Family Support

Family support for learning activities was assessed in terms of the quality of home-school communication, parental involvement in the homework process, and parental support for school activities. Table 6-9 summarizes descriptive information for these measures. Given the mixed nature of the data (*e.g.*, normal vs. non-normal), multivariate methods could not used to analyze this group of related variables.

Table 6-9. Summary descriptive information for the family support measures.

	Period					
	Start		Middle		End	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
PCF Classroom						
• Rating of Quality of Home-School Communication (range 1-7)	5.50	1.41	4.48	1.40	3.91	1.30
• Average Number of Home-School Contacts Each Week	0.38	0.81	0.75	1.20	0.34	0.86
• Nightly Homework Help (minutes)	15.86	13.05	*	*	10.18	11.61
• Active Support for School Activities Each Week (minutes)	46.36	94.29	70.43	95.59	20.614	40.41
Standard Classroom						
• Rating of Quality of Home-School Communication (range 1-7)	4.26	1.38	3.72	1.63	4.35	1.25
• Average Number of Home-School Contacts Each Week	1.64	2.37	1.07	1.26	1.13	1.71
• Nightly Homework Help (minutes)	8.92	9.84	*	*	11.42	17.54
• Active Support for School Activities Each Week (minutes)	57.86	63.89	57.85	109.01	112.86	157.74

* Insufficient data for analysis.

6.2.3.1 Home-School Communication

Subjective information about home-school communication was gathered from parents using the *Parental Involvement Form*. Each form covered a single-week and was distributed at the end of the week. Data were collected on at most three randomly selected weeks during each 12-week period. Any parent who did not return at least one self-report form during each 12-week period was excluded from the reported analyses. Complete data were available for a total of 29 families.

6.2.3.1.1 Perceived Quality of Home-School Communication

Parents were asked to rate the quality of home-school communication on a scale of 1 to 7 where 1 signified very bad and 7 signified very good. An ANOVA of parent's mean rating indicated that the PERIOD x CLASS interaction was significant ($F[2,54] = 3.60$, $p < 0.05$). No other significant main effects or interactions were found ($p > 0.05$). As shown in Figure 6-5, PCF parents during weeks 1-12 rated the quality of home-school communication significantly higher than control parents rated it weeks 1-24 (LSD, $p < 0.05$). Further, PCF parents during weeks 1-12 rated the quality of home-school communication significantly higher than they did in weeks 25-36 (LSD, $p < 0.05$).

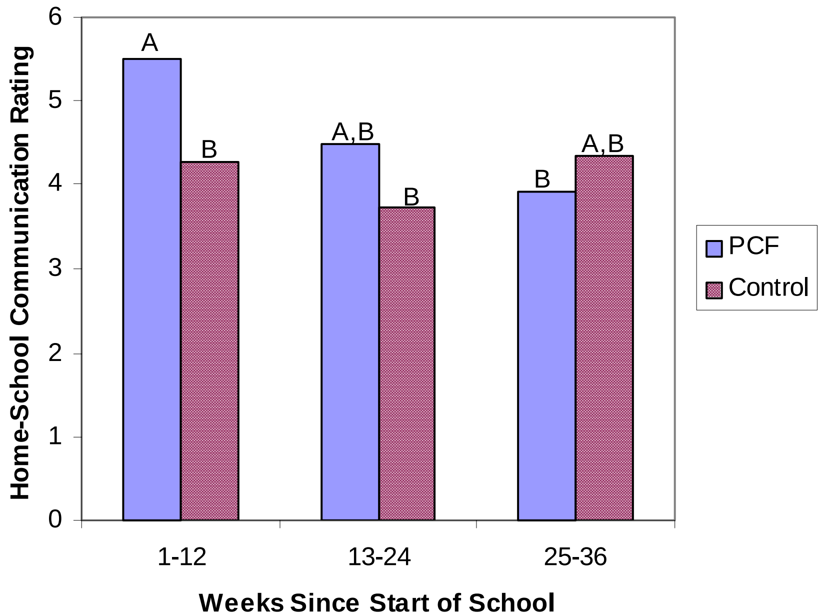

Figure 6-5. Effect of CLASS x PERIOD on parents' average rating of home-school communication quality. Larger values indicate more positive attitudes. Means with the same label are not significantly different (LSD, $p > 0.05$).

6.2.3.1.2 Parent-School Contacts

Parents were asked to specify the number of school contacts in the previous week. A contact was considered traditional if it was face-to-face, by phone, or by letter. As preliminary tests indicated the data were non-normal ($p < 0.05$), a RGLM was used to analyze changes in the average number of weekly parent-school contacts. This analysis indicated that the main of effect of CLASS was significant, with control parents contacting the school significantly more frequently than PCF parents ($F[1,27] = 4.48$, $p < 0.05$). The main effect of MODE was also significant with parents from both classes contacting the school significantly more often using traditional media than the Internet ($F[1,27] = 36.19$, $p < 0.001$). As shown in Figure 6-6, the main effect of PERIOD was significant ($F[2,54] = 4.91$, $p < 0.01$), with parents contacting the school significantly more often in weeks 13-24 than in other periods of the school year (LSD, $p < 0.05$).

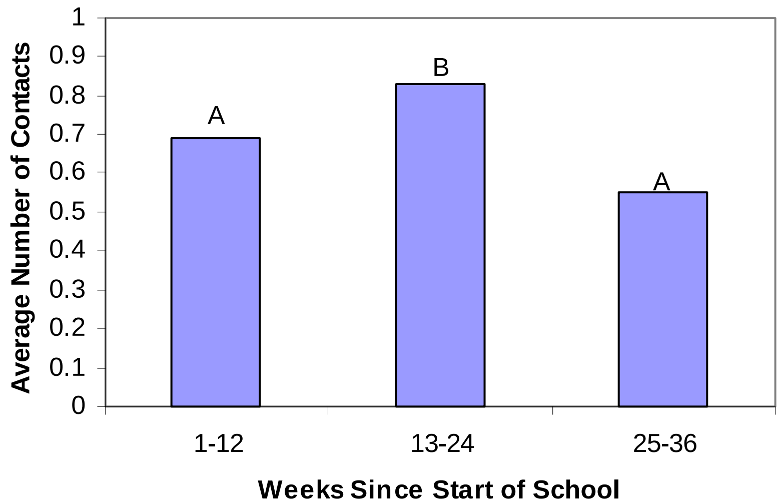

Figure 6-6. Effect of PERIOD on parental school contacts. Means with the same label are not significantly different (LSD, $p > 0.05$).

As shown in Figure 6-7, the MODE x CLASS interaction was also significant ($F[1,27] = 5.08$, $p < 0.05$), with parents using traditional media to contact the school significantly more frequently than the Internet (LSD, $p < 0.05$). Additionally, control parents using traditional media contacted the school significantly more often than PCF parents using the same media (LSD, $p < 0.05$). No other significant main effects or interactions were found for this measure ($p > 0.05$).

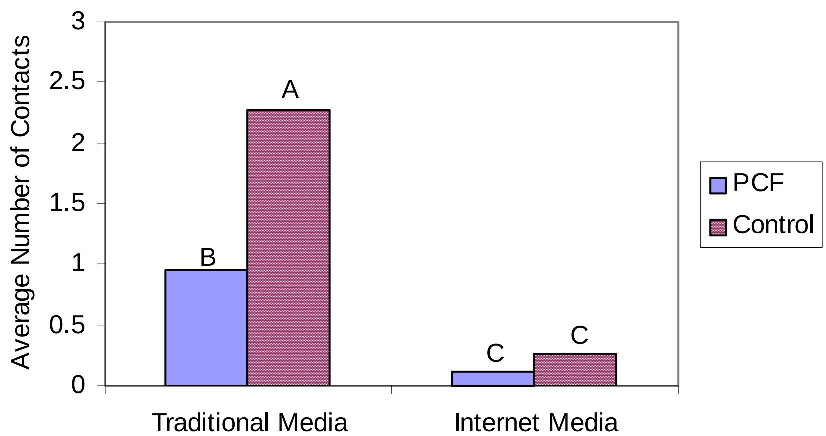

Figure 6-7. Effect of MODE x CLASS interaction on parental school contacts. Means with the same label are not significantly different (LSD, $p > 0.05$).

6.2.3.1.3 Email as a Medium for Parent-Teacher Communication Among PCF Families

All recorded instances of parent-teacher, Internet-enabled communication related to email. This analysis investigates the adoption of email as a technology for parent-staff communication among PCF families. The basic unit of analysis for this discussion was the weekly percentage of families who either sent email to classroom staff (*i.e.,* classroom teacher or technologist) or received email from classroom staff. The count data used to formulate these percentages were extracted from project proxy server logs, which recorded all email sent or received by PCF families from their home computers.

Figures 6-9 and 6-10 present role networks of email communication among PCF parents and teachers for the school year. Figure 6-11 shows how the percentage of parents using email to contact the classroom staff changed over the course of the school year. During that time, the classroom teacher sent an average of 2.792 email messages to each set of parents and received an average of 0.750 messages. During the same period of time, the classroom technologist sent an average of 106.375 messages to parents and received an average of 4.500 messages.

A RGLM was used to perform an ANOVA on the percentage of families that communicated with the classroom teacher using email each week. This analysis indicated that the technologist communicated with a significantly higher percentage of parents using email each week than did the teacher ($F[1,70] = 185.73$, $p < 0.001$). Additionally, teaching staff sent email to a significantly higher percentage of parents each week than the percentage of parents they received email from ($F[1,70] = 144.39$, $p < 0.001$). As shown in Figure 6-8, the DIRECT x ROLE interaction was significant ($F[1,70] = 123.68$, $p < 0.001$), with the technologist sending email to a significantly higher percentage of parents each week than she received email from and than the teacher either sent or received email from (LSD, $p < 0.01$).

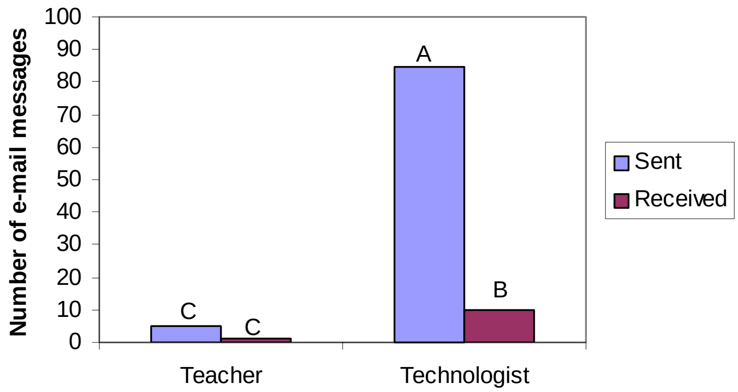

Figure 6-8. Effect of the DIRECT x ROLE interaction on the number of weekly, email interactions with parents. Means with the same label are not significantly different (LSD, $p < 0.01$).

A significant correlation was found between the weekly number of email messages received by parents and the number of messages sent by the teachers for the week ($r = 0.749$, $p < 0.001$); no significant relationship was found between the number of messages received by teachers and the number of messages sent by parents.

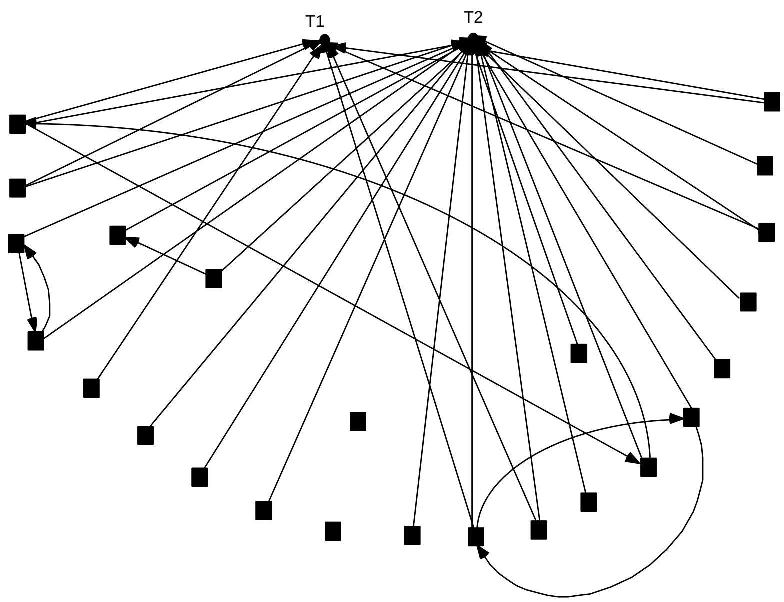

Figure 6-9. Parent initiated email communication among PCF parents and teachers for the 1998-1999 school year. Squares indicate parents, T1 represents the classroom teacher, and T2 denotes the classroom technologist.

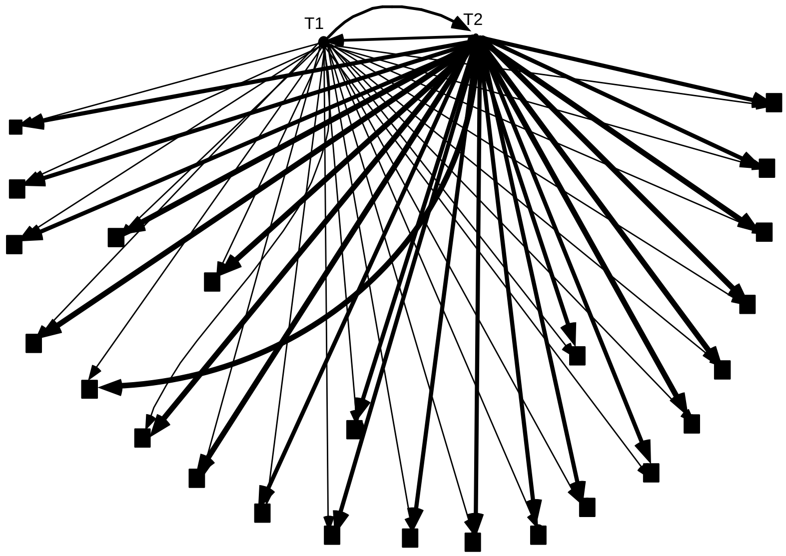

Figure 6-10. Teacher initiated email communication among PCF parents and teachers for the 1998-1999 school year. Squares indicate parents, T1 represents the classroom teacher, and T2 indicates the classroom technologist. Lines denote email communication between individuals, with line width denoting frequency.

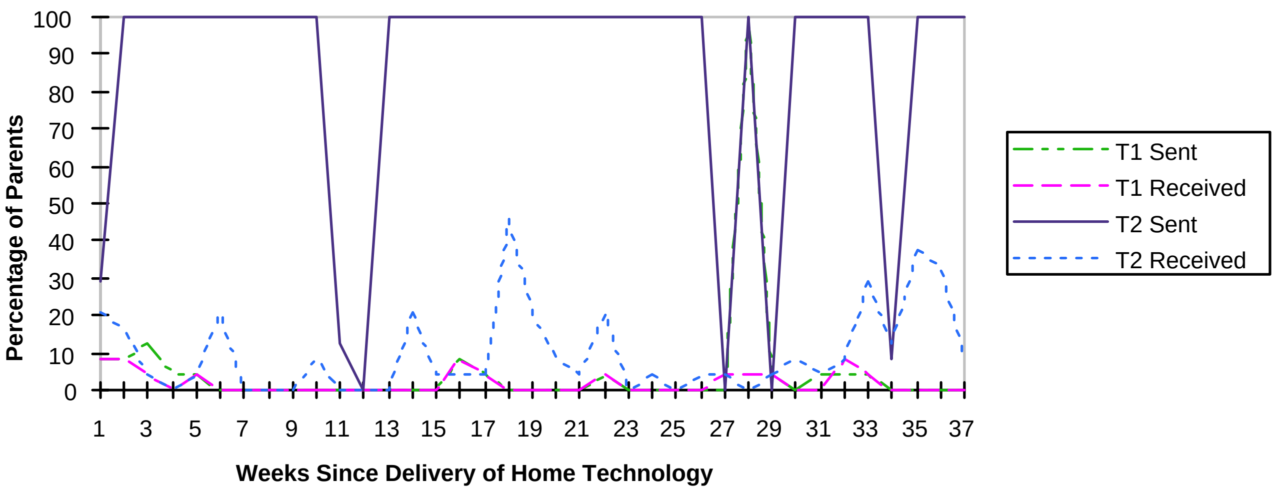

Figure 6-11. Changes in email enabled parent - staff communication during the school year. T1 represents the classroom teacher, and T2 indicates the classroom technologist.

6.2.3.2 Homework Help

Information about parental help with homework was gathered using the *Family Homework Effort* self-report form, with each form covering a single night. Self-report forms were distributed only on full school days; if weather caused school to be released early, the forms were distributed to students on the next full day of school. Data were collected on at most six randomly selected school days during each 12-week period.

Any student who did not return at least three self-report forms during each period was excluded from the reported analyses. As insufficient data were available for the second 12-week period in the school year, that period was excluded from the analyses reported here. In all, complete data were available for 37 of the students participating in the field experiment.

An ANOVA of Ranks on the average number of minutes parents helped students with homework each day indicated the CLASS x PERIOD interaction was significant ($F[1,33] = 5.10$, $p < 0.05$); no other significant main effects or interactions were found ($p > 0.05$). As shown in Figure 6-12, post-hoc tests provided significant evidence that during the first 12 weeks PCF parents spent more time helping students with homework than they did in the last 12 weeks of the school year (LSD, $p < 0.05$). Further, they spent significantly more time helping with homework than parents in the control class did during the first 12 weeks (LSD, $p < 0.05$) or the last 12 weeks (LSD, $p < 0.05$).

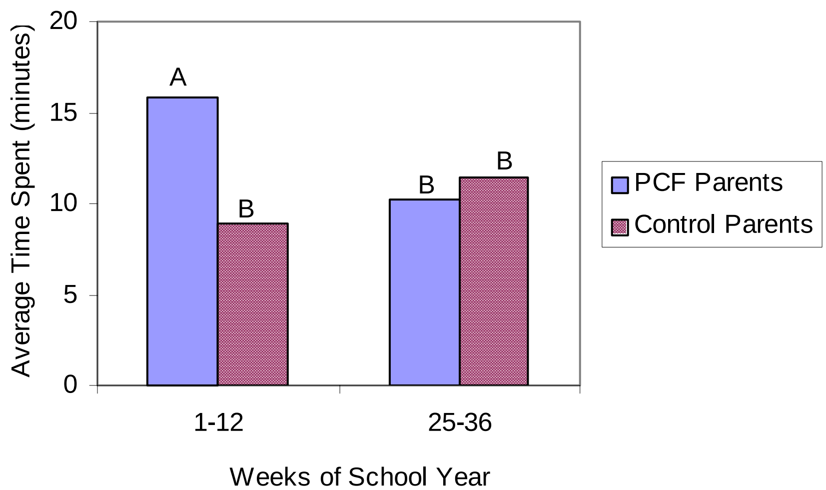

Figure 6-12. Effect of CLASS x PERIOD interaction on the time parents spent helping students with homework. Means with the same label are not significantly different (LSD, $p > 0.05$).

Parental homework help was positively correlated with student typing speed ($r_s = 0.323$, $p < 0.05$); it was negatively correlated with a variety of SOL SS scores and GPA gain measures. Additional significant correlations for this measure can be found in Appendix E.

6.2.3.3 Support For School Activities

Active support for school activities included time spent by parents volunteering at the school, participating in school activities, and preparing items for bake sales, school fairs, and other school functions at home. Time spent at school for weekly training classes was excluded from the total. Information about parental support for school activities was gathered from parents using the *Parental Involvement Form*. Complete data were available for a total of 29 families. As complete data were available for only three girls from the control class, GENDER could not be included as an effect in the analysis models. As preliminary tests indicated this data was non-normal ($p < 0.05$), a RGLM was used to analyze the average amount of time parents spent each week actively supporting the school. This analysis found no significant main effects or interactions ($p > 0.05$).

6.3 Patterns and Predictors of Computer Usage

Computer usage was analyzed in terms of the classroom and home. Analyses explored differences in both the nature and amount of computer between students in the two classrooms. An in-depth analysis of the patterns and predictors of network usage among families in the PCF program is also presented in this section.

Additional details for the analyses can be found in the appendix titled *Descriptive Information and Detailed Analysis Results.* A summary of the significant correlations between usage measures and other experimental variables ($p < 0.05$) can be found in the appendix titled *Summary Tables of Significant Correlations Between Evaluation Measures.*

6.3.1 Classroom Computer Usage

Analysis of classroom computer use was based upon Historian computer logs for the PCF class and teacher reports of computer laboratory use by the control class. The school year was broken up into three 12-week periods for the analyses described here. Because of delays in Historian installation, usage logging in the PCF classroom did not begin until the sixth week of school. Thus the analyses discussed here cover only weeks 7-36 of the school year, with the weeks of Christmas break excluded from these analyses.

Because of the disk space requirements of Historian logs, the software was only installed on two student machines in the PCF classroom. Usage of these two computers was logged the entire year, resulting in a maximum of 24 weekly totals from the network classroom for each 12-week period. As different students used these computers at different times, the data was treated as between-subject for analysis purposes. The exact number of weekly totals varied across periods due to the late installation of the Historian software and instances of inadvertent disabling of the Historian software by students. In all, there were 57 weekly totals for these measures.

6.3.1.1 Total Time Spent Using the Computer

Students in the PCF classroom used classroom computers an average of 256.51 minutes each week. Due to resource limitations, the maximum amount of time the control class could spend in the computer laboratory was 180 minutes. The control teacher treated computer laboratory time like music or art, and with the exception of early releases or assemblies, would uniformly spend the scheduled time in the computer laboratory. The data used for PCF classroom were the weekly totals of classroom computer use from the Historian logs. The unit of measurement for these totals was minutes. Table 6-10 presents descriptive information for time spent using the computer in the PCF classroom each 12-week period. Figure 6-13 shows how the average amount of daily computer use changed across the school year.

One sample t-tests provided significant evidence that overall actual usage in the network classroom significantly exceeded scheduled usage by the control classroom (df = 56, t = 3.91, $p < 0.001$). Post-hoc t-tests indicated that only in the last 12 weeks of school was there evidence that computer use in the network classroom was significantly greater than scheduled usage for the control class (df = 23, t = 4.48, $p < 0.001$).

Table 6-10. Descriptive Statistics for Network Classroom Computer Use by 12-Week Period.

	Mean	*Std*
Period 1 (weeks 1-12)	257.30	158.90
Period 2 (weeks 13-24)	195.41	129.54
Period 3 (weeks 26-36)	309.53	141.71

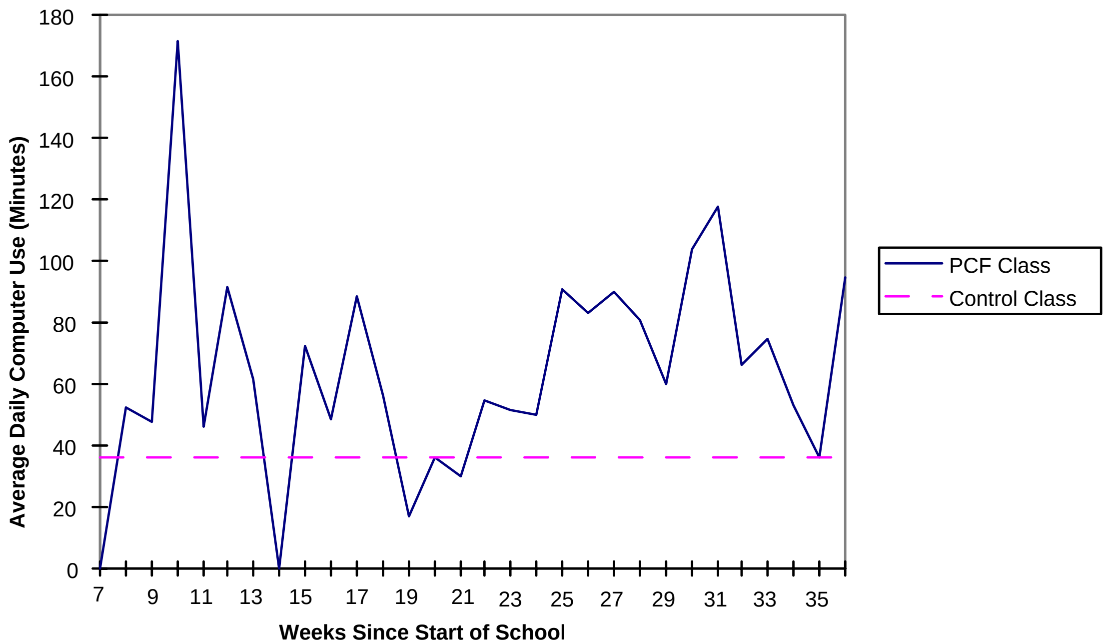

Figure 6-13. Changes in the average daily amount of classroom computer use across the school year.

6.3.1.2 Nature of PCF Classroom Usage

Historian logs allowed researchers to explore computer use in the PCF classroom in greater detail. In particular, researchers were able to examine categories of application use, the number of different applications used each week, and World Wide Web (WWW) accesses. In order to control for the variable effect of holidays, snow days, and such on weekly totals for these items, the number of days classes were in session each week was used as the covariate for these analyses.

6.3.1.2.1 Category of Application Use

Applications was categorized as either 1) Internet-related, *e.g.*, web browsers and ftp applications, 2) production-related, *e.g.*, word-processors and drawing programs, or 3) other which related primarily to CAIs and non-educational games, *e.g.*, solitaire. Figure 6-14 shows how usage in each category changed across the school year.

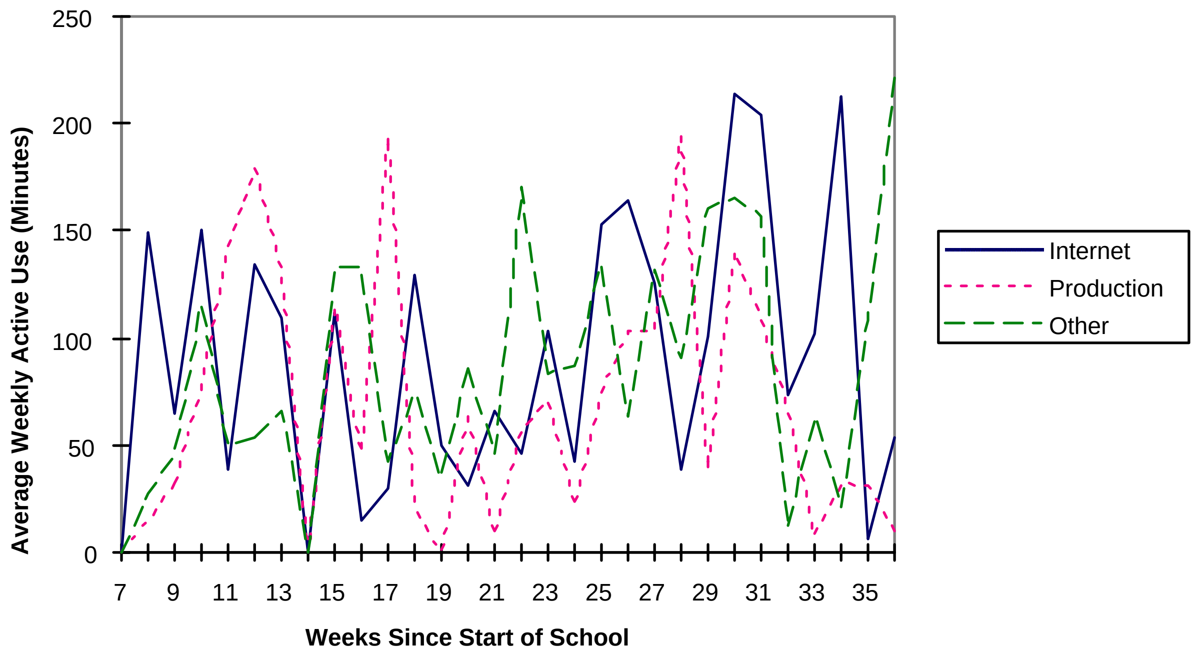

Figure 6-14. Changes in Classroom Application Use over the Course of the School Year.

An ANCOVA on ranks of weekly totals for the amount of time students spent actively using software[12] in a particular category indicated that the main effect of PERIOD was significant ($F[1,53] = 4.11$, $p < 0.05$). The number of days school was in session for the week served as the covariate for this analysis. As shown in Figure 6-15, application usage in the network classroom during the last 12 weeks of the school year was found to be significantly higher than usage during the middle 12 weeks of school (LSD, $p < 0.05$).

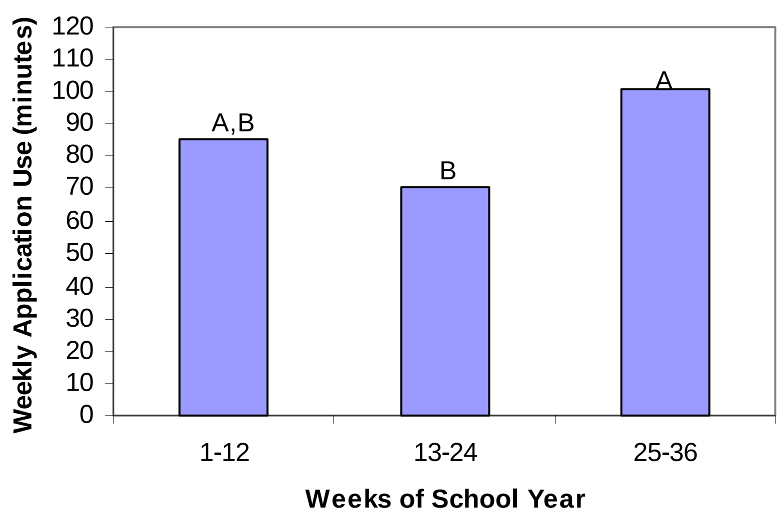

Figure 6-15. Effect of PERIOD on application use in the PCF classroom. Means with the same label are not significantly different (LSD, $p > 0.05$).

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[12] A student was considered to be actively using the software if an action, *e.g.*, character typed, had been taken in the previous five minutes.

6.3.1.2.2 *Breadth of Application Use*

The number of different applications used each week measured the breadth of application usage in the PCF classroom. An ANCOVA of this value found no evidence that the breadth of classroom application usage changed over the course of the school year. The number of days school was in session for the week served as the covariate for this analysis.

6.3.1.2.3 *Classroom World Wide Web Usage*

The number of web pages accessed each week measured WWW usage in the PCF classroom. An ANCOVA of this measure found no significant evidence that usage changed over the course of the school year ($p < 0.05$). The number of days school was in session for the week served as the covariate for this analysis.

6.3.2 *Student Self-Reports of Home Computer Usage*

Student residential computer use was assessed in terms of general use and homework-specific use. Information about residential use was gathered using self-report forms, with each form documenting usage for a single night. As the number of self-report forms returned varied from student to student, the basic unit of analysis for these measures was the average amount of daily use (minutes). Given the disparate characteristics of the associated data (*e.g.*, normal vs. non-normal), multivariate methods could not be used to analyze this group of related variables. Students without access to home computer technology were excluded from these analyses. Summary information for these variables can be in Table 6-11.

Table 6-11. Summary descriptive information for the student self-reports of home computer use. Self-report values are given in minutes.

	Weeks 1-12		Weeks 13-24		Weeks 26-36	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
Daily Amount of Use						
• PCF Classroom	65.63	32.36	65.54	56.08	41.81	29.04
• Standard Classroom	55.75	39.28	142.50	123.95	55.83	60.72
Daily Game-Playing						
• PCF Classroom	12.29	14.91	15.42	17.44	8.58	11.71
• Standard Classroom	67.31	62.71	32.50	37.32	56.80	72.36
Daily Internet Use						
• PCF Classroom	23.62	24.13	74.29	110.02	29.17	33.88
• Standard Classroom	22.85	24.13	41.38	47.57	20.07	17.55
Daily Homework Use						
• PCF Classroom	10.18	14.23	*	*	19.49	12.73
• Standard Classroom	14.44	22.97	*	*	10.74	14.39
Daily Homework Internet Use						
• PCF Classroom	2.95	7.30	*	*	6.54	14.10
• Standard Classroom	5.00	12.25	*	*	4.17	6.46

* Due to insufficient participation in the middle period, this information was not included in the analyses.

6.3.2.1 Overall Patterns of Home Computer Use

Information about student home computer use was gathered using the *Student Home Computer Use* self-report form. Self-report forms were distributed only on school days. Data were collected on at most four randomly selected school days during each 12-week period. Any student who did not return at least two self-report forms during each 12-week period was excluded from the reported analyses. Due to insufficient control group data, GENDER could not be included as an effect in the analysis model.

6.3.2.1.1 Time Spent Using Home Computer

An ANOVA indicated the main effect of PERIOD was significant (F[2,60] = 5.41, $p < 0.01$). As shown in Figure 6-16, post-hoc tests indicated that use in weeks 13-24 was significantly higher than use in weeks 26-36 (LSD, $p < 0.05$). No other significant main effects or interactions were found for this measure ($p > 0.05$).

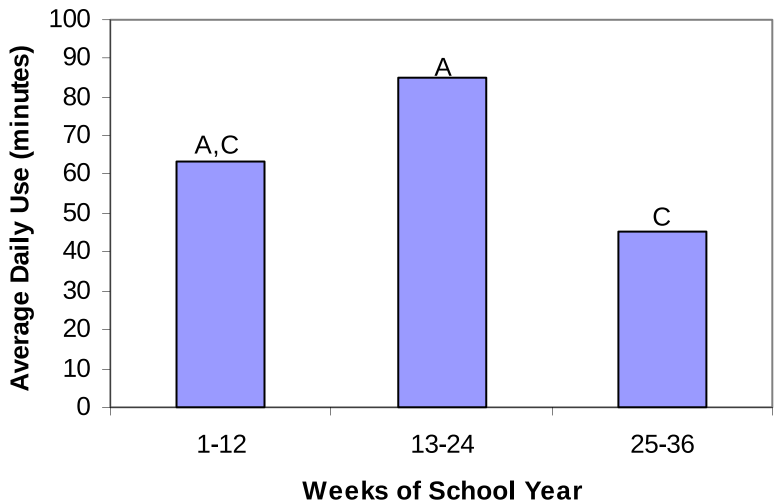

Figure 6-16. Effect of PERIOD on time spent using the home computer. Means with the same label are not significantly different (LSD, $p > 0.05$).

A number of significant correlations were found for this measure including the entry feel about computers score ($r_s = 0.353$, $p < 0.05$) and various SOL scores. A complete listing of significant correlations can be found in Appendix E.

6.3.2.1.2 Time Spent Playing Computer Games

The mean usage reported by students from the PCF classroom was 12.09 minutes with a standard deviation of 14.93, while the mean usage for students from the standard classroom was 52.26 minutes with a standard deviation of 58.62. As preliminary tests indicated the data were non-normal ($p < 0.05$), a RGLM was used to analyze this measure. This analysis indicated the main effect of CLASS was significant with students in the control class spending significantly more time playing computer games at home than PCF students (F[1,30] = 6.63, $p < 0.05$). No other significant main effects or interactions were found ($p > 0.05$). A number of significant correlations were found for this measure including the Knudson writing score gain ($r_s = 0.406$, $p < 0.001$), the MMPI Judging-Perceiving Score ($r_s = 0.303$, $p < 0.05$), and various SOL scores. A complete listing of significant correlations can be found in Appendix E.

6.3.2.1.3 Time Connected to the Internet

Students without home Internet access or complete data were excluded from this analysis. Preliminary tests indicated the data were non-normal ($p < 0.05$). Analysis of this measure using a RGLM indicated no significant main effects or interactions ($p > 0.05$). A number of significant correlations were found for this measure including the training skills score ($r_s = 0.410$, $p < 0.01$), and various SOL scores. A complete listing of significant correlations can be found in Appendix E.

6.3.2.2 Homework-related Computer Use

Information about homework-specific computer use was gathered using the *Family Homework Effort* self-report form, with each form documenting usage for a single night. Self-report forms were distributed only on full school days; if weather caused school to be released early, the forms were distributed to students on the next full day of school. Data were collected on at most six randomly selected school days during each 12-week period. As insufficient data were available for the second 12-week period in the school year, that period was excluded from the analyses reported here. Any student who did not return at least three self-report forms during both the first and third 12-week periods was excluded from the reported analyses. Due to insufficient control group data, GENDER could not be included as an effect in the analysis models.

Computer use for homework purposes was assessed in terms of the total time and the time spent using the Internet. Due to mixed nature of the data, multivariate techniques could not be used to analyze these related measures. Results of the analyses are summarized below.

- An ANOVA of Ranks for the total amount of time indicated no significant main effects or interactions ($p > 0.05$).

- Analysis of the amount of Internet usage with a RGLM indicated no significant main effects or interactions were found ($p > 0.05$). Students without a residential Internet connection were excluded from this analysis.

A significant linear relationship between the total amount of computer use for homework purposes and the training skills score was found ($r_s = 0.332$, $p < 0.05$).

6.3.3 Home Internet Usage By PCF Students

Proxy logs from the PCF server made possible more detailed analyses of home network usage by PCF students. This section explores patterns and predictors of Internet usage among PCF students, with the main focus being predictors of Internet usage and students' Internet-enabled communication networks. In order to study whether students' use of the Internet would change over time, research analyses included a time variable. The project proxy server recorded the data included in these analyses between 4 October 1998 and 4 October 1999.

6.3.3.1 Dispersion of Internet Technologies

In order to examine differences in the adoption of available Internet technologies, the percentage of students accessing each technology was analyzed. Figure 6-17 shows how the percentage of students using different technologies changed with time.

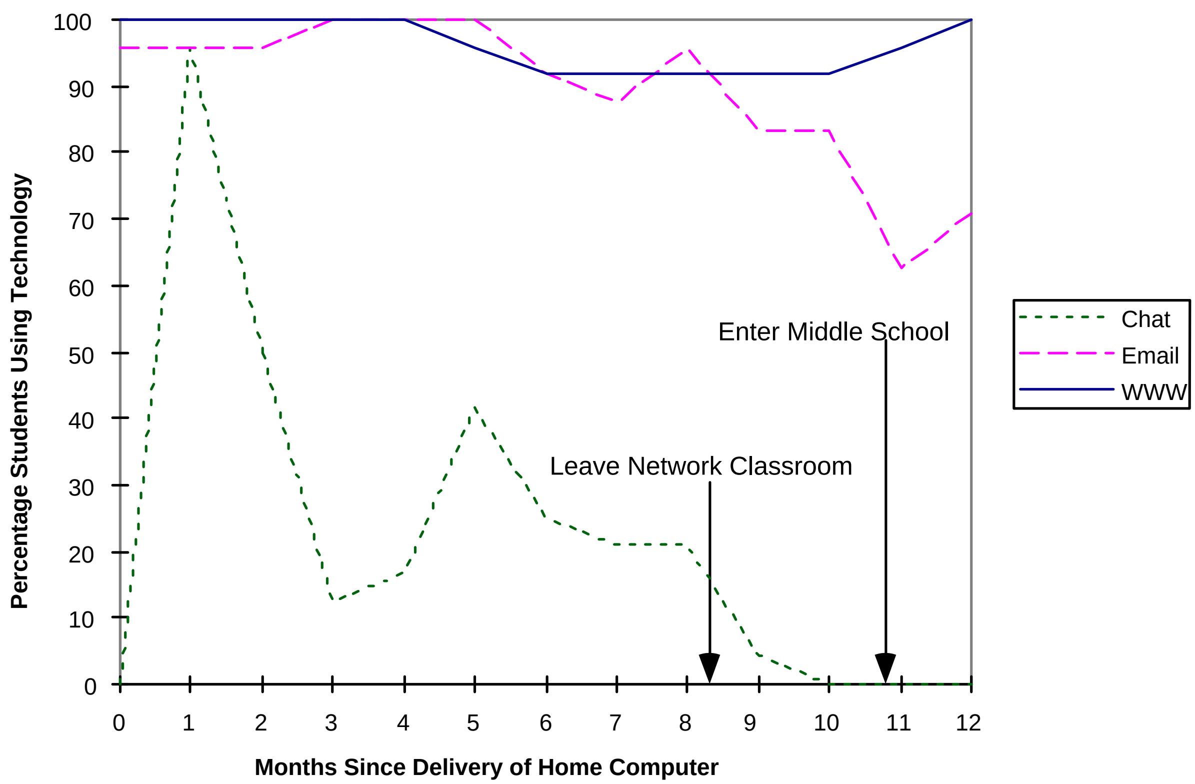

Figure 6-17. Changes in Internet technology access among PCF students.

As preliminary tests indicated this data were non-normal ($p < 0.05$), a RGLM was performed on the percentage of students using the technologies each week. This analysis indicated that the percentage of students using each technology differed significantly ($F[2,204] = 447.13$, $p < 0.001$), with the web used by the greatest percent of students and chat used by the smallest percent (LSD, $p < 0.05$). The interaction between the kind of technology and gender was also significant ($F[2,204] = 8.59$; $p < 0.001$). As seen in Figure 6-18, the percentage of boys using the web was significantly higher than a) the percentage of girls using the web and b) the percentage of either boys or girls using email (LSD, $p < 0.05$).

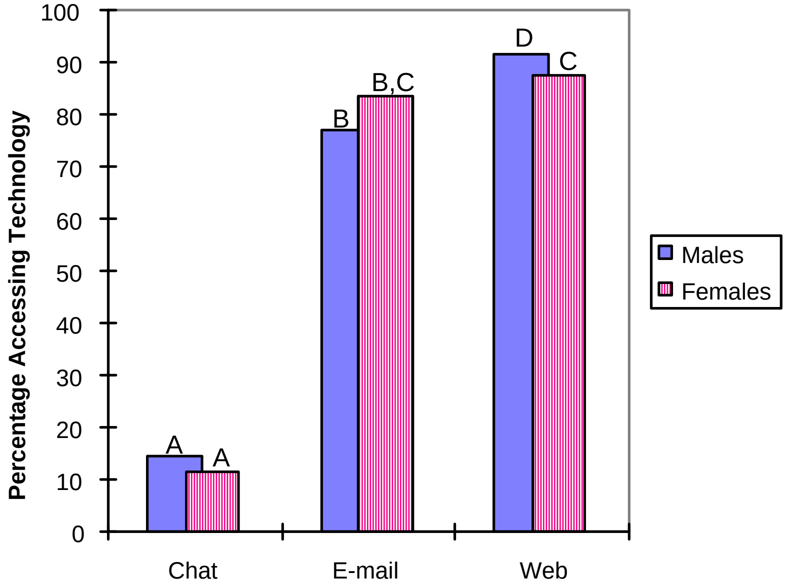

Figure 6-18. Differences in the percentage of students accessing the available Internet technologies. Means with the same label are not significantly different (LSD, $p > 0.05$).

6.3.3.2 Relative Importance of Different Internet Technologies

In order to examine the relative importance of the different Internet technologies to students, the percentage of days each month students accessed the individual technologies was analyzed. As preliminary tests indicated the data were non-normal ($p < 0.05$), a RGLM was used to analyze the data. This analysis indicated that the frequency with which students accessed each of the technologies varied significantly ($F[2,44] = 163.32$, $p < 0.001$), with students preferring the web to either email or chat (LSD, $p < 0.05$). Additionally, students chose email more frequently than chat (LSD, $p < 0.05$).

As shown in Figure 6-19, the frequency with which students accessed the Internet varied significantly over the course of the year ($F[11,242] = 22.76$, $p < 0.001$). The interaction between medium and duration of home technology availability was also significant ($F[22,484] = 10.35$, $p < 0.001$). Students choose the web over email during the first month of home technology availability and during the last three months of the field experiment (LSD, $p < 0.05$). Additionally, as shown in Figure 6-20, students preferred the web to chat throughout the year (LSD, $p < 0.05$).

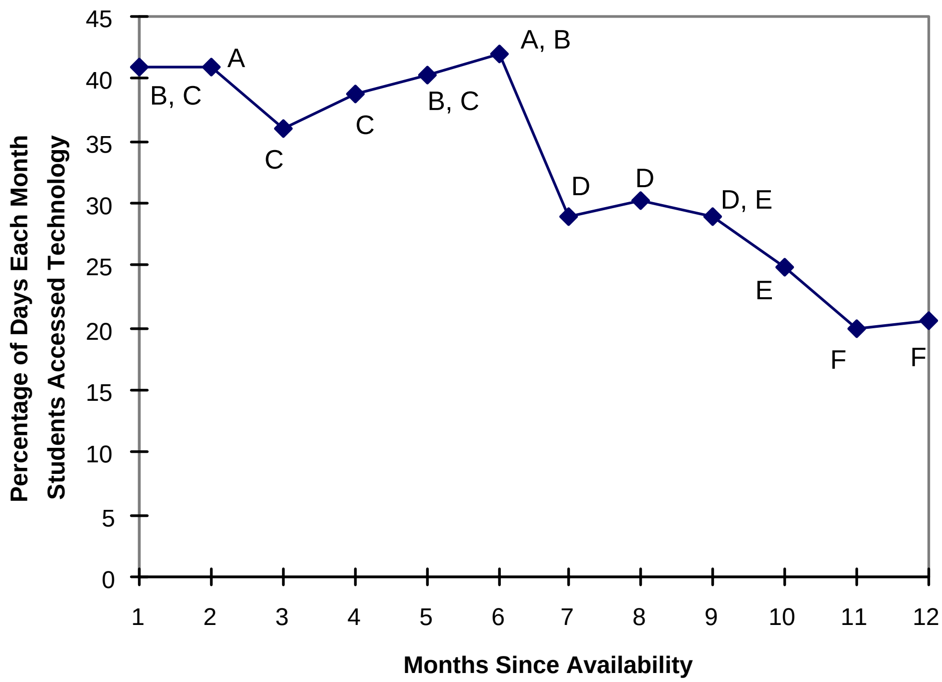

Figure 6-19. Differences in the percentage of days each month students accessed Internet technology. Means with the same label are not significantly different (LSD, p > 0.05).

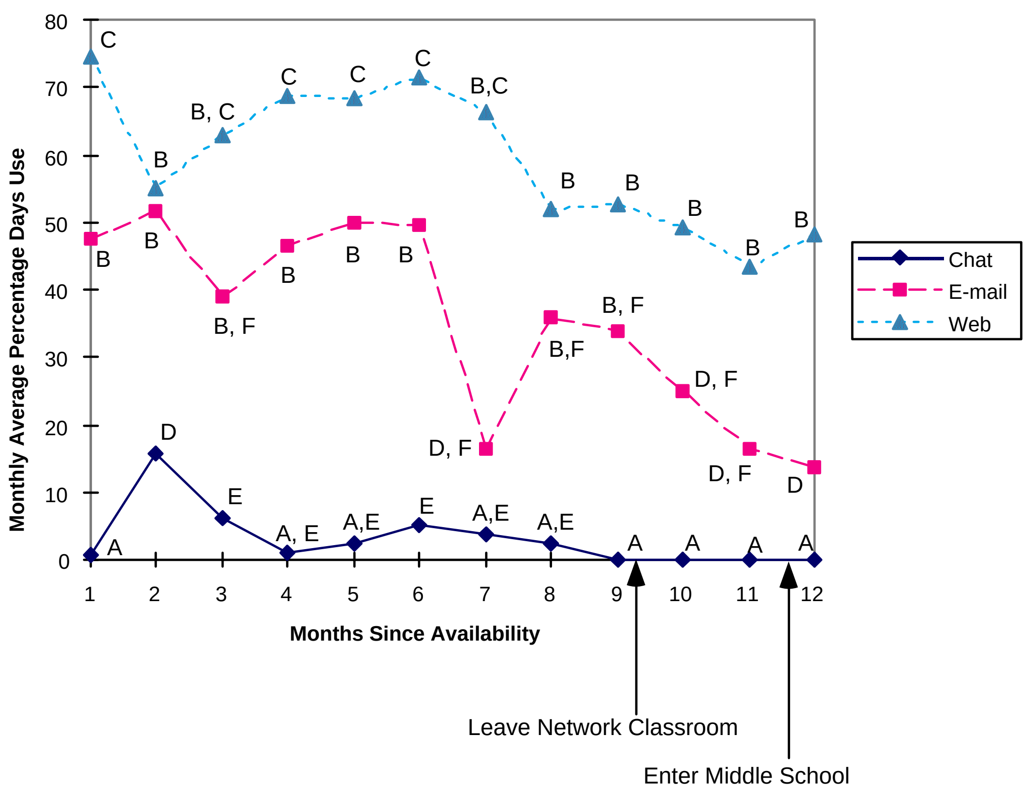

Figure 6-20. Differences in the percentage of days each month students accessed the different Internet technologies. Means with the same label are not significantly different (LSD, p > 0.05).

6.3.3.3 Interrelationships Between Internet Usage Measures

In order to explore the relationships between different kinds of network computer use across the year, the weekly Internet measures for individual students were correlated with each other. Chat usage was significantly correlated with the number of email messages sent to students (r = 0.118, df = 1248, $p < 0.001$) and sent by students (r = 0.118, df = 1248, $p < 0.001$) each week, but not with WWW usage. WWW usage was significantly correlated with the number of email messages sent to students (r = 0.060, df = 1248, $p < 0.05$), but not with email messages sent by the students.

Student Internet usage was also influenced by classroom activities. The average number of minutes of classroom computer use each week was positively correlated with student email measures (messages sent by: r = 0.304, df = 1248, $p < 0.001$; messages sent to: r = 0.563, df = 1128, $p < 0.001$) and family WWW usage (r = 0.167, df = 1248, $p < 0.001$). The number of days school was in session was correlated with both the number of email messages sent by students (r = 0.301, df = 1248, $p < 0.001$) and sent to students (r = 0.128, df = 1248, $p < 0.001$) but not with the chat or WWW measures. Additionally, teacher email measures were significantly correlated with student email measures (sent by: r = 0.158, df = 1248, $p < 0.001$; sent to: r = 0.466, , df = 1248, $p < 0.001$) and chat usage (r = 0.158, df = 1248, $p < 0.001$), with the number of messages sent to teachers significantly related to the family WWW usage (r = 0.060, df = 1248, $p < 0.05$).

Student patterns of Internet usage were also correlated with that of other students and family members. The amount of chat use by an individual student was positively correlated with the total number of chat users (r = 0.374, df = 1248, $p < 0.001$). Similarly, the number of emails sent by an individual student was related to the total number of email messages sent by other students (r = 0.303, df = 1248, $p < 0.001$) and the number of student email users (r = 0.243, df = 1248, $p < 0.001$). Further, the number of web pages loaded by a student was related to the number of student web users (r = 0.073, df = 1248, $p < 0.01$) but not the total number of pages loaded by other students. The number of messages sent to parents was significantly correlated with family WWW usage (r = 0.749, df = 1248, $p < 0.001$) and student email measures (message sent by: r = 0.267, df = 1248, $p < 0.001$; messages sent to: r = 0.451, df = 1248, $p < 0.001$).

6.3.3.4 Factors Influencing Internet Usage

The following Internet usage metrics were developed from the PCF server logs: (a) the number of WWW pages loaded by a participating family each week[13], (b) the number of email messages sent by a participant each week,[14] (c) the number of email messages sent to students, and (d) the number of lines input to the chat

[13] The measure was only available for PCF families; it was not available for either the classroom teacher or the project technologist.

[14] The reader should note that the number of e-messages sent to a student may not be the same as the number of messages received by a student as a message would be “received” only if the individual logged onto email and downloaded it.

application each week by a participant. This kind of data is known as time series cross-sectional (TSCS) data, or alternatively as panel data. The influences on student Internet usage were explored using TSCS regression methods, which account for autocorrelation within time units as well panel components (SAS, 1998). The influence variables for these analyses can be divided into the following groups:

- *Social Influences.* In addition to home Internet use metrics for classroom teachers and family members, the following variables were used to explore social influences on student use: (1) the number of days school was in session each week, (2) the number of minutes of computer use in the network classroom recorded by the logging software, (3) grade level, (4) the number of students engaging a particular Internet activity from home each week, (5) the amount of home Internet use each week by other students, *e.g.,* the number of email sent by other students in the program, and (6) whether the student was in the network classroom.

- *Individual Differences.* The following measures were used to explore the impact of student individual differences: (1) gender, (2) fifth grade Virginia Standards of Learning scaled scores (SS), (3) third grade Stanford 9 SS, (4) grade point averages (GPAs), (5) Murphy-Meisgeier personality type indicator (MMPI) scores (Thinking-Feeling, Judging-Perceiving, Extroversion-Introversion, Sensing-Intuition), (6) learning style scores (verbal, visual, kinesthetic), (7) School Attitude Measure scores, (8) school attendance, and (9) computer attitude survey scores.

- *Family Demographics*. The following measures were used to explore the impact of family variables: (1) the highest level of education achieved by a family member, (2) the number of family members living at home, (3) family members' years of computer experience, (4) the number of years the family had a home computer, and (5) the number of years the family had home Internet Access.

Additionally, *lagged usage* (*i.e.,* the corresponding value from the preceding week) represented the extent to which usage remained stable from one week to the next.

Best subsets of predictors were developed using the maximum R^2 criterion, where R^2 is the proportion of variance accounted for by the predictors.[15] That is, the best one predictor regression model was selected based on the largest R^2 value, then the next best two predictor model was developed, and the process continued until all predictors were used. The model with the highest R^2 value was then selected, and predictors who were not significant ($p > 0.05$) deleted from the final model.

[15] As the traditional R^2 value can yield a number outside the [0,1] interval for time series cross-sectional regression, a modified R^2 value is used instead (SAS, 1998).

6.3.3.4.1 Influences on WWW Usage

Figure 6-21 shows how World Wide Web (WWW) usage among PCF families varied over the course of the field experiment. Among participating families, the extent of WWW use varied as shown in Figure 6-22.

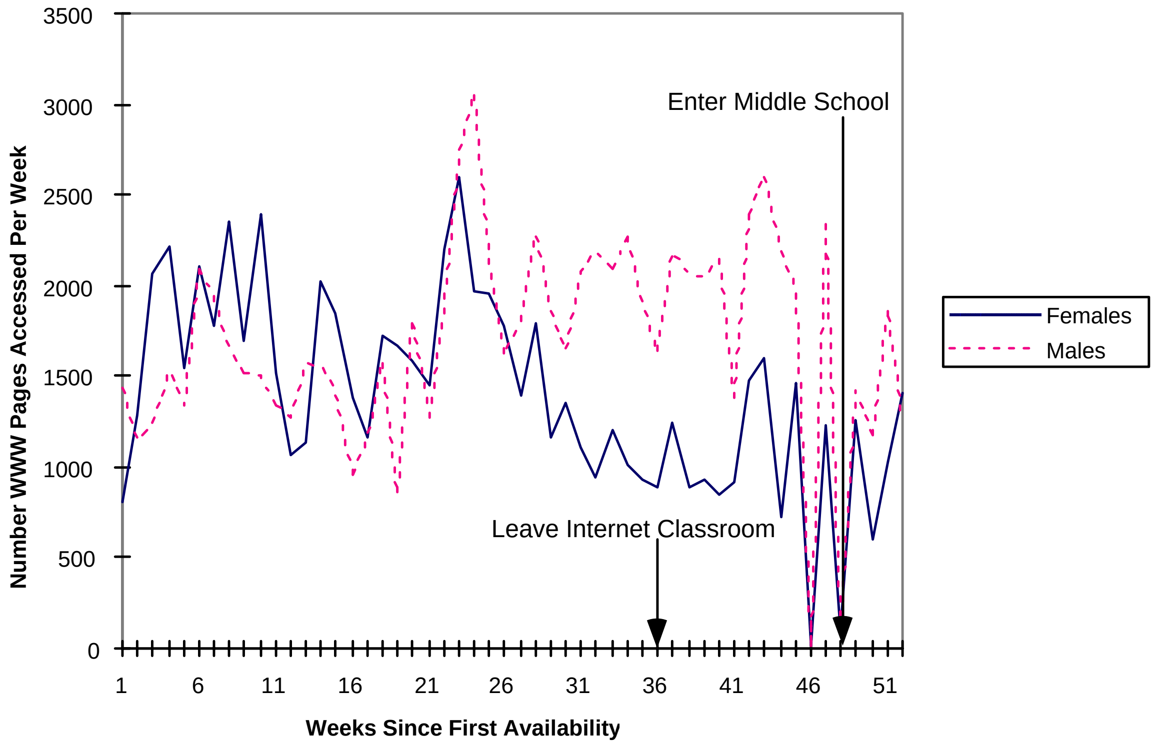

Figure 6-21. Weekly number of family WWW accesses by student gender.

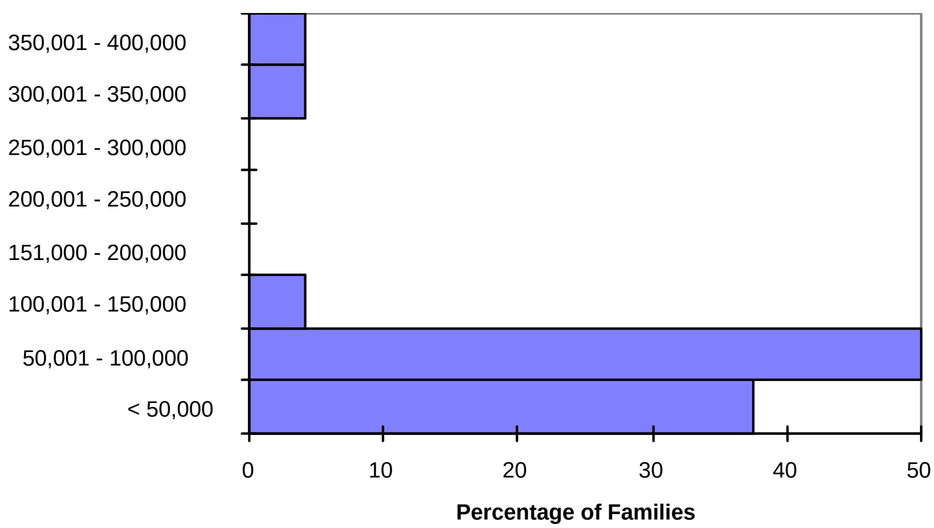

Figure 6-22. Distribution of the total number of WWW accesses made by families during the field experiment.

TSCS regression methods were used to determine what aspects of the classroom system most influenced home WWW use. The dependent measure for this analysis was the number of WWW pages loaded during a week for each family. As the data displayed predominantly autoregressive components within family cross-sections and had contemporous correlation, a TSCS Parks model (SAS, 1998) was used to analyze the data. This technique assumes a first-order autoregressive process (*i.e.,* usage values for a given week are related to values from the previous week) and cross-sectional correlations between family usage patterns (*i.e.*, usage values for one family are related to the values of other families). Using this technique, best subsets of predictors were developed for WWW use the maximum R^2 criterion, where R^2 is the proportion of variance accounted for by the predictors

As shown in Table 6-12, the best resulting subset of predictor variables was comprised of the number of days the student was absent during the previous six-week period (ABSENT), the student MMPI sensing-intuitive score (SN), the number of days the student was tardy in the fourth grade (TARDY), the student's science grade for the last six-week period (SCIENCE), the student's writing computer survey score (WCOMP), student's lagged WWW usage (WWWLAG), and the number of email sent by the student (SENT). The corresponding first order model is shown in Equation 6-1:

$$\begin{aligned} WWW = {} & 1050.418 + 161.224\ ABSENT + 8.907\ SN + 73.104\ TARDY + \\ & 0.632\ WWWLAG - 157.013\ SCIENCE - 23.136\ WCOMP + \\ & 7.132\ SENT \end{aligned} \qquad (6\text{-}1)$$

where WWW is the number of WWW pages loaded by the family for the week. The variables in this model accounted for 68.64 percent of the variance in WWW usage.

Table 6-12. Test of significance of family WWW usage model parameters.

Variable	*b*	*Standard Error Estimate*	*t for H_0: b=0*	*p*	*R^2*
WWWLAG	0.626	0.021	30.04	0.001	0.563
ABSENT	169.674	16.715	10.17	0.001	0.035
SN	8.935	1.906	4.55	0.001	0.021
SCIENCE	-162.54	17.919	-9.03	0.001	0.019
TARDY	74.822	12.616	5.93	0.001	0.016
SENT	7.132	1.690	4.22	0.001	0.015
WCOMP	-22.333	3.533	-6.39	0.001	0.006

6.3.3.4.2 Influences on Email Usage

Figures 6-23 and 6-24 show how email usage by PCF students varied during the field experiment, with average use tapering off after students left the network classroom. Among participating families, the extent of email use varied as shown in Figure 6-25.

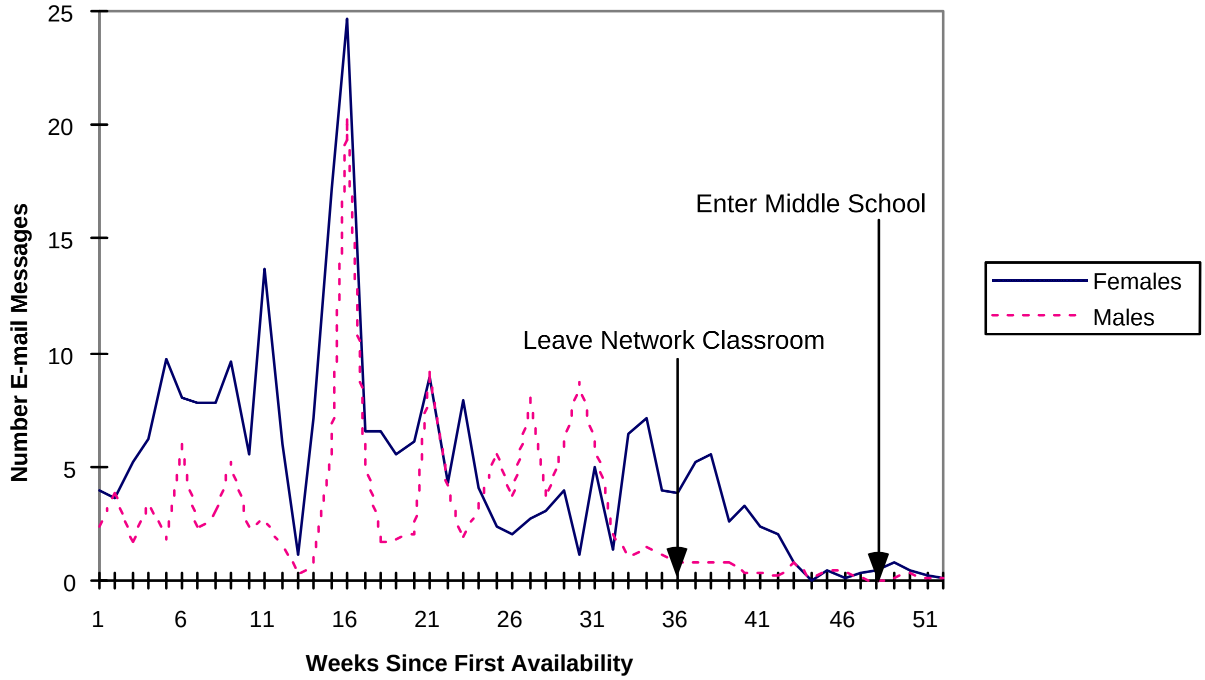

Figure 6-23. Weekly number of email messages sent by students.

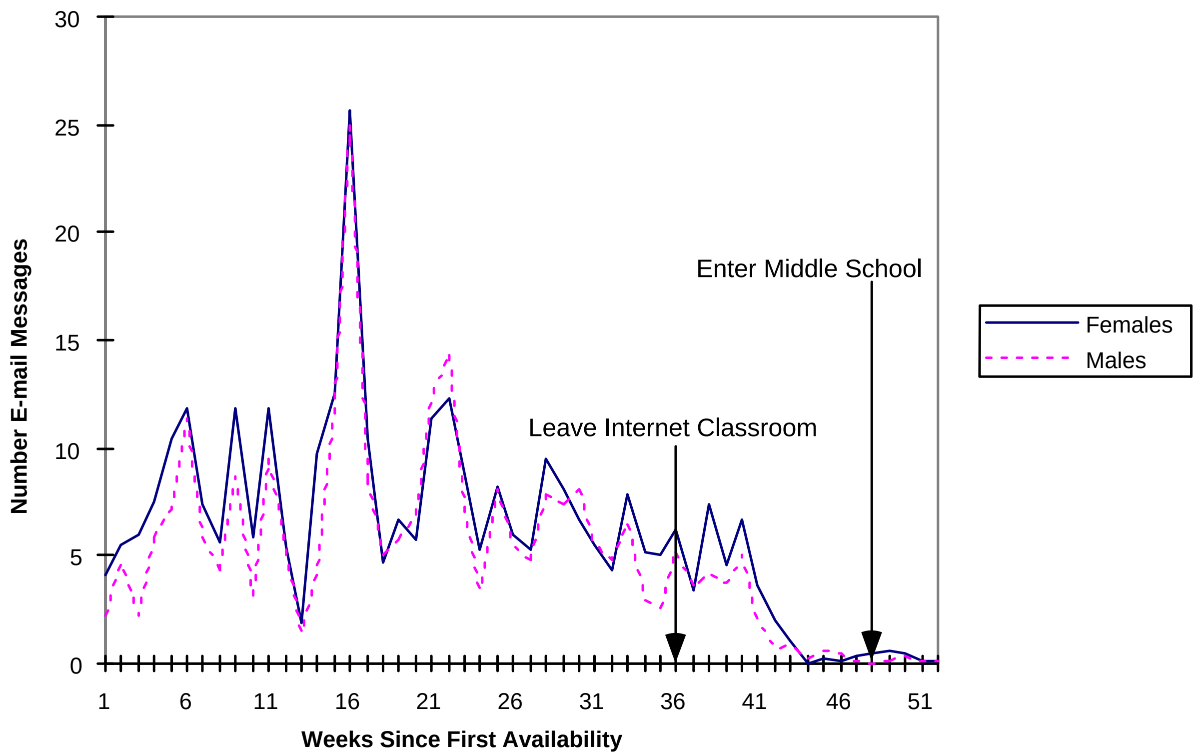

Figure 6-24. Weekly number of email messages sent to students.

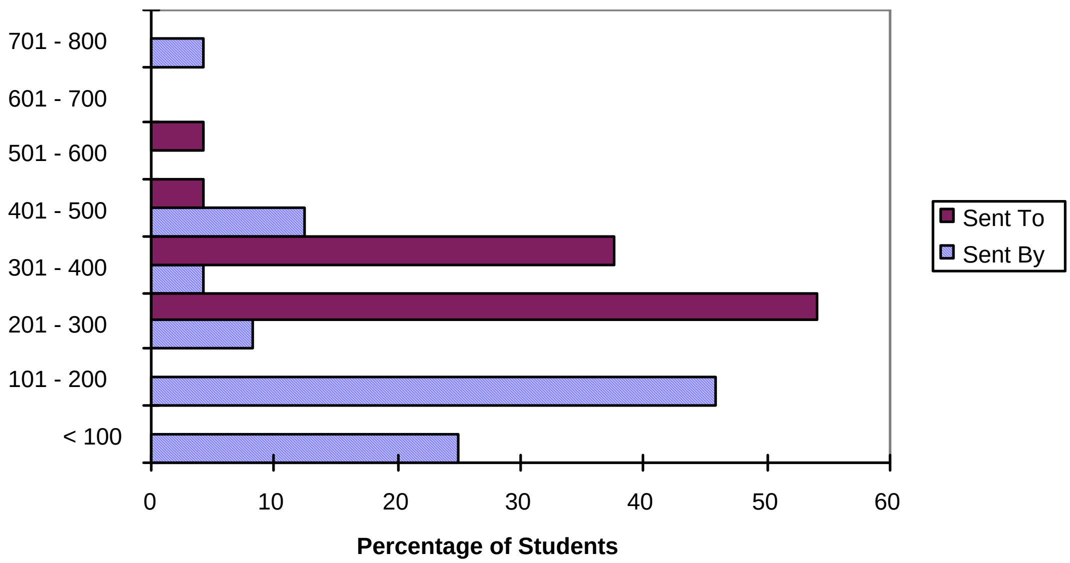

Figure 6-25. Distribution of the number of student email messages over the course of the field experiment.

TSCS regression methods were used to determine what aspects of the classroom system most influenced student home email use. The dependent measure for this analysis was the number of email messages sent during a week by each student. As the data displayed mainly autoregressive components within student cross-sections and had contemporous correlation within student cross-sections, a TSCS Parks model (SAS, 1998) was used to analyze the data.

As shown in Table 6-12, the best resulting subset of predictor variables was comprised of the student's gender (GENDER),[16] the percentage of the student's learning style that relates to visual processing (VISUAL), the average number of emails sent by parent(s) for the current week (PSENT), the student's current classroom setup (CLASS),[17] the student's SOL science SS (SCIENCE), the lagged number of emails sent by student (SENTLAG), the lagged number of emails sent to students (RECLAG), and the number of emails sent by other PCF students during the current week (OTHER). The corresponding first order model is shown in Equation 6-2:

$$\begin{aligned} SENT = &-11.509 + 1.008\ GENDER + 0.0522\ VISUAL - 0.025\ PSENT + \\ &0.387\ CLASS + 0.013\ SCIENCE + 0.117\ RECLAG + \\ &0.216\ SENTLAG + 0.027\ OTHER \end{aligned} \tag{6-2}$$

where SENT is the number of email message sent by a student during the week. The variables in this model accounted for 73.42 percent of the variance in student email usage.

[16] Gender was coded as follows for this analysis (Male = 1, Female = 2).
[17] Classroom setup was coded as follows for this analysis (Network Classroom = 5, Standard Classroom = 6).

Table 6-13. Test of significance of email usage model parameters.

Variable	*b*	*Standard Error Estimate*	*t for H_0: b=0*	*p*	*R^2*
CLASS	0.388	0.148	2.62	0.009	0.023
VISUAL	0.052	0.007	7.08	0.001	0.028
SCIENCE	0.013	0.001	9.48	0.001	0.012
PSENT	-0.025	0.002	-13.58	0.001	0.081
GENDER	1.009	0.115	8.75	0.001	0.053
SENTLAG	0.216	0.025	8.73	0.001	0.180
RECLAG	0.117	0.019	6.23	0.001	0.063
OTHER	0.027	0.001	31.86	0.001	0.296

6.3.3.4.3 Influences on Chat Usage

Students were the sole users of the PCF chat room for the year. Figure 6-26 shows how chat usage varied during the field experiment.

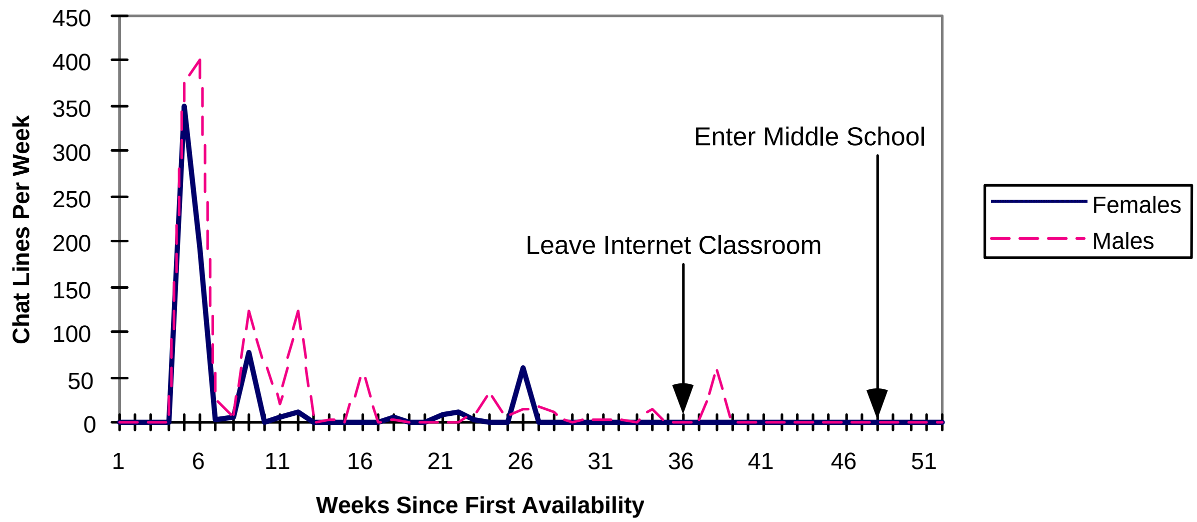

Figure 6-26. Weekly chat usage by students.

Of the 24 students and 2 teachers whom had access to the PCF chat facility, 22 students logged into the chat room. During the period under consideration, participants wrote a total of 25,444 lines. Among the participants, chat usage differed as shown in Figure 6-27.

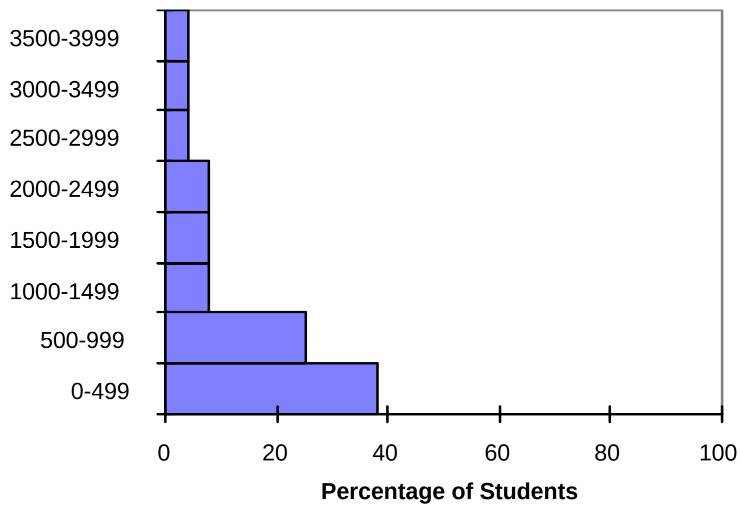

Figure 6-27. Distribution of the number of chat lines for students during the year.

The basic measure of chat usage was the weekly number of chat lines entered by a student. As this data were predominantly zeroes, TSCS regression methods were not an appropriate analysis technique. Instead, the weekly chat totals were used to create yearly totals for each student. As preliminary tests indicated the data were non-normal ($p < 0.05$), RGLM regression was then used to identify the characteristics of classroom system that most influenced differences in the total number of chat lines between participants. As shown in Table 6-14, the best resulting subset of predictor variables was comprised of student MMPI judging-perceiving score (JP), 4th grade mathematics GPA (MGPA), 4th grade science GPA (SGPA), and 3rd grade Stanford 9 mathematics score (MSTAND). The corresponding first order model is shown in Equation 6-3:

$$TC = -32.530 - 0.281\ JP + 5.170\ MGPA - 6.878\ SGPA + 0.111\ MSTAND \qquad (6\text{-}3)$$

where TC is the rank value for the total number of chat lines input for the year. The variables in this model accounted for 58.48 percent of the variance in total chat lines.

Table 6-14. Test of significance of chat usage model parameters.

Variable	*b*	*Standard Deviation Estimate*	*t for H_0: b=0*	*p*	R^2
MGPA	5.170	1.884	2.74	0.013	0.067
JP	-0.281	0.109	-2.58	0.018	0.072
SGPA	-6.878	2.445	-2.81	0.011	0.173
MSTAND	0.111	0.039	0.001	0.009	0.281

6.3.3.4.4 Nature of Chat Interactions

As chat transcripts were created by the PCF proxy server, the following additional metrics could be developed for chat interactions: (a) the number of conversations, *i.e.*, chat sessions involving more than one user with no more than two minutes of idle time between individual lines, (b) the number of non-connections, *i.e.*, sessions involving only one user, and (c) frequency counts of different categories of chat lines (*e.g.,* social).

While the average student logged into the chat room approximately 1.778 times a month, some of the participants logged onto the chat room several times a week and entered over 2000 chat lines. Of the 555 logins to the chat facility, student logins resulted in 178 non-connections, *i.e.,* instances of the user never interacting with other individuals while in the chat room, with the remaining logins resulting in a total of 123 conversations. As shown in Figure 6-28, the majority of chat rooms conversations involved only two individuals.

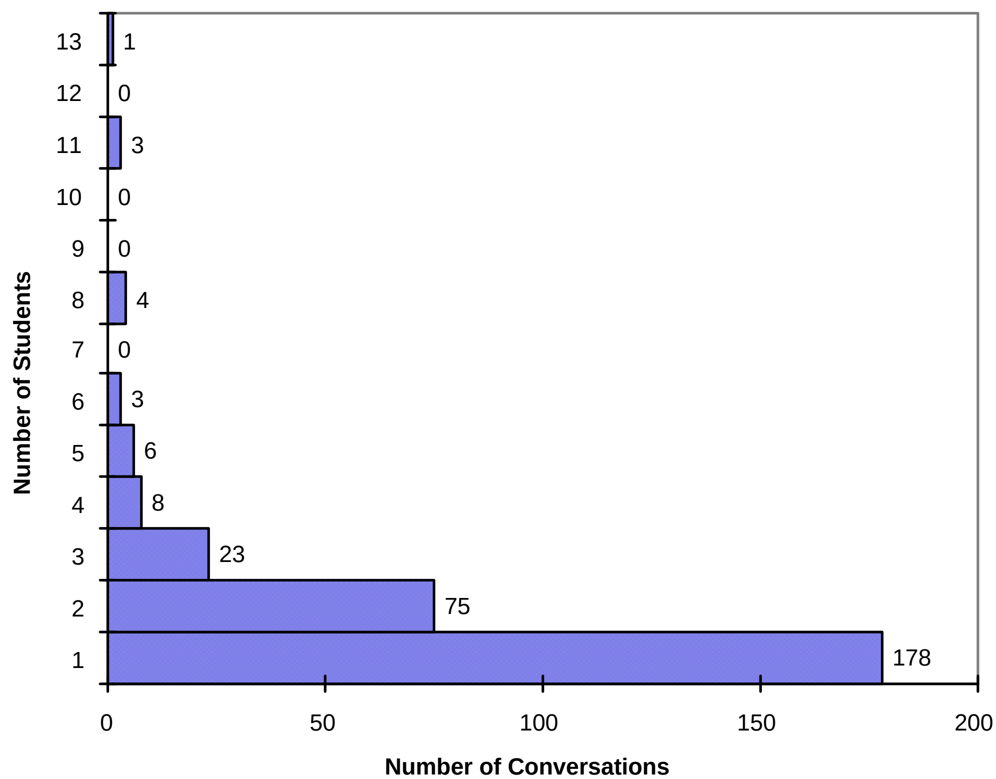

Figure 6-28. Group sizes during chat sessions.

Individual lines from chat transcripts were classified as either (a) disruptive, *e.g.,* blank lines or random strings of characters, (b) social, or (c) school related. In all, 17354 lines were classified as disruptive, 30 lines related to class work, and 8073 lines were social in nature. An RGLM analysis found that usage differed significantly by category (F[2,44] = 71.38, $p < 0.001$), with chat being used more often for social and disruptive purposes than for class work ($p < 0.05$, LSD). Additionally, the GENDER x CATEGORY was significant (F[2,44] = 6.59, $p < 0.001$). As shown in Figure 6-29, male disruptive use was significantly higher than all other types of use ($p < 0.05$, LSD).

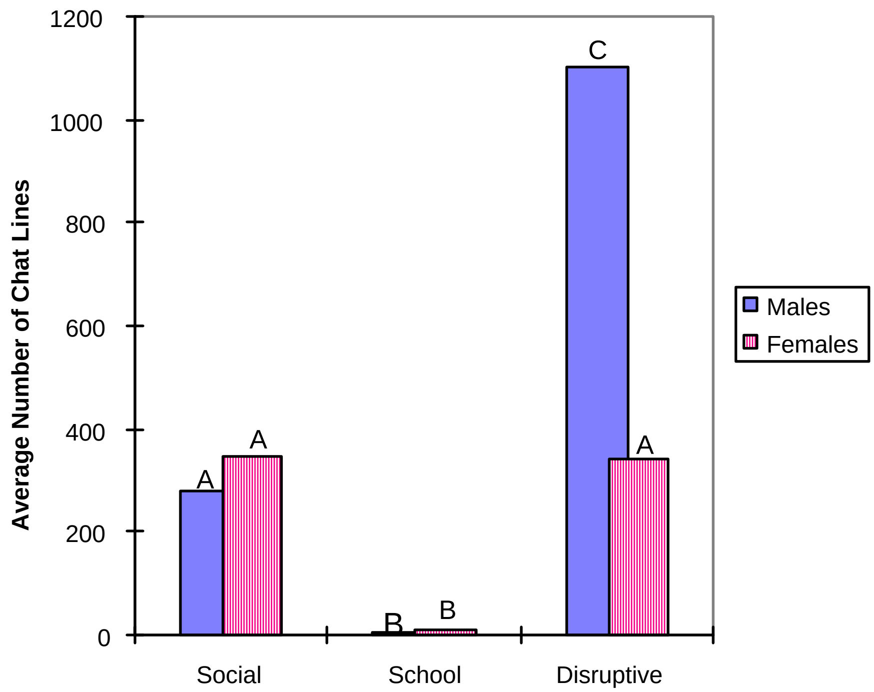

Figure 6-29. Effect of GENDER x CATEGORY interaction on home chat usage. Means with the same label are not significantly different (LSD, $p > 0.05$).

6.3.4 Evolution of Electronic Social Networks

Tracking of electronic networks was limited to the home as the classroom teacher had instructed project system staff to replace individual email accounts with a single group account in order to simplify classroom management. In the home, email and chat communication was logged for all program participants, including students, teachers, and family members.[18] Internet-enabled networks between classroom members (*e.g.,* students and teachers) are the primary focus of the analyses presented here. All characteristics of network structure used for these analyses were computed by UCINET 5.0 (Borgatti, Everett, and Freeman, 1999).

Email communication was considered directional; that is, ties between individuals were oriented from one actor to another. A total of n(n-1) ties are possible in a directional network, where n is the number of individuals in the network. The strength of a tie between individuals was increased by one each time an email message was sent, with the sender determining communication direction. During the year in question, each student sent email to every other student and the technologist at least once, while 79.167 percent of the students sent email to the classroom teacher. The classroom email network for the year is shown in Figure 6-30. During the year, students sent an average of 6.195 messages to each person in the network; the teacher sent an average of 9.375 messages to each student and the technologist sent an average of 57.583 messages. Students received an average of 8.352 messages from each person in the network; the teacher received an

[18] Project tracking of email usage by teaching staff was limited to transactions with students and family.

average of 3.333 messages from each student and the technologist received an average of 9.708 messages.

Chat communication was considered non-directional; that is, the origin and direction of chat communication could not be determined. A total of n(n-1)/2 ties are possible in a non-directional network, where n is the number of individuals in the network. The strength of a tie between individuals was increased by one each time they jointly participated in a chat conversation (*i.e.*, chat sessions involving more than one user with no more than two minutes of idle time between individual lines). For the year in question, only students used chat; no instances of teacher participation were recorded. The classroom chat network for the year is shown in Figure 6-31. The average tie strength between students in the chat network was 2.412, with the tie strength for some pairs of students in the twenties.

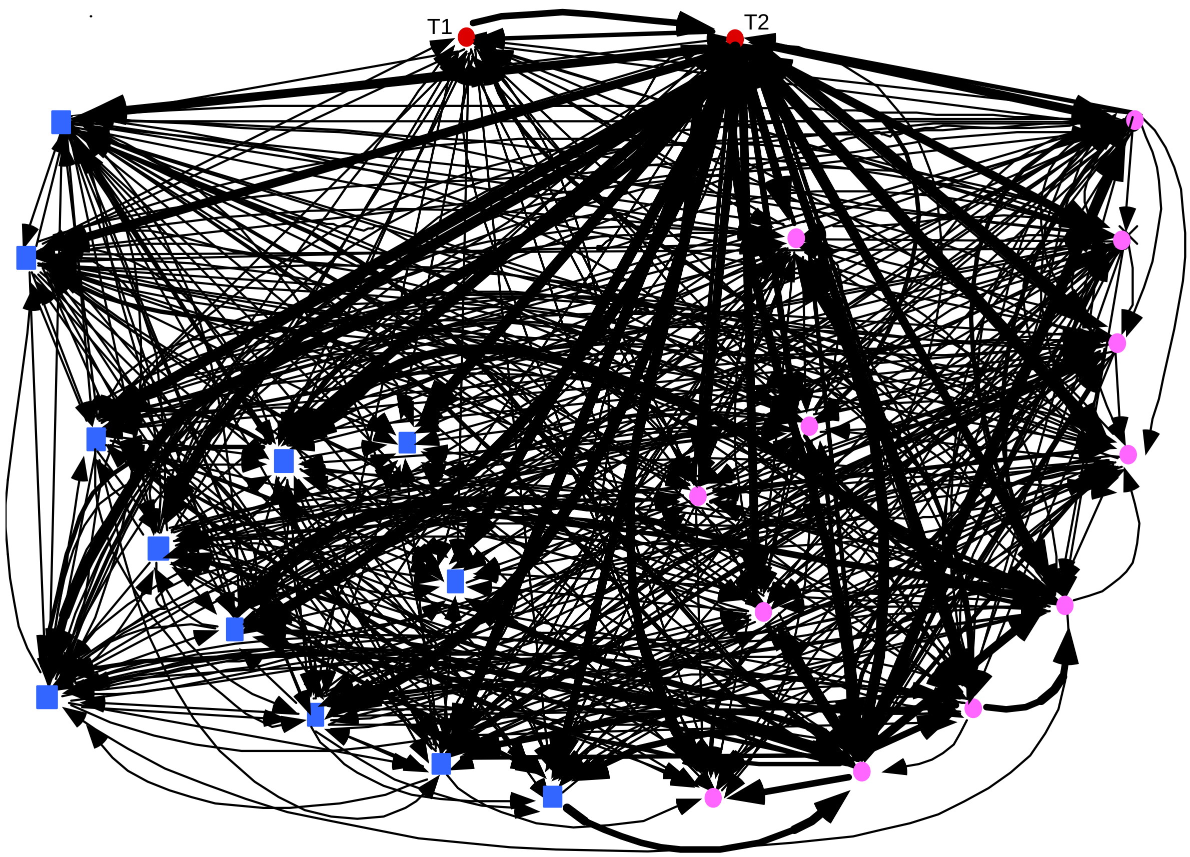

Figure 6-30. Graph of the email communication network among PCF students and teachers for the year. Squares indicate boys, circles denote girls, T1 represents the classroom teacher, and T2 denotes the classroom technologist. Lines indicate email communication between individuals, with line width indicating frequency.

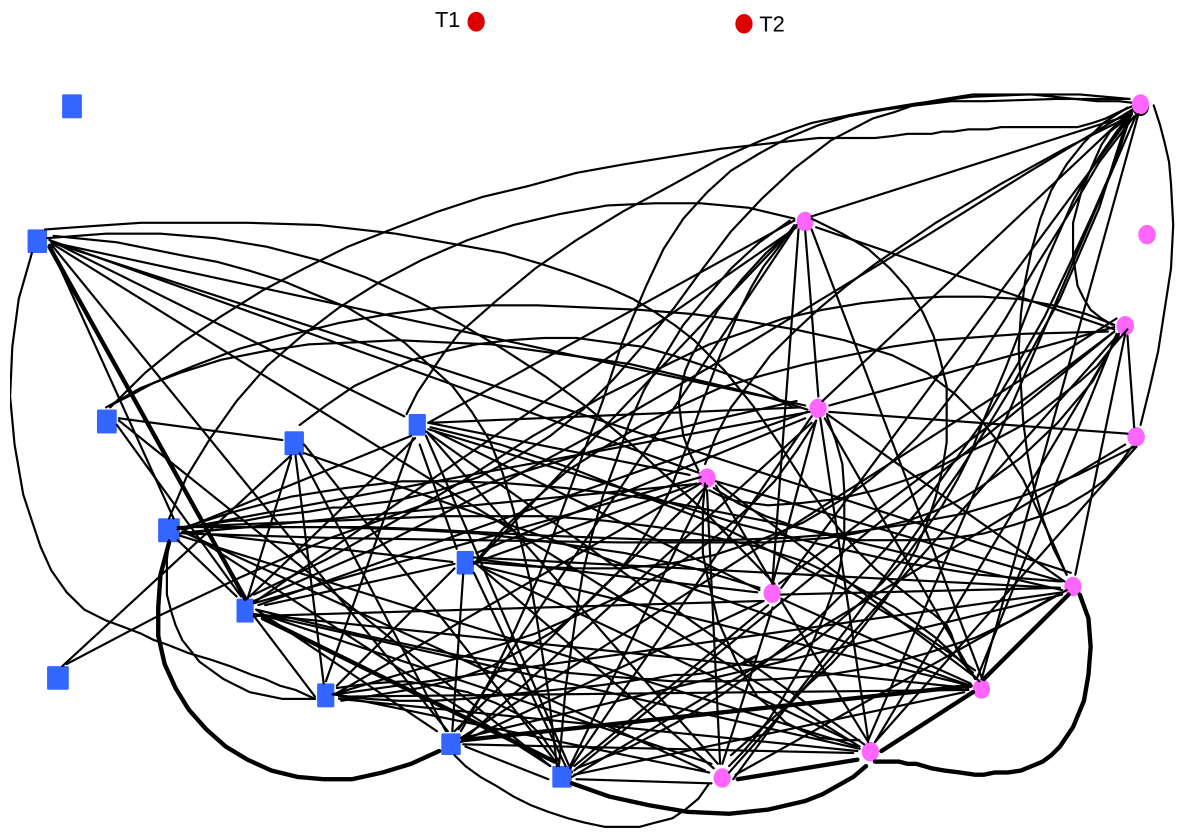

Figure 6-31. Graph of the chat communication network among PCF students and teachers for the year. Squares indicate boys, circles denote girls, T1 represents the classroom teacher, and T2 denotes the classroom technologist. Lines indicate chat communication between individuals, with line width indicating frequency.

6.3.4.1 Factors Influencing Network Density

In order to determine the extent to which the Internet connected students and teachers outside the classroom, the densities of unvalued networks for each medium were calculated. Density is a commonly recommended measure of group cohesion (Wasserman and Faust, 1997). It is the proportion of possible ties that are actually present in a social network. Thus, it equals the number of ties with a non-zero value divided by the number of possible ties. It can range from 0, if there are no ties present, to 1, if all possible ties are present. This metric does not take into account differences in the strength of ties; it is only concerned with the existence of ties. As preliminary tests indicated the data were non-normal ($p < 0.05$), analysis was limited to non-parametric techniques.

6.3.4.1.1 Effect of Communication Medium

In order to investigate whether email or chat was better at facilitating communication among participating students and teachers, weekly densities were calculated for each medium. The network used to compute weekly densities was comprised of 26 actors: 24 PCF students, the classroom teacher, and the project technologist. Figure 6-32 shows how network density changed across the year.

The mean density for email was 0.103 with a standard deviation of 0.103, while the mean density for chat was 0.018 with a standard deviation of 0.059. As the data involved ordinal measures within paired replicates, the weekly differences could be used to determine the effect of medium on network density. A sign test indicated that the density of the email network was significantly higher than that of the chat network (S = 43, n = 52, $p < 0.001$).

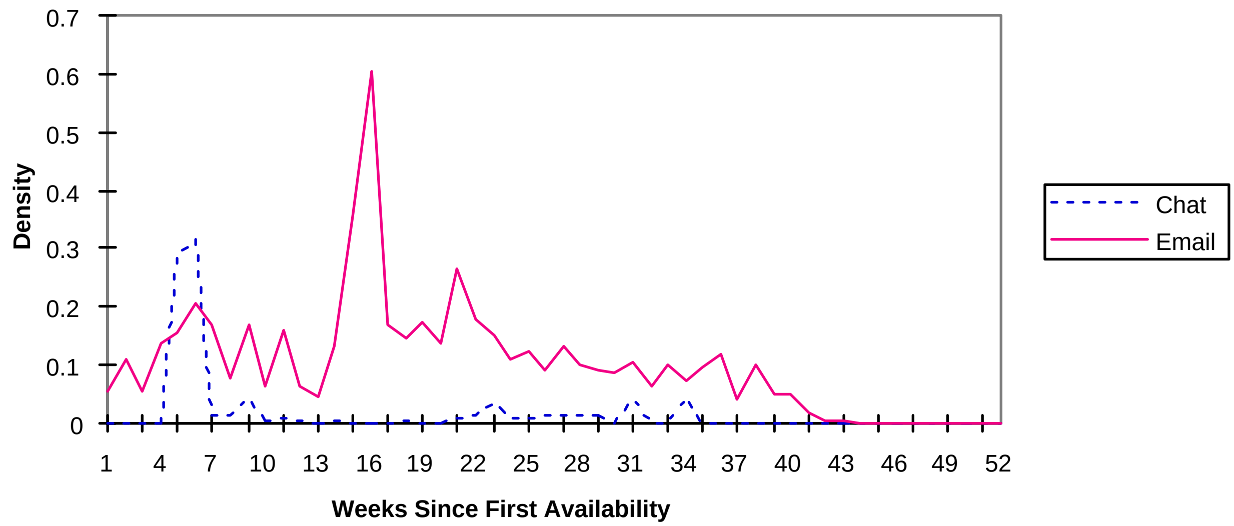

Figure 6-32. Changes in student-teacher network density as a function of communication medium and the number of weeks since the home network technology was first available. Students left the network classroom during week 36.

6.3.4.1.2 Centrality of the Teaching Staff

Comparing the density of the student-teacher network to the density of the student-only network assessed the role of the teaching staff in Internet-enabled communication. As teachers did not utilize chat, this analysis was limited to email networks.

Figure 6-33 shows how the density of these networks changed across the year. The basic unit of analysis was the weekly network densities for email communication. The mean density for the complete network was 0.103 with a standard deviation of 0.103, while the mean density for the student-only network was 0.069 with a standard deviation of 0.089. A Friedman test indicated that removal of the teaching staff had a significant negative effect on the density of the email network (S = 48.94, df = 1, $p < 0.001$).

As the density of the student-teacher network was significantly different from that of the student-only network, the role of the teacher and the technologist in email communication was explored. Disregarding technologist email usage, the mean density for the network was 0.076 with a standard deviation of 0.0890, while ignoring teacher usage resulted in a mean density of 0.095 with a standard deviation of 0.100. Friedman tests indicated that removal of either the classroom teacher (S = 32.22, df = 1, $p < 0.001$) or the technologist (S = 25.56, df = 1, $p <$

0.001) had a significant negative effect on network density. Further, a sign test indicated that removal of the technologist from the network had a significantly greater negative impact on network density than removal of the classroom teacher (S = 33, n = 52, $p < 0.001$).

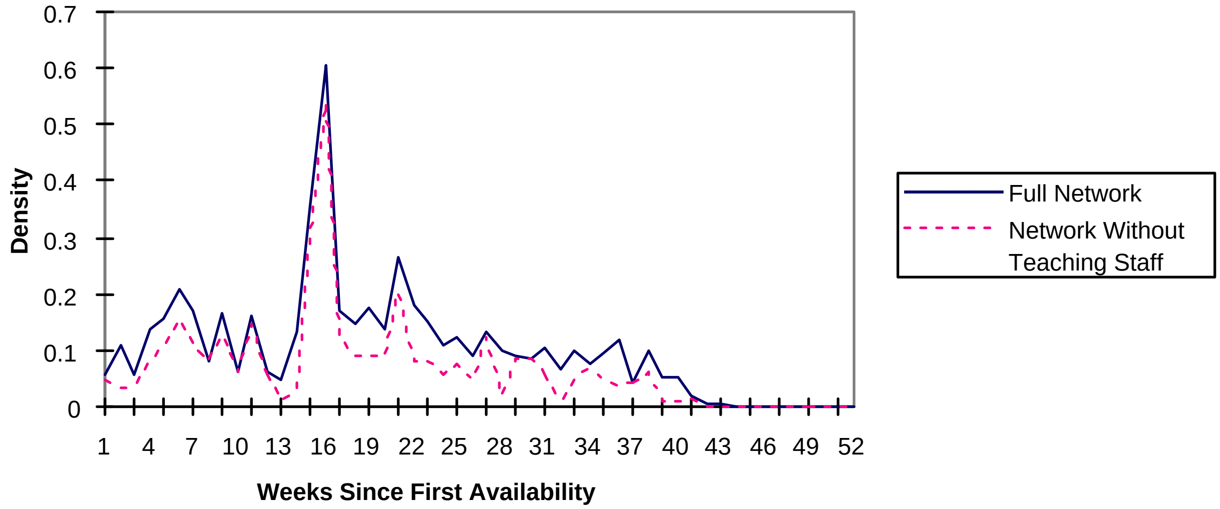

Figure 6-33. Differences in network density for student-teacher and student-only email communication networks. Students left the network classroom during week 36.

6.3.4.1.3 Effect of Leaving the Network Classroom

A Mann-Whitney test was used to assess the effect of leaving the network classroom on Internet-facilitated student communication networks. As chat usage had effectively ceased long before students left the network classroom, this analysis was limited to email communication. Weekly network densities for email communication were used for this analysis. During the school year, the mean density for the student email network was 0.103 with a standard deviation of 0.103, while the mean density after students left the classroom was 0.069 with a standard deviation of 0.089. This analysis indicated that network density during the school year was significantly higher than network density in the weeks after students left the network classroom (W = 980.5, $p < 0.001$).

6.3.4.2 Differences in Student Network Characteristics

The measures most commonly used for the identification of important actors in a social network are centrality and prestige (Wasserman and Faust, 1997). Actors are considered important if they interact frequently with others. While centrality focuses on the choices made by a particular actor, prestige is concerned with the choices made by other actors. When communication is non-directional, as with chat, the choices made by an actor cannot be distinguished from those made by other actors, and prestige cannot be defined (Wasserman and Faust, 1997). For directional forms of communication, such as email, centrality measures focus on actor-initiated communication, while prestige measures focus on communication where the actor is the recipient.

The network used to compute student structural characteristics for the year in question was comprised of 26 actors: 24 PCF students, the classroom teacher, and the project technologist. Regression techniques were used to relate student network characteristics to student behaviors and performance. The influence variables for these analyses can be divided into the following groups:

- *Academic Influences*. The following factors were used to examine the effect of school variables on centrality scores: (1) student GPAs, (2) student standardized test scores (3) self-reports of time spent on homework, (4) student school attendance, and (5) the percentage of homework assignments delivered on-time during fifth grade.

- *Student Attitudes and Beliefs*. The following measures were used to explore the impact of student attitudes and beliefs on centrality scores: (1) SAM scores at the beginning of fifth grade, and (2) computer attitude survey scores at the beginning of fifth grade.

- *Student Individual Differences*. (1) student Murphy-Meisgeier personality type indicator (MMPI) scores, (2) student learning style scores, and (3) student gender (1=male, 2=female).

Best subsets of predictors were developed using the maximum R^2 criterion, where R^2 is the proportion of variance accounted for by the predictors. Regression tables for these analyses can be found in the appendix titled *Descriptive Information and Detailed Analysis Results.*

6.3.4.2.1 Factors Influencing Student Centrality

The standardized degree centrality $[C'_D(n_i)]$ discussed in Wasserman and Faust (1997) was used to assess a student's centrality. It is a function of the degree of an actor and the number of actors in the network. In this case, the degree for an actor can be found by summing the individual's tie strengths for a particular type of network communication. Although originally defined for non-directional relationships, it has the advantage of being easily computable for directional relationships. The larger the value for an actor, the more central the actor to the network.

6.3.4.2.1.1 Influences on Email Centrality

As centrality is concerned with the choices made by an actor, $C'_D(n_i)$ was computed from the out-degree of each student. Thus, $C'_D(n_i)$ equals the out-degree for each actor (*i.e.*, the number of messages sent by the individual to others in the network) divided by n-1, where n is the number of actors in the network. $C'_D(n_i)$ ranged from 1.36 to 25.68 for students. The teacher had a centrality rating of 10.84, while the centrality rating of the technologist was 25.4. The average $C'_D(n_i)$ for students was 6.005 with a standard deviation of 5.457. Spearman's rank correlations indicated a significant linear relationship between a student's email centrality and the following student variables: email prestige ($r_s = 0.701$, $p < 0.001$), chat centrality ($r_s = 0.624$, $p < 0.001$), entry SAM score ($r_s = 0.417$, $p < 0.05$), and SAM change for the school year ($r_s = -0.507$, $p < 0.05$).

As preliminary tests indicated the data were non-normal ($p < 0.05$), RGLM regression was used to identify student and family characteristics that most influenced differences in student email centrality. As shown in Table 6-15, the best resulting subset of predictor variables was comprised of the student MMPI Thinking-Feeling score (TF), the student's change on the SAM Academic Self-Concept / Reference-based Scale for the school year (RSELF), and the student's gender code (GENDER). The corresponding first order model is shown in Equation 6-4:

$$EC = 34.283 - 0.416\ TF - 0.086\ RSELF + 5.908\ GENDER \qquad (6\text{-}4)$$

where EC is the rank value for the student's centrality for the email network. The variables in this model accounted for 65.31 percent of the variance in student email centrality.

Table 6-15. Test of significance of model parameters for student email centrality.

Variable	*b*	*Standard Error Estimate*	*F for H_0: b=0*	*p*	*R^2*
TF	-0.416	0.130	10.02	0.005	0.344
RSELF	-0.086	0.041	4.45	0.050	0.158
GENDER	5.908	2.172	7.40	0.015	0.151

6.3.4.2.1.2 Influences on Chat Centrality

As chat communication was considered non-directional, $C'_D(n_i)$ was computed from the degree of each student. Thus, $C'_D(n_i)$ equals the degree for each actor (*i.e.*, the number of chat conversations with others in the network) divided by n-1, where n is the number of actors in the network. Student chat centrality values ranged from 0.000 to 5.120 for students, with members of the teaching staff have a chat centrality value of 0.000 The average $C'_D(n_i)$ for students was 2.243 with a standard deviation of 1.615. Spearman's rank correlations indicated a significant linear relationship between a student's chat centrality and the following student variables: email prestige ($r_s = 0.668$, $p < 0.001$), email centrality ($r_s = 0.624$, $p < 0.001$), and entry SAM score ($r_s = 0.532$, $p < 0.01$).

A General Linear Model (GLM) regression was used to identify student and family characteristics that most influenced differences in student chat centrality. As shown in Table 6-16, the best resulting subset of predictor variables was comprised of the number of people in the student's family (NFAM), the student's entry SAM Motivation for Schooling NP (MOT), the student's entry SAM Academic Self-Concept -- Performance Based (SELF), the student's fifth grade SOL social studies SS (SOC), the student's fifth grade SOL earth science SS

(ESCI), and the student's fifth grade SOL computer operations SS (COPS). The corresponding first order model is shown in Equation 6-5:

$$CC = 10.375 + 0.375\ NFAM + 0.013\ MOT + 0.138\ SELF - 0.034\ SOC + 0.096\ ESCI - 0.131\ COPS \quad (6\text{-}5)$$

where CC is the student's centrality for the chat network. The variables in this model accounted for 95.44 percent of the variance in student chat centrality.

Table 6-16. Test of significance of model parameters for student chat centrality.

Variable	*b*	*Standard Error Estimate*	*F for H_0: b=0*	*p*	*R^2*
NFAM	0.375	0.105	12.78	0.003	0.220
MOT	0.013	0.004	10.43	0.006	0.404
SELF	0.138	0.019	53.17	0.001	0.135
SOC	-0.034	0.005	55.22	0.001	0.120
ESCI	0.096	0.014	46.62	0.001	0.041
COPS	0.131	0.019	48.10	0.001	0.034

6.3.4.2.2 Factors Influencing Student Prestige

As prestige can only be calculated for directional relationships and chat is non-directional, this analysis is restricted to student email networks. Since prestige is concerned with the choices made by other actor, $P'_D(n_i)$ was computed from the in-degree of each student. Thus, $P'_D(n_i)$ equals the in-degree for each actor (*i.e.*, the number of messages received from others in the network) divided by n-1, where n is the number of actors in the network. $P'_D(n_i)$ ranged from 1.360 to 13.761 for students. The teacher had a prestige rating of 4.320, while the prestige rating of the technologist was 11.164. The average $P'_D(n_i)$ for students was 8.160 with a standard deviation of 1.822. Spearman's rank correlations indicated a significant linear relationship between a student's email prestige and the following student variables: email centrality ($r_s = 0.701$, $p < 0.001$), Feel About Computers gain for the school year ($r_s = -0.418$, $p < 0.05$), chat centrality ($r_s = 0.668$, $p < 0.001$), entry SAM score ($r_s = 0.590$, $p < 0.01$), and SAM change for the school year ($r_s = -0.572$, $p < 0.01$).

As preliminary tests indicated the data were non-normal ($p < 0.05$), RGLM regression was used to identify student and family characteristics that most influenced differences in student email prestige. As shown in Table 6-17, the best resulting subset of predictor variables was comprised of the student's NP change for the SAM Academic Self-Concept / Reference-based Scale (RSELF), the student's entry Writing with the Computer survey score (WRITE), and the coded gender value (GENDER). The corresponding first order model is shown in Equation 6-6:

$$EP = -25.888 - 0.090\ RSELF + 0.733\ WRITE + 9.165\ GENDER \quad (6\text{-}6)$$

where EP is the rank value for the student's prestige for the email network. The variables in this model accounted for 71.80 percent of the variance in student email prestige

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Table 6-17. Test of significance of model parameters for student email prestige.

Variable	*b*	*Standard Error Estimate*	*F for H_0: b=0*	*p*	R^2
RSELF	-0.090	0.038	88.68	0.001	0.405
WRITE	0.733	0.214	185.47	0.001	0.195
GENDER	9.165	2.273	255.971	0.001	0.118

6.3.4.3 Social Roles and Communication

For the purposes of role analysis, senders and receivers were classified as female students, male students, teachers, or families, *i.e.*, family members of students. As chat usage was utilized only by students, no role analysis was undertaken for that medium. The reader should note that tracking of email communication by the teacher role was limited to interactions involving PCF students or families. Figure 6-34 summarizes patterns of communication between the different roles for the year under consideration. χ^2 tests for association were performed on the number of email messages sent between groups during the year. Post-hoc tests were done by decomposing RxC contingency tables into 2x2 contingency tables and performing χ^2 tests.

The different role groups were found to have significantly different patterns of communication ($\chi^2 = 3901.916$, df = 9, $p < 0.001$). Post-hoc tests revealed teachers are significantly more likely to send email to students and their families than other groups ($\chi^2 = 247.306$, df = 1, $p < 0.001$), while family members were significantly more likely to send email to a teacher than to a student or other family member ($\chi^2 = 1232.013$, df = 1, $p < 0.001$). Students were significantly more likely to email students of the same gender than they were to email students of the opposite gender ($\chi^2 = 2932.329$, df = 3, $p < 0.001$). Additionally, female students were more likely than male students to send email to teachers ($\chi^2 = 27.050$, df = 1, $p < 0.001$). However, male students were more likely than female students to send email outside their role group ($\chi^2 = 48.271$, df = 1, $p < 0.001$).

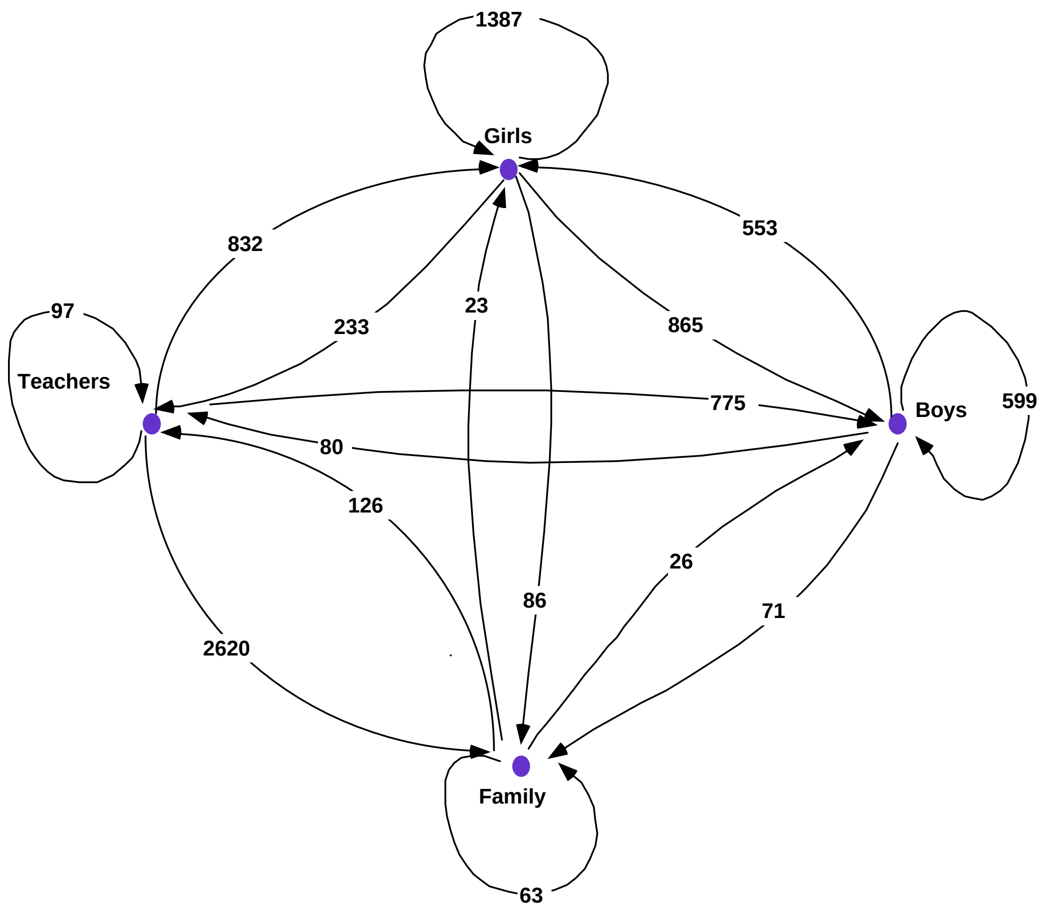

Figure 6-34. Summary role network for PCF participants.

6.3.5 *Musculoskeletal Effects of PCF Student Computer Use*

Student musculoskeletal discomfort was assessed by *the Child Discomfort Survey*. The survey is a modification of adult Cornell Musculoskeletal Discomfort Questionnaires (Human Factors and Ergonomics Laboratory at Cornell University, 1997). PCF students completed the survey three times during the school year. Students who failed to complete three surveys were not included in this analysis. Complete data were available for a total of 22 students (11 girls, 11 boys) in the PCF classroom.

Using the survey, students could indicate in which parts of their body, they were experiencing pain or discomfort. Figure 6-35 illustrates the distribution of students' complaints across body parts.[19] With few exceptions, all instances of complaints can be attributed to the last two surveys.

[19] Each time a student reported experiencing any discomfort in a body part on a single survey. If for instance a student reported discomfort in their legs on each of the surveys, the count for the legs would be increased by three.

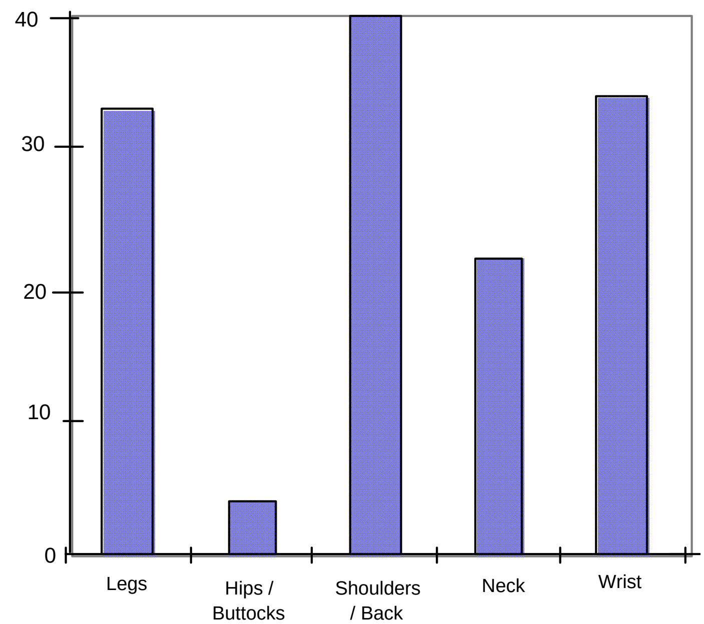

Figure 6-35. Counts of student citing pain in a particular body area on the *Child Discomfort Survey*.

The *Child Discomfort Survey* was composed of three scales which assessed 1) the frequency of discomfort, 2) the magnitude of discomfort, and 3) if their discomfort kept them from working on the computer. A maximum score of 144 was possible for the survey, with 72 the maximum for the first scale and 36 the maximum for the remaining scales.

Table 6-18. Summary descriptive information for the student self-reports of musculoskeletal complaints. Higher values indicate greater discomfort.

	Mean	*std*
Start of School Year	4.00	8.19
Middle of School Year	7.45	8.93
End of School Year	12.36	23.15

Table 6-18 summarizes the survey scores for the PCF class. An RGLM on the survey score indicated that the main effect of PERIOD was significant (F[2,40] = 706.91, $p < 0.01$), with post-hoc tests finding musculoskeletal discomfort significantly lower at the beginning of the school year than at the middle or end of the school year (LSD, $p < 0.05$).

6.3.5.1.1 Relationship to Classroom Workstation Dimensions

The mismatch between student and workstation dimensions was expected to play a significant role in the development of musculoskeletal discomfort. Table 6-19 summarizes the differences between student body dimensions and classroom workstation dimensions.[20] The reader should note that the student's elbow and eye

[20] Student workstations dimensions were fixed as follows: seat height, 18.5 inches; keyboard height, 25.5 inches, and monitor height 43.25.

height were measured while the students were sitting in the classroom workstation chair and *not* in a chair suited to their sitting height.

Table 6-19. Degree of disparity between student body dimensions and PCF classroom workstation dimensions. All values are given in inches.

	Mean	*std*	*Minimum*	*Maximum*
Chair Height - Student Sitting Height				
• Males	2.01	0.55	1.00	2.82
• Females	1.44	1.11	-0.70	2.75
Keyboard Height - Student Elbow Height				
• Males	-0.666	0.82	-2.13	1.00
• Females	-0.608	1.19	-2.25	2.50
Monitor Height - Student Eye Height				
• Males	-0.589	1.72	-3.55	2.56
• Females	-1.025	1.71	-4.12	1.75

Spearman's rank correlations were used to explore the relationship between changes in student musculoskeletal discomfort, student home computer use variables, and differences between student-workstation dimensions. A significant linear relationship was found between the change in student's survey score over the course of a semester and the following variables: the difference between student elbow height and keyboard height ($r_s = -0.953$, $p < 0.001$), the mismatch between student eye height and monitor height ($r_s = 0.958$, $p < 0.001$), and average amount of self-reported computer use during a semester ($r_s = 0.380$, $p < 0.05$). No other significant correlations were found for this variable.

6.4 Patterns and Predictors of Student Changes

This section presents the multi-dimensional analyses that were undertaken to better understand the relationships among system variables. This section is comprised of the following subsections

> Section 5.1.1, *Differences in Student Academic Efficiency,* compares academic performance of an individual student to other students using Data Envelopment Analysis (DEA).
>
> Section 5.1.2, *Patterns of Relationships Among Experimental Measures,* explores the "fit" of the conceptual constructs underlying the PCF intervention through cluster and canonical analyses.

Of particular interest for these analyses was the effect of PCF intervention elements on students. As objective measures of computer use were available only for the PCF students and further, at least among PCF students, were not well correlated with subjective measures, these analyses, with the exception of the DEA analysis, are limited to PCF students.

6.4.1 Differences in Student Academic Efficiency

To gauge overall academic changes made by individual students during fifth grade, an overall measure of academic efficiency was formulated from student standardized test results through DEA. DEA is an optimization technique for assessing the relative technical efficiencies of different work units, in this case students; it was originally developed by Charnes, Cooper, and Rhodes (1978). DEA was chosen to formulate the overall measure of academic efficiency as it

1. assimilates multiple measures into a single aggregate measure for each student,
2. focuses on individual changes instead of average improvements, and
3. is robust for non-normal data

(Charnes, Cooper, Lewin, and Seiford, 1994). As a general rule of thumb, the product of the number of inputs and the number of outputs is approximately equal to the number units classified as 100 percent efficient (Boussofiane, Dyson, and Thanassoulis, 1991). Thus to ensure effective discrimination between individual work units, the number of inputs and outputs should be minimized (Smith, 1997). In practice, when two inputs (or two outputs) exhibit a high positive correlation and the ratio of the number of measures to units is low, then one of the variables is considered for elimination from the analysis (Smith, 1997).

The objective of the DEA analysis discussed here was to determine what level of achievement individual students would be expected to exhibit at the end of fifth grade given their previous record of achievement, so a CCR ratio model with output orientation was used to create an efficiency score for each student. As student output achievement levels are expected to directly reflect their input levels, a constant return to scale was assumed resulting in individual students being compared to all other students when determining their relative efficiency.

Input achievement levels were given by the Stanford 9 test, which was taken by the students during third grade, while output achievement was assessed by the SOL test, which were taken at the end of fifth grade. In order to minimize the number of inputs and outputs, the total scores from both tests were used for this analysis. Table 6-20 provides summary information for these variables. Any student for which these scores were not available was excluded from the reported analyses. Full data were available for 43 of the 47 students participating in the field experiment.

Table 6-20. Summary of input and output measures included in the DEA model.

	Mean	*Std*
Inputs		
• Third Grade Stanford 9 Raw Score (RS) Total	135.30	25.49
• Days of Instruction in Fifth Grade	211.49	4.88
Outputs		
• Fifth Grade SOL Total SS[21]	2701.00	272.56

DEA analysis found two academically efficient and 41 inefficient students. Efficiency scores ranged from 79.13% to 100%. The average efficiency score for an individual student was 89.87 with a standard deviation of 5.36. Figure 6-36 shows the distribution of efficiency scores for individual students relative to their initial Stanford 9 raw score, while Table 6-21 provides summary descriptive information.

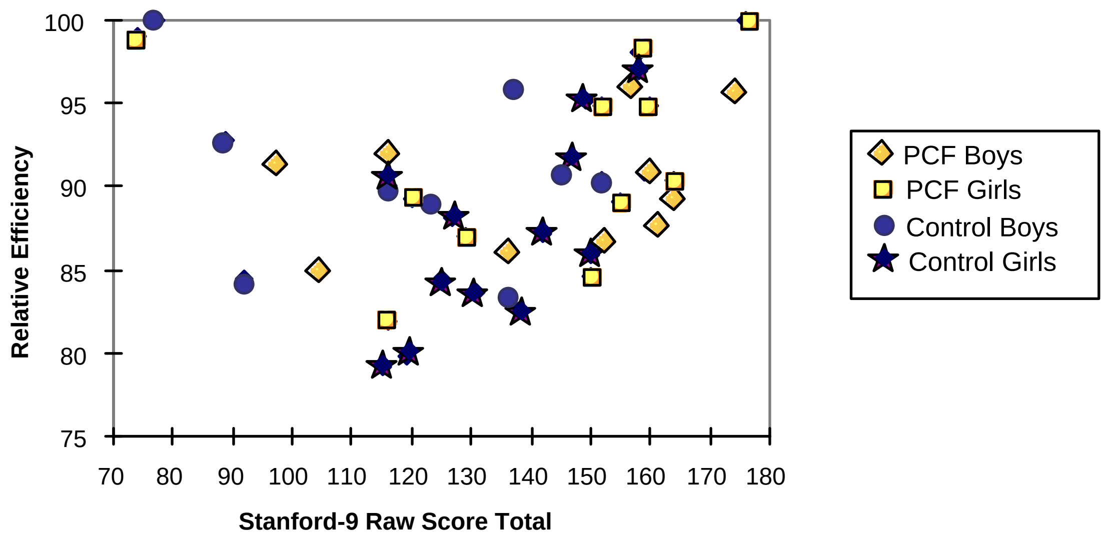

Figure 6-36. . Impact of student entry achievement on student DEA efficiency score.

Table 6-21. Summary descriptive information for DEA efficiency scores.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
Males	90.20	3.65	90.74	5.16
Females	91.74	6.02	87.12	5.78

6.4.1.1 Factors Associated With Academic Efficiency

In order to determine if project participation had an impact on academic efficacy, a GLM was used to perform an ANOVA on the DEA efficiency scores. This analysis found no significant main effects or interaction ($p > 0.05$).

[21] This composite score was formulated by summing the individual section scores from the SOL test.

Next, in order to determine the conditions associated with higher DEA efficiency ratings among PCF students, a multiple regression analysis was undertaken. The influence variables for this analysis can be divided into the following groups:

- *Computer Availability and Use*. The following variables were used to explore the effects of computer use on efficiency scores: (1) the number of home computers, (2) the number of home Internet connections, (3) self-reports of home computer use, (4) average number of web pages loaded by the family each week, (5) average number of email messages sent by students each week, (6) average number of email messages sent to students each week, and (7) average number of chat lines entered by students each week.

- *Academic Influences*. The following factors were used to examine the effect of school variables on efficiency scores: (1) student GPAs, (2) third grade Stanford 9 scores, (3) self-reports of time spent on homework, (4) student school attendance, and (5) the percentage of homework assignments delivered on-time during fifth grade.

- *Student Attitudes and Beliefs.* The following measures were used to explore the impact of student attitudes and beliefs on efficiency scores: (1) SAM scores at the beginning of fifth grade, and (2) computer attitude survey scores at the beginning of fifth grade.

- *Student Individual Differences.* (1) student Murphy-Meisgeier personality type indicator (MMPI) scores, (2) student learning style scores, and (3) student gender (1=male, 2=female).

- *Family Influences.* The following factors were used to explore the effect of different family variables on efficiency scores: (1) the highest level of education achieved by a parent or guardian, and (2) self-reports of parental homework help.

Best subsets of predictors were developed using the maximum R^2 criterion, where R^2 is the proportion of variance accounted for by the predictors. Best subsets of predictors were developed using the maximum R^2 criterion, where R^2 is the proportion of variance accounted for by the predictors. Regression tables for these analyses can be found in the appendix titled *Descriptive Information and Detailed Analysis Results*

The best resulting subset of predictor variables for efficiency scores was comprised of (1) the student's SAM *Academic Self-Concept -- Reference-based* scale NP (OTHER), (2) the student's SAM *Instructional Mastery* scale NP (INSTRUCT), (3) the student's fourth grade GPA (GPA), (4) the average number of minutes students reported using a computer after-school each day (CUSE), (5) the average number of email sent to students each week (SENTTO), (6) the number of family members (NFAMILY), and (7) the number of days the student was tardy in 4th grade (TARDY4). The variables in this model accounted for

80.89 percent of the variance in the efficiency scores of the PCF students. Summary information for this model can be found in Table 6-22.

Table 6-22. Test of significance of empirical model parameters for academic efficacy scores of the PCF students.

Variable	*b*	*Standard Error Estimate*	*F for H_0: b=0*	*p*	R^2
OTHER	0.219	0.034	42.25	0.001	0.244
SENTTO	-1.890	0.493	14.68	0.002	0.137
CUSE	0.081	0.025	10.92	0.006	0.101
TARDY4	-1.237	0.258	23.02	0.001	0.100
NFAMILY	3.318	0.701	22.41	0.001	0.082
GPA4	-3.471	0.997	12.11	0.004	0.073
INSTRUCT	-0.106	0.028	14.52	0.002	0.071

6.4.2 Patterns of Relationships Among Experimental Measures

The “fit” of the conceptual constructs underlying student achievement were explored using cluster, canonical, and regression analysis techniques. Often structural equation modeling[22] is used to quantify the fit of conceptual models; however, due to sample size constraints, it was not a viable approach for the field evaluation data. The primary goals of the analyses presented in this section were

1. To determine if the hypothesized relationships between model constructs were consistent with those found in the experimental data set.
2. To investigate similarities among experimental outcome measures.
3. To find groups of factors that best explained differences in student outcomes.

As objective measures of computer use were not available for the control class, only data from PCF students and families were used for these analyses. Thus conceptual constructs related to technology availability and classroom pedagogy could be excluded from these analyses. Additionally, as the factors impacting student technology use had been explored using time series techniques in a previous section, they were not included in the analyses presented here. Figure 6-37 maps the remaining conceptual constructs to specific experimental measures.

A more detailed description of the measure set can be found in the appendix titled *Descriptive Information and Detailed Analysis Results.* With the exception of technology measures, all measures were formulated to assess the magnitude and direction of changes occurring over the course of fifth grade. The ratio of the SOL SS to the Stanford-9 SS was used as a measure of change in standardized test performance for each subject area. Complete data were available for 21 of the 24 PCF students. The reader should note that in order to maximize sample size,

[22] A multivariate technique that can be used to test models that specify casual relationships between model variables.

minor experimental measures for which complete data were not available were excluded from the analyses.

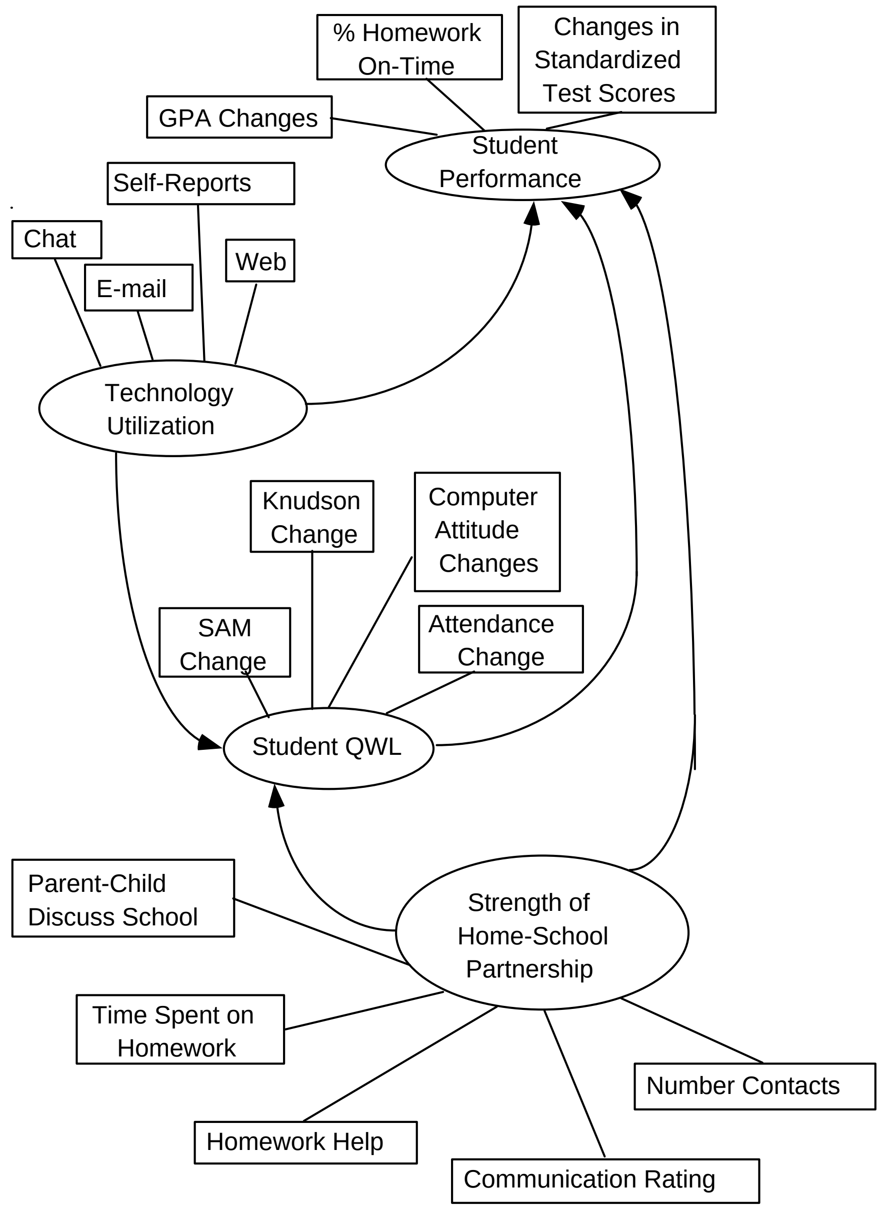

Figure 6-37. Relationship diagram for dependent measures and simplified conceptual model elements.

6.4.2.1 Relationships Between Model Constructs

In order to determine if the hypothesized relationships between model constructs were consistent with those found in the experimental data set, a sequence of canonical correlation analyses were undertaken. Canonical correlation is a technique for exploring the relationship between two sets of variables. The technique is invariant to differences in scale among the measures under consideration (Rechner, 1995). Further details of significant canonical analyses can be found in the appendix titled *Descriptive Information and Detailed Analysis Results.*

The following notation is used in this section: r_c is the canonical correlation between two sets of variables, and F* is the approximate F value for the hypothesis that all canonical correlations are zero.

6.4.2.1.1 Relationship Between Technology Usage and QWL Measures

Multivariate canonical analysis found significant evidence of a relationship between the technology and QWL measures ($r_c = 0.824$, $F^*[25,53] = 1.73$, $p < 0.05$). Only the first pair of canonical variables was significant. Neither of the first pair of variables was a good overall predictor of the other set. Technology measures explain 0.136 of variance in QWL, while QWL variables explain 0.204 of the variance in technology usage.

The significant canonical variable for the technology measures was a weighted sum of WWW weekly usage (0.884), self-reports of daily after-school Internet usage (0.490), self-reports of daily after-school computer use (-0.218), chat usage (-0.205) and emails sent (0.070). As the coefficients for the chat usage and daily computer use have different signs than their correlations with the canonical variable, they are suppresor variables. The squared multiple correlations indicate the canonical variable has fair predictive power for tardy change (0.562) and absent change (0.106) but almost none for the remaining QWL measures.

The significant canonical variable for the QWL measures was a weighted sum of tardy change (0.880), absent change (0.433), Feel About Computers RS change (-0.272), Knudson survey gain (-0.101), and SAM change (0.082). The squared multiple correlations indicate the canonical variable has fair predictive power for web usage (0.606), self-reports of Internet use (0.231), and self-reports of computer use (0.179) but almost none for the remaining technology usage measures.

Additionally, univariate regressions done as part of the previous analysis did indicate a significant linear relationship between tardy change and self-reports of Internet use ($\beta = 0.609$, $t = 2.40$, $p < 0.05$), tardy change and WWW use ($\beta = 0.674$, $t = 4.04$, $p < 0.001$), and SAM change and self-reports of daily computer use ($\beta = 0.666$, $t = 2.11$, $p < 0.05$).

6.4.2.1.2 Relationship Between Technology Usage and Achievement Measures

The multivariate canonical analysis found significant evidence of a relationship between the technology and achievement measures ($r_c = 0.973$, $F^*[40,42] = 1.99$, $p < 0.05$). Only the first pair of canonical variables is significant. Neither of the first pair of variables is a good overall predictor of the other set. Technology variables explain 0.126 of variance in achievement measures, while achievement variables explain 0.175 of the variance in technology usage.

The significant canonical variable for the technology measures was a weighted sum of WWW weekly usage (-1.094), self-reports of daily after-school computer use (0.285), chat usage (0.081), self-reports of daily after-school Internet usage (0.066), and emails sent (0.054). As the coefficients for the self-report variables have a different sign than their correlations with the canonical variable, they are suppresor variables. The squared multiple correlations indicate the canonical variable has good predictive power for GPA gain (0.354) and the percentage of homework delivered on-time (0.481) but almost none for the remaining achievement measures.

The significant canonical variable for the achievement measures was a weighted sum of the percentage of homework delivered on-time (0.717), GPA gain (-0.514), reading standardized test ratio (-0.472), science standardized test ratio (0.386), SOL technology SS (0.285), math standardized test ratio (-0.266), writing standardized test ratio (0.239), and social studies standardized test ratio (0.104). As the coefficients for the reading and mathematics standardized test measures have a different sign than their correlations with the canonical variable, they serve as suppresor variables. The squared multiple correlations indicate the canonical variable has good predictive power for web usage (0.848) but almost none for the remaining technology measures.

Additionally, univariate regressions done as part of the previous analysis did indicate a significant linear relationship between Writing standardized test ratio and self-reports of Internet use ($\beta = 0.775$, t = 2.24, $p < 0.05$), Science standardized test ratio and the number of email sent ($\beta = 0.557$, t = 2.66, $p < 0.05$), GPA change and WWW weekly use ($\beta = 0.680$, t=3.28, $p < 0.01$), and percentage of homework assignments delivered on-time and WWW weekly use ($\beta = -0.733$, t=-4.04, $p < 0.001$).

6.4.2.1.3 Relationship Between Home-School Partnership and QWL Measures

The multivariate canonical analysis found no evidence that the highest possible correlation between any linear combination of the home-school partnership measures and any linear combination of QWL measures was significant.

6.4.2.1.4 Relationship Between Home-school Partnership and Achievement Measures

The multivariate canonical analysis found no evidence that the highest possible correlation between any linear combination of the home-school partnership measures and any linear combination of achievement measures was significant.

6.4.2.1.5 Relationship between QWL and Achievement Measures

The multivariate canonical analysis found significant evidence of a relationship between QWL and achievement measures ($r_c = 0.956$, $F^*[40,42] = 2.00$, $p < 0.05$). Only the first pair of canonical variables was significant. The first pair of variables is a poor overall predictor of the other set. QWL variables explain 0.034 of variance in achievement measures, while achievement variables explain 0.109 of the variance in QWL usage.

The significant canonical variable for the QWL measures was a weighted sum of tardy change (0.588), absent change (0.673), SAM change (-0.373), Feel About Computers change (-0.216), and the Knudson Writing change (-0.520). As the coefficient for the Feel About Computers change measure has a different sign than its correlation with the canonical variable, it serves as a suppresor variable. The squared multiple correlations indicate the canonical variable has good predictive power for GPA gain (0.272) and the percentage of homework delivered on-time (0.661) but almost none for the remaining achievement measures.

The significant canonical variable for the achievement measures was a weighted sum of the percentage of homework delivered on-time (0.718), GPA gain (-0.514), reading standardized test ratio (-0.472), science standardized test ratio (0.386), SOL technology SS (0.285), math standardized test ratio (-0.266), writing standardized test ratio (0.239), and social studies standardized test ratio (0.104). As the coefficients for the reading and mathematics standardized test measures have a different sign than their correlations with the canonical variable, they serve as suppresor variables. The squared multiple correlations indicate the canonical variable has good predictive power for tardy change (0.535) and absent change (0.192) but almost none for the remaining QWL variables.

Univariate regressions done as part of the previous analysis did indicate a significant linear relationship between the absence change and GPA change ($\beta = 0.807$, $t = 3.70$, $p < 0.01$), Reading standardized test ratio and Knudson Writing RS change ($\beta = 0.719$, $t = 2.46$, $p < 0.05$), Writing standardized test ratio and the SAM change ($\beta = -0.471$, $t=-2.27$, $p < 0.05$), and percentage homework on-time and tardy change ($\beta = -0.833$, $t=-6.86$, $p < 0.001$).

6.4.2.2 Similarities Among Outcome Measures

Next, a cluster analysis was undertaken to determine which outcome measures assess the same underlying attribute or behave in a similar manner. By convention, such an analysis is known as a R-analysis. R-analysis groups measures into clusters suggested by the data and is not constrained by a priori assumptions of the researcher. The resulting clusters provide insights into whether the measures behave in the manner predicted by the research model. In general, one would expect that measures assessing the same attribute should behave in a similar manner and thus should be members of the same cluster. For example in the case of this research, one would assume that if one QWL measure improves for a student, all QWL measures for that student should similarly improve. Similarly, measures assessing different, but positively related, attributes may appear in the same cluster. For instance, technology use measures are expected to be positively related to QWL measures, and thus might appear in the same cluster.

As the goal of the cluster analysis was to explore associations between outcome measures, Pearson's product-moment correlation coefficient was chosen as the resemblence coefficient for the analyses. A value of 1.0 indicates maximum similarity, while a value of -1.0 indicates maximum dissimilarity. Commonly used for R-analyses, the coefficient has the advantage of being insensitive to differences in the range of individual variables while remaining sensitive to differences in shape (Romesburg, 1990). The unweighted pair-group method using arithmetic averages (UPGMA) clustering method was selected for the analysis. The UPGMA method specifies the similarity between any two clusters to be the average of the similarities between items in one cluster with the items in the other (Romesburg, 1990). This method has the advantage of producing less distortion when transforming the similarities between items into trees (Farris, 1969). It is also sometimes called the group average method or the average linkage method (Romesburg, 1990).

The starting point for this R-analysis was the measures shown in Figure 6-37. Non-normal data were converted to ranks prior to the analysis. The resemblence matrix for this data is given in the appendix titled *Descriptive Information and Detailed Analysis Results.* The clusters resulting from the R-analysis are illustrated by the dendrogram in Figure 6-38. Individual clusters were determined by examining the values of the amalgamation coefficients to discover a "jump" in the value of the coefficient. This "jump" indicates dissimilar clusters have been merged, so the "ideal" number of clusters equals the number of clusters prior to the merger (Aldenderfer and Blashfield, 1984). In this case, the jump occurred between the fourth and fifth clusters. The resulting grouping of variables is shown in Figure 6-38.

The cluster solution provides limited support for the experimental model. Student performance measures were most closely aligned with the conceptual model. All but two student performance measures (GPA change and the Writing standardized test ratio) were members of the same cluster. The results for the other constructs were less clear, with measures from an individual construct distributed across multiple groups. This distribution suggests that these constructs should be decomposed into smaller, more homogenous, groups.

Like the canonical analyses from the previous section, cluster analysis suggests that some technology utilization and student outcome measures are positively related, with measures from both categories appearing together in three clusters. All but one standardized test measure was positively linked to computer use self-report measures and changes in SAM, while the remaining measure for writing was positively related to objective measures of network communication application use. Improvements in student attitudes towards computers were positively related to the time students spent on homework and the time parents spent helping students with homework.

Canonical correlation analyses were used to validate this cluster solution. Given the cluster distance measure, the cluster solution would be considered valid if the canonical analyses indicated (a) the canonical correlations were not significantly different from zero or (b) a negative relationship between groups when the canonical correlation was significantly different from zero. Only the canonical correlation for groups 1 and 3 were significant ($p < 0.05$), with the measures from group 1 which accounted for the majority of group variance negatively correlated with the only significant canonical variable from group 3. Thus, the cluster solution was considered valid. Table 6-23 provides summary information for these analyses. Further analysis details for the significant canonical correlation can be found in the appendix titled *Descriptive Information and Detailed Analysis Results.*

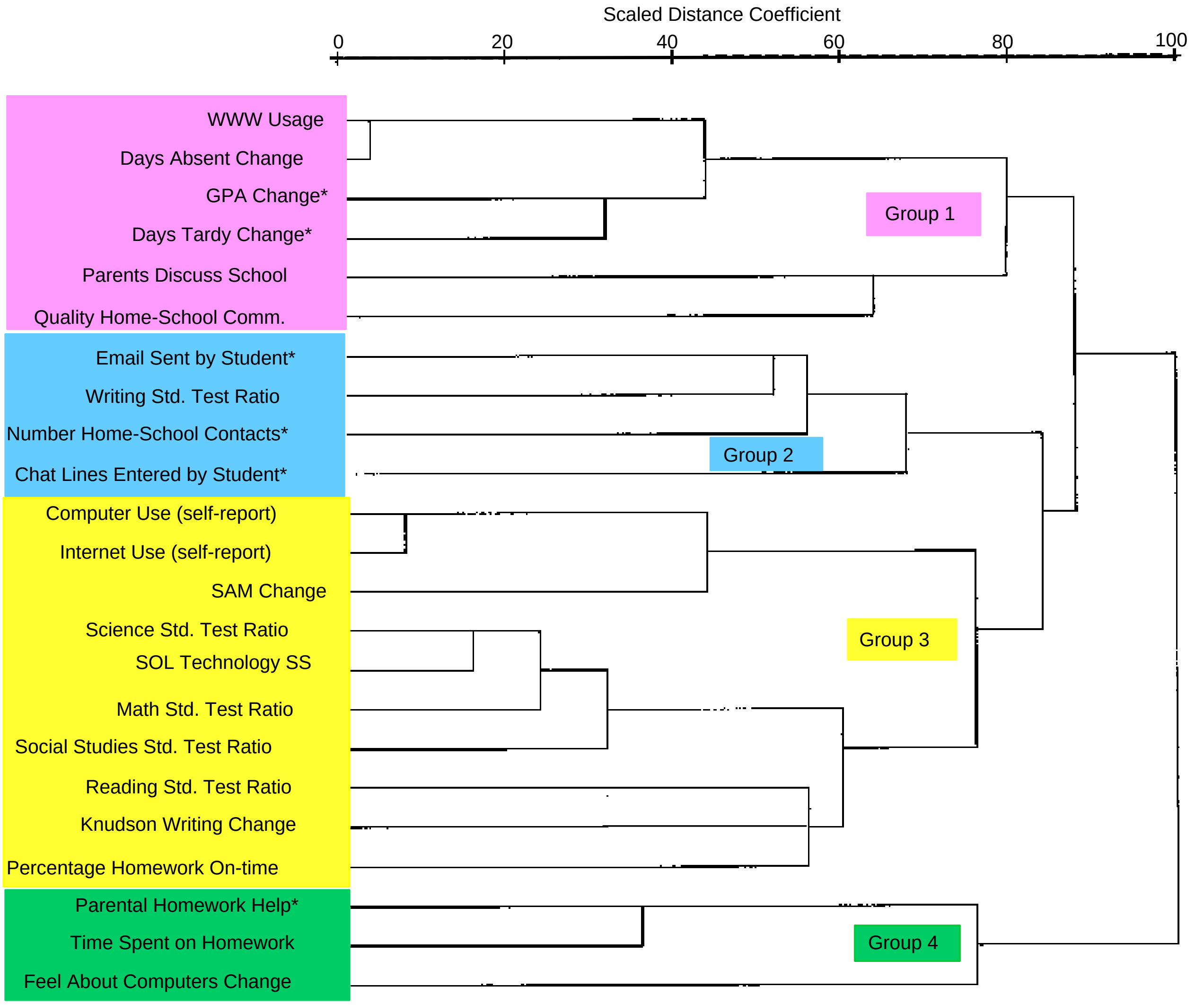

Figure 6-38. Average linkage dendogram, R-analysis of variables from the simplified conceptual model. * indicates measures that were converted to ranks for analysis.

Table 6-23. Summary information for canonical correlation analyses of solution clusters. F* is the approximate F value for the hypothesis that all canonical correlations are zero.

	Group 1	Group 2	Group 3
Group 2	$r_c = 0.691$ F*[24,50.05] = 0.86 $p < 0.646$		
Group 3	$r_c = 0.975$ F*[45,34.42] = 1.75 $p < 0.036$*	$r_c = 0.872$ F*[40, 32.19] = 0.93 $p < 0.593$	
Group 4	$r_c = 0.843$ F*[18,40.08] = 1.86 $p < 0.064$	$r_c = 0.647$ F*[12,42.62] = 1.43 $p < 0.190$	$r_c = 0.815$ F*[24,29.60] = 1.20 $p < 0.314$

* significant at $p < 0.05$

6.4.2.3 Factors Influencing Student Outcomes

Next, a series of regression analyses were undertaken to explain differences in student outcomes. Best subsets of predictors were developed using the maximum R^2 criterion, where R^2 is the proportion of variance accounted for by the predictors. The superset of possible variables included conceptual model measures along with student and family entry characteristics. Regression tables for these analyses can be found in the appendix titled *Descriptive Information and Detailed Analysis Results.*

6.4.2.3.1 Influences on Student Achievement

6.4.2.3.1.1 Classroom Performance

6.4.2.3.1.1.1 Factors Influencing Student GPA

RGLM regression was used to identify the student and family characteristics that most influenced differences in a student's GPA change (*i.e.*, a student's fifth grade GPA minus 4^{th} grade GPA). As shown in Table 6-24, the best resulting subset of predictor variables for the change in a student's GPA was comprised the number days the student missed school in fifth grade minus the number missed in 4^{th} grade (ABGAIN), the number of days the student was tardy in 4^{th} grade (TARDY), the student's MMPI judging-perceiving score (JP), the student's SAM NP at the start of fifth grade (SAM), the average number of web pages loaded by the student each week (WEB), the average number of chat lines entered by the student each week (CHAT), and the average amount of time each day parents report discussing school with the student (DISCUSS). The corresponding first order model is shown in Equation 6-7:

$$\text{GPAGAIN} = -24.417 - 0.870\ \text{ABGAIN} - 1.456\ \text{TARDY} + 0.252\ \text{JP} + 0.291\ \text{SAM} + 0.005\ \text{WEB} - 0.064\ \text{CHAT} - 0.013\ \text{DISCUSS} \qquad (6\text{-}7)$$

where GPAGAIN is the rank value for the change in the student's GPA. The variables in this model accounted for 94.23 percent of the variance in GPA gain. Summary information for this model can be found in Table 6-24. Computer use variables accounted for 28.13 percent of the total variance, while motivation values accounted for 57.09 percent.

Table 6-24. Test of significance of model parameters for GPA gain.

Variable	*b*	*Standard Error*	*F for H_0: b=0*	*p*	*R^2*
ABGAIN	-0.087	0.232	14.07	0.002	0.045
TARDY	-1.456	0.278	27.29	0.001	0.143
JP	0.252	0.053	23.03	0.001	0.054
SAM	0.291	0.027	116.75	0.001	0.382
WEB	0.005	0.001	48.63	0.001	0.200
CHAT	-0.064	0.024	7.05	0.020	0.082
DISCUSS	-0.013	0.005	8.18	0.013	0.036

6.4.2.3.1.1.2 Factors Influencing On-time Completion of Homework Assignments

Multiple regression was used to identify the student and family characteristics that most influenced differences in the average percentage of homework assignments completed on-time each week. As shown in Table 6-25, the best resulting subset of predictor variables for the percentage of homework assignments completed on-time was comprised of the number of days a student was tardy in 4^{th} grade (TARDY), the number of days the student was tardy in fifth grade minus the number in 4^{th} grade (TARDYGAIN), the student's 3^{rd} grade Stanford 9 language SS (LANG), the average amount of time each day parents report discussing school with the student (DISCUSS), the student's 3^{rd} grade Stanford 9 science SS (SCI), the average number of email messages sent by the student each week (EMAIL), the student's 4^{th} grade GPA (GPA), the student's MMPI sensing-intuitive score (SN), and the student's MMPI extrovert-introvert score (EI). The corresponding first order model is shown in Equation 6-8:

$$\begin{aligned} \text{ONTIME} = {} & 110.470 - 1.651\ \text{TARDY} - 0.325\ \text{EI} + 0.138\ \text{SN} + 4.485\ \text{GPA} + \\ & 0.941\ \text{EMAIL} + 0.020\ \text{DISCUSS} + 0.153\ \text{LANG} - 0.199\ \text{SCI} \\ & - 1.675\ \text{TARDYGAIN} + 0.124\ \text{SAMCHANGE} \end{aligned} \tag{6-8}$$

where ONTIME is the average percentage of homework assignments completed on-time each week. The variables in this model accounted for 99.00 percent of the variance for this measure. Summary information for this model can be found in Table 6-24. Computer use measures accounted for 4.73 percent of the total variance, while motivation changes accounted for 27.38 percent. Student entry characteristics accounted for 47.06 percent.

Table 6-25. Test of significance of model parameters for average weekly percentage of homework on-time.

Variable	*b*	*Standard Error*	*F for H_0: b=0*	*p*	*R^2*
SAM	0.124	0.014	75.88	0.001	0.047
TARDY	-1.651	0.186	78.81	0.001	0.212
TARDYGAIN	-1.676	0.131	162.72	0.001	0.227
EI	-0.325	0.055	35.07	0.001	0.035
SN	0.138	0.037	14.12	0.004	0.014
GPA	4.485	0.584	58.82	0.001	0.038
EMAIL	0.941	0.107	77.36	0.001	0.047
DISCUSS	0.020	0.003	47.14	0.001	0.150
LANG	0.153	0.011	167.55	0.001	0.116
SCI	-0.200	0.017	140.32	0.001	0.104

6.4.2.3.1.2 Standardized Test Performance

6.4.2.3.1.2.1 Factors Influencing Reading Performance

Multiple regression was used to identify the student and family characteristics that most influenced differences in reading standardized test performance. As shown in Table 6-26, the best resulting subset of predictor variables for the SOL reading SS was comprised of the student Knudson writing score at the start of fifth grade (KNUD), the student's 3rd grade Stanford 9 mathematics SS (MATH), and the student's 3rd grade Stanford 9 language SS (LANG). The corresponding first order model is shown in Equation 6-9:

$$SOLREAD = -388.737 - 2.231\ KNUD + 0.712\ MATH + 0.778\ LANG \qquad (6\text{-}9)$$

where SOLREAD is the SOL Reading SS. The variables in this model accounted for 84.51 percent of the variance in this measure. Summary information for this model can be found in Table 6-26.

Table 6-26. Test of significance of model parameters for SOL Reading SS.

Variable	*b*	*Standard Error*	*F for H_0: b=0*	*p*	*R^2*
KNUD	-2.313	0.744	8.99	0.001	0.058
LANG	0.237	0.139	26.22	0.001	0.632
MATH	0.637	0.146	28.33	0.001	0.157

6.4.2.3.1.2.2 Factors Influencing Writing Performance

Multiple regression was used to identify the student and family characteristics that most influenced differences in writing standardized test performance. As shown in Table 6-27, the best resulting subset of predictor variables for the SOL Writing SS was comprised of the student's MMPI sensing-intuitive score (SN), the average number of minutes students reported working on homework each day (HWORK), the average number of email messages sent each week by student (SENT), and the student's 3rd grade Stanford 9 mathematics SS (MATH). The corresponding first order model is shown in Equation 6-10:

SOLWRITE = -500.732 + 3.839 SN + 1.367 HWORK + 8.150 SENT + 0.976 MATH (6-10)

where SOLWRITE is the SOL Writing SS. The variables in this model accounted for 70.22 percent of the variance in the scores.

Table 6-27. Test of significance of model parameters for SOL Writing scores.

Variable	*b*	*Standard Error*	*F for H_0: b=0*	*p*	R^2
SN	3.839	1.415	7.37	0.0153	0.085
HWORK	1.367	0.423	10.46	0.005	0.110
SENT	8.150	3.554	5.26	0.036	0.098
MATH	0.976	0.264	13.63	0.002	0.410

6.4.2.3.1.2.3 Factors Influencing Social Studies Performance

Multiple regression was used to identify the student and family characteristics that most influenced differences in social studies standardized test performance. As shown in Table 6-28, the best resulting subset of predictor variables for the SOL social studies SS was comprised of the student's 3rd grade Stanford 9 language SS (LANG), the students 4th grade GPA (GPA), the student's Feel About Computers survey score at the start of fifth grade (FCOMP), and the average amount of time each day parents report helping students with homework (HELP). The corresponding first order model is shown in Equation 6-11:

SOLSS = 55.152 + 31.710 GPA + 1.660 FCOMP - 0.804 HELP + 0.275 LANG (6-11)

Equation 6-1. First order model of SOL Social Studies SS among PCF students.

where SOLSS is the SOL Social Studies SS. The variables in this model accounted for 83.09 percent of the variance in this measure. Student entry characteristics accounted for 76.09 percent of the variance for this measure.

Table 6-28. Test of significance of empirical model parameters for SOL Social Studies SS.

Variable	*b*	*Standard Error*	*F for H_0: b=0*	*p*	R^2
GPA	31.710	7.130	19.79	0.001	0.552
FCOMP	1.660	0.518	10.28	0.006	0.132
HELP	-0.804	0.296	7.35	0.015	0.070
LANG	0.275	0.132	4.39	0.053	0.076

6.4.2.3.1.2.4 Factors Influencing Science Performance

Multiple regression was used to identify the student and family characteristics that most influenced differences in science standardized test performance. As shown in Table 6-29, the best resulting subset of predictor variables for the SOL science SS was comprised of the student's 3rd grade Stanford 9 science SS (SCI) and the average number of minutes students reported working on homework each day (HWORK). The corresponding first order model is shown in Equation 6-12:

SOLSCI = -474.244 - 0.545 HWORK + 1.500 SCI (6-12) where SOLSCI is the SOL Science SS. The variables in this model accounted for 84.48 percent of the variance in this measure.

Table 6-29. Test of significance of model parameters for SOL Science SS.

Variable	*b*	*Standard Error*	*F for H_0: b=0*	*p*	*R^2*
HWORK	-0.545	0.197	7.67	0.013	0.066
SCI	1.501	0.154	66.83	0.001	0.779

6.4.2.3.1.2.5 Factors Influencing Mathematics Performance

Multiple regression was used to identify the student and family characteristics that most influenced differences in mathematics standardized test performance. As shown in Table 6-30, the best resulting subset of predictor variables for the SOL Mathematics SS was comprised of the number of days the student was absent in 4^{th} grade (ABSENT), the average number of minutes each day the student report using the home computer (CUSE), the student's 3^{rd} grade Stanford 9 mathematics SS (MATH), and the student's 3^{rd} grade Stanford 9 science SS (SCI). The corresponding first order model is shown in Equation 6-13:

$$\begin{aligned} SOLMATH = &-602.210 - 7.51\ ABSENT + .644\ CUSE + \\ &0.932\ MATH + 0.690\ SCI \end{aligned} \qquad (6\text{-}13)$$

where SOLMATH is the SOL Mathematics SS. The variables in this model accounted for 86.99 percent of the variance in this measure. Student entry characteristics accounted for 82.99 percent of the variance in this measure, while computer use accounted for only 4 percent.

Table 6-30. Test of significance of empirical model parameters for SOL Mathematics SS.

Variable	*b*	*Standard Error*	*F for H_0: b=0*	*p*	*R^2*
ABSENT	-7.51	1.799	17.41	0.001	0.106
CUSE	0.644	0.292	4.86	0.043	0.040
MATH	0.933	0.208	20.07	0.001	0.090
SCI	0.689	0.250	7.60	0.014	0.634

6.4.2.3.1.2.6 Factors Influencing Technology Performance

Multiple regression was used to identify the student and family characteristics that most influenced differences in technology standardized test performance. As shown in Table 6-31, the best resulting subset of predictor variables for the SOL Technology SS was comprised of the number of days a student was tardy in 4^{th} grade (TARDY), the student's 3^{rd} grade Stanford 9 language SS (LANG), the average amount of time each day parents report helping students with homework (HELP), the student's MMPI judging-perceiving score (JP), the student's SAM NP at the start of fifth grade (SAM), and the average parental rating of home-school communication (COMM). The corresponding first order model is shown in Equation 6-14:

$$\begin{aligned} SOLTECH = &-41.10 - 8.05\ TARDY + 1.644\ JP + 1.10\ SAM \\ &- 1.22\ HELP - 15.08\ COMM + 0.712\ LANG \end{aligned} \qquad (6\text{-}14)$$

where SOLTECH is the SOL Technology SS. The variables in this model accounted for 87.08 percent of the variance in the scores. Student entry characteristics accounted for 61.98 percent of the variance in the scores.

Table 6-31. Test of significance of model parameters for SOL Technology scores.

Variable	*b*	*Standard Error*	*F for H_0: b=0*	*p*	*R^2*
LANG	0.712	0.179	15.86	0.001	0.445
TARDY	-8.053	3.401	5.61	0.033	0.107
COMM	-15.077	5.095	8.76	0.010	0.095
HELP	-1.219	0.416	8.59	0.011	0.083
SAM	1.098	0.319	11.88	0.004	0.068
JP	1.645	0.586	7.87	0.014	0.073

6.4.2.3.2 Influences on Student QWL

6.4.2.3.2.1 Factors Influencing School Attendance

Multiple regression was used to identify the student and family characteristics that most influenced differences in a student's absence gain (*i.e.*, number fifth grade absences minus the number of 4th grade absences). As shown in Table 6-32, the best resulting subset of predictor variables for the absence change was comprised of the student's MMPI extrovert-introvert score (EI), the average number of web pages loaded by the student each week (WEB), the average number of chat lines entered by the student each week (CHAT), and the student's 3rd grade Stanford-9 SS (SCI). The corresponding first order model is shown in Equation 6-15:

$$\text{ABGAIN} = -13.850 - 0.231\ \text{EI} + 0.003\ \text{WEB} + 0.043\ \text{CHAT} + 0.035\ \text{SCI} \qquad (6\text{-}15)$$

where ABGAIN is the change in the number of days a student was absent. The variables in this model accounted for 80.01 percent of the variance in absence change. Computer use variables accounted for 59.75 percent of the total variance, while student entry characteristics accounted for 19.73 percent.

Table 6-32. Test of significance of model parameters for absence gain.

Variable	*b*	*Standard Error*	*F for H_0: b=0*	*p*	*R^2*
EI	-0.231	0.081	8.24	0.001	0.072
WEB	0.003	0.0003	52.83	0.001	0.548
CHAT	0.043	0.020	4.44	0.050	0.055
SCI	0.035	0.013	6.64	0.020	0.125

6.4.2.3.2.2 Factors Influencing SAM Score

Multiple regression was used to identify the student and family characteristics that most influenced differences in a student's SAM NP change (*i.e.*, a student's SAM NP at the start of fifth grade minus the one at the end of 5th grade). As shown in Table 6-33, the best resulting subset of predictor variables for the change in a student's SAM NP over the course of fifth grade was comprised the student's SAM NP at the start of fifth grade (SAM), the average number of minutes each day the student reports using the home computer (CUSE), the average amount of time each day parents report discussing school with the student (DISCUSS), the student's 3rd grade Stanford 9 reading score (READ), and the student's 3rd grade Stanford 9 language score (LANG). The corresponding first order model is shown in Equation 6-16:

$$SAMCHANGE = 1.126 - 0.564\ SAM + 0.361\ CUSE - 0.061\ DISCUSS - 0.360\ READ + 0.422\ LANG \quad (6\text{-}16)$$

where SAMCHANGE is the change in the student's SAM NP over the course of 5th grade. The variables in this model accounted for 73.26 percent of the variance in SAM NP change. Computer use variables accounted for 30.4 percent of the total variance, while student entry characteristics accounted for 29.8 percent.

Table 6-33. Test of significance of empirical model parameters for SAM NP change.

Variable	*b*	*Standard Error*	*F for H_0: b=0*	*p*	R^2
SAM	-0.564	0.177	10.12	0.006	0.141
CUSE	0.361	0.136	7.02	0.018	0.304
DISCUSS	-0.061	0.030	4.17	0.059	0.131
READ	0.360	0.140	6.60	0.021	0.124
LANG	0.422	0.145	8.42	0.011	0.033

6.4.2.3.2.3 Factors Influencing Knudson Score

Multiple regression was then used to identify the student and family characteristics that most influenced changes in a student's Knudson Writing Survey score (*i.e.*, a student's score at the start of fifth grade minus the one at the end of 5th grade). As shown in Table 6-34, the best resulting subset of predictor variables for the change in a student's Knudson Writing Survey score over the course of fifth grade was comprised the number of days a student was tardy in 4th grade (TARDY), the student's MMPI sensing-intuitive score (SN), the student's Feel About Computers survey score at the start of fifth grade (FCOMP), the student's 4th grade GPA (GPA), the average number of WWW pages the student accessed during a week (WEB), the average number of chat lines the student entered during a week (CHAT), the average amount of time each day parents report discussing school with the student (DISCUSS), the student's 3rd grade Stanford 9 reading score (READ), and the student's 3rd grade Stanford 9 social studies score (SS). The resulting first order model is shown in Equation 6-17.

$$KNUDCHANGE = -45.850 - 1.008\ TARDY + 0.399\ SN + 0.451\ FCOMP + 11.781\ GPA + 0.004\ WEB + 0.063\ CHAT + 0.024\ DISCUSS + 0.064\ READ - 0.167\ SS \quad (6\text{-}17)$$

where KNUDCHANGE is the change in the student's Knudson Writing Survey over the course of 5th grade. The variables in this model accounted for 89.10 percent of the variance in Knudson survey change. Computer use variables accounted for 10.7 percent of the total variance, while student entry characteristics accounted for 72.50 percent.

Table 6-34. Test of significance of model parameters for Knudson survey score change.

Variable	*b*	*Standard Error*	*F for H_0: b=0*	*p*	*R^2*
TARDY	-1.008	0.333	9.19	0.011	0.134
SN	0.399	0.078	26.39	0.001	0.164
FCOMP	0.451	0.086	27.63	0.001	0.120
GPA	11.781	1.799	42.86	0.001	0.130
WEB	0.004	0.001	39.66	0.001	0.086
CHAT	0.063	0.027	5.29	0.042	0.021
DISCUSS	0.024	0.006	18.25	0.001	0.059
READ	0.064	0.025	6.48	0.027	0.027
SS	-0.167	0.030	20.72	0.001	0.150

6.5 Brief Summary

Although most PCF participants were enthusiastic about the presence of computers in the classroom and the home, the benefits of the technology were not always clear-cut. With the exception of writing standardized test performance and some subjective motivation differences, few significant differences were found between the PCF and control groups on non-technology measures. No evidence was found that the intervention was the driver for sustained changes in family support or involvement in learning. However, despite limited utilization of the computer during classroom hours, these results demonstrate intriguing links between student home computer use and changes in student performance and motivation. Student computer use was associated with student entry characteristics and different personality type indicators. The results from this study will be discussed in further detail after examining the results from the "micro" participatory study of the PCF classroom workstation.

CHAPTER 7. "MICRO" EVALUATION OF THE PCF CLASSROOM WORKSTATION

Chapter Table of Contents

7.1 INTRODUCTION....138
7.2 BACKGROUND LITERATURE....138
7.2.1 Fitting Workstations to Users....139
7.2.2 Supporting Collaboration in the Classroom....140
7.2.3 Participatory Ergonomics and the Classroom....141
7.3 DESIGN OF THE ORIGINAL PCF CLASSROOM WORKSTATION....142
7.3.1 Workspace Design....143
7.3.2 Computer Controls....144
7.4 METHODOLOGY....145
7.4.1 Participants....145
7.4.2 Procedures....145
7.4.2.1 Participatory Evaluation Process....145
7.4.2.2 Participatory Sessions....146
7.5 RESULTS FROM THE PARTICIPATORY SESSIONS....147
7.5.1 What Students Want in a Workstation....148
7.5.1.1 Collaboration....148
7.5.1.2 Control....148
7.5.1.3 Comfort....151
7.5.2 What Parents Think Students Need in a Workstation....151
7.5.3 What Teachers Think Students Need in a Workstation....151

7.1 Introduction

Often sized for adults and reflecting the preferences of adult buyers, the workstations used by children in the classroom look much like the ones used by adults in offices. Further, very little research has addressed the special needs of children, forcing designers of child workstations to rely primarily on guidelines developed from studies with adult users. But children are not miniature adults and, unlike adults, typically work on computers in pairs or larger groups, especially in the classroom. Adapting the workstation to children means designers cannot just assume children are short adults. Children have very different skills, preferences, and goals. These differences are likely to have a profound effect on the design of child workstations.

Classroom computers and network connectivity present special challenges to workstation designers. Classrooms are already crowded with a medley of students and learning materials, leaving little or no room for workstations. Classroom workstations must also support a range of activities unheard of in the typical office environment. Learning activities require flexible workspaces that allow reading of books, writing and drawing on paper, cutting and pasting, and even finger painting. Using the computer is only one of many tasks that must be supported by the classroom workstation. The design task is made even more challenging by the dual-edged nature of computer technology. The same technology, which facilitates learning, can also distract if used at inappropriate times by students. Classroom workstation design demands flexible and robust construction, particularly when applied in an elementary school setting.

The research presented in this chapter investigated shared workstations in the PCF classroom using participatory methods. Participatory methods have been used successfully to involve users in computer hardware and software design (*e.g.*, Good, 1992). This study extends these methods to the design of the physical workspace. The student workstation was selected as the focus of these efforts based on mid-year results from the PCF field study that indicated students were experiencing an increase in musculoskeletal discomfort, classroom observations, and participant comments that indicated significant issues related to workstation usability. The intent of this work was to explore student perceptions of shared, classroom workstations and to identify differences in design preferences among classroom stakeholders, *e.g.*, students and teachers. Before discussing this work in greater detail, a brief overview of the literature related to shared, student workstations and the use of participatory methods will be presented.

7.2 Background Literature

Poorly designed computer workstations are generally accepted as having a negative effect on both the health and performance of users (Bergqvist, Wolgast, Nilsson, and Voss, 1995; Carter and Banister, 1994; Kroemer, 1997). Successful outcomes depend on a number of inter-related factors, including workstation configuration, user characteristics, and the nature of the supported tasks. The design of shared, student workstations presents special challenges to the workspace designer as 1) computers were designed to support individual users and not groups, and 2) the majority of studies available to designers pertain to individual adults working in office settings.

7.2.1 Fitting Workstations to Users

Each component of a computer workstation must "fit" with the other components of the system, including the user. User anthropometric dimensions play a special role in workstation design, with user body dimensions directly related to proper workstation dimensions. User dimensions most commonly used in determining the anthropometric "fit" of seated, computer workstations include

- eye height, the vertical distance from the surface to the outer corner of the eye (NASA, 1978), establishes the location of the primary visual targets, *e.g.* monitor, keyboard, source document.
- popiteal height, the vertical distance from the floor to the underside of the thigh immediately behind the knee (NASA, 1978), establishes the height of the seat.
- knee height, the vertical difference from the floor to the uppermost point on the knee (NASA, 1978), and thigh clearance, the vertical distance from the sitting surface to the highest point of the right thigh (NASA, 1978), relate to the needed height of the workstation leg room.

(Grandjean and Kroemer, 1997; Kroemer, 1997). The standards governing workstation design generally advocate adjustability in workstation components to promote the "fit" between users and workstations.

The standards and literature related to computer workstations almost exclusively focus on adult settings. However, research has demonstrated that a well-designed learning environment impacts teachers and students physiologically, emotionally, and psychologically, and it contributes to a higher degree of learning and information handling (Bowers and Burkett, 1989; Caldwell, 1993; Knirk, 1987; Linton, Hellsing, Halme, and Akerstedt, 1994). Similarly, improperly designed classrooms can impede learning by contributing to teacher and student fatigue, discomfort, and irritation, as well as posing distractions.

Although anecdotal evidence suggests students in technology rich classrooms are experiencing headaches, wrist pain, eye strain, and other conditions common to adult computer users (e.g., Oppenheimer, 1997), researchers have not, to date, extensively investigated child perceptions of workstations or the long-term, cumulative effect of frequent computer use on children. Preliminary work with children indicates adjusting the dimensions of the workstation to fit their anthropometric dimensions can significantly improve the seated posture of children performing keyboarding tasks resulting in increased computer task performance (Laeser, 1997). Multiple students sharing a single computer further complicate the issue of "fit" in classroom workstation design. Very differently-sized students sharing a workstation make workstation adjustment especially challenging (Linton *et al.*, 1994; McCreary *et al.*, 1998).

One trigger for student workstation problems is likely the rarity and cost of adjustable ergonomic furniture for children in schools. In adult users, the postures that result from mismatches between computer users and workstation elements are thought to a cause of health problems among users (Hagberg and Rempel, 1997). A variety of health complaints have been attributed to computer work including musculoskeletal pain, headaches, circulatory problems, and eye strain. Visual symptoms and musculoskeletal complaints comprise the majority of subjective and objective symptoms (Kroemer, 1997). Musculoskeletal problems are common among computer workers, with the frequency of complaints a function of work duration and frequency (Carter and Bannister, 1997; Jeyeratnam, Ong, Kee, Lee, and Koh, 1989). In a survey of 694 computer operators, Jeyeratnam *et al.* (1989) found that 60% had neck pain, 54% had back pain, and 43% had shoulder pain. In general, 25 to 30 percent of regular computer users are thought to experience musculoskeletal pain (Baber, 1997). Similar figures are not available for child computer users.

Even if appropriately sized, adjustable computer furniture was available in classroom settings, workstation "fit" might not improve for child users. Educational furnishings are not traditionally adjusted to fit users (Linton *et al.*, 1994), and the addition of adjustable workstations to the classroom does not change that practice (McCreary *et al.*, 1998). If anything, the introduction of computers to a classroom makes adjustment less likely given the reticence of teachers to undertake any workstation adjustments that involve moving the technology (McCreary *et al.*, 1998). The extent to which students are willing to make workstation adjustments is unknown; however, studies with adults have found that adjustments will be made only when the associated device is easy to use (*e.g.*, Tougas and Nordin, 1987). Further, even when ergonomically designed furniture is available, students, like adults, often do not use it in the recommended manner (Linton, *et al.*, 1994).

7.2.2 Supporting Collaboration in the Classroom

As discussed in an earlier chapter, shared workspaces have many benefits for students. Besides the obvious space savings and cost benefits, studies suggest that the learning experience is enhanced when classroom computers are shared by multiple students (Blaye *et al.*, 1991; Hawkins, *et al.*, 1984; Inkpen *et al.*, 1995; McLellan, 1994; Natassi and Clements, 1993; Peters, 1996; Watson, 1991). Even when given individual computers, students often work together around a single computer (Watson, 1991). Computer sharing promotes student interaction and collaboration, and may result in improved achievement and more positive attitudes towards learning. Inkpen *et al.* (1995) found that students were more motivated to play and performed better when they played together on a single machine than they did when playing alone or side-by-side on an individual computer. Similarly, Blaye *et al.* (1991) found pairs of students performed better than individuals on a complex computer-based planning task.

Computers, however, are designed to support individual users and come equipped with a single set of input devices. Thus only one student can interact directly with the computer at a time, with typically one student on a team using the input devices more than the others. Some researchers have found that one mouse can cause resource contentions (Nastasi and Clements; 1992, Inkpen *et al.*, 1995) as well as gender bias among paired users working together at a single machine (Inkpen *et al.*, 1995). Exactly what direct access to the computer yields in terms of learning is still under debate. However, Cole (1995) reported that students in direct interaction with the computer spent more time on low level details and made fewer contributions at the conceptual level on an educational task than did their fellow group members who were not in contact with the input devices.

Only a limited number of studies have investigated the effect of multiple input devices on collaboration and performance. In a qualitative study, Peters (1996) found that the addition of a second keyboard and mouse facilitated social interaction among pairs of 3rd graders exploring the Internet. Similarly, anecdotal evidence from the Bricker *et al.* (1995) study of 8th graders found that multiple input devices reduced conflict between users and eliminated contention for the input devices. Results from a usability test of a multi-user drawing program involving 3rd, 4th, and 5th graders indicated students felt the two mouse condition was easiest and most fun (Stewart, Bederson, and Druin, 1999). In the most rigorous study to date, Inkpen *et al.* (1995) found that the addition of a second mouse had a positive effect on the performance of children using problem-solving software. Except for the qualitative data gathered by Peters (1996) involving pairs of third graders exploring the Internet, the literature related to multiple input devices has focused on students' use of mouse-driven, problem-solving software. To date, no studies have addressed the effect of multiple input devices on students' use of more keyboard-driven software, e.g. word processing.

7.2.3 Participatory Ergonomics and the Classroom

Participatory ergonomics is a key element of the macroergonomic approach (Hendricks and Kleiner, 2000). It is a collaborative process that leverages the special expertise of users by partnering them with human factors engineers and other specialists to design, evaluate, and refine system elements at both the macro and micro levels. Its benefits include improved performance, more accurate information about user needs, higher quality products, increased motivation, improved fit between technology and other system elements, and greater acceptance of system changes (Gronbaek, Grudin, Bodker, and Bannon, 1993; Lanning, 1991; Noro and Imada, 1991). Participation can occur at any stage in the macroergonomic process.

Participatory ergonomics has an extensive history in adult organizations and has become popular for interface design. It has been used to create and evaluate virtual reality devices (*e.g.*, Good, 1992), food stands (Imada and Stawowy, 1996), expert systems (*e.g.*, Mumford, 1993), physical environments (*e.g.*, Snow, Kies and Williges, 1997), training materials (*e.g.*, Lindberg, 1996), and administrative systems (*e.g.*, Gronbaek *et al.*, 1993). An array of techniques for participatory ergonomics has been used with adult users of technology. Techniques for participatory ergonomics are as varied as its applications and include cooperative prototyping (Bodker and Gronbaek, 1991), contextual inquiry (Holtzblatt and Jones, 1993), paper prototyping (Ehn and Kyng, 1991), PICTIVE (Muller, 1993), scenarios (Karat and Bennett, 1991), and participatory analysis (Chin, Rosson, and Carroll, 1997).

Participatory ergonomics has also found its way into the classroom. The PCF classroom had been created using a participatory design process that included teachers, school technologists, and researchers (McCreary *et al.*, 1998). Other researchers attempting to introduce technology into the classroom have also engaged in participatory design activities with teachers as a means of creating tools for technology-rich settings (*e.g.*, Chin et al, 1997). For instance, in the LiNC project teachers worked with researchers and developers using scenario-based design methods to design a web-based system to support student group projects (Koenemann, Carroll, Shaffer, Rosson, and Abrams, 1999). Some researchers have recruited children as design partners. For example, researchers at Apple used a card design approach to act out *KidSim*, a simulation authoring tool for kids (Cypher and Smith, 1995). Fifth graders were asked to use the authoring language to program their movement around the classroom as a means of evaluating the programming language. Post-it notes stuck on clothing were used to keep track of programming instructions. Other researchers have taken a participatory design approach with kids and had them work directly with adult researchers and developers to create low-tech interface prototypes (*e.g.*, Druin and Solomon, 1996; Druin, Stewart, Proft, Bederson, and Hollan, 1997).

The participatory methods and techniques used in classroom settings have demonstrated the value of low-tech tools to engage students and teachers in the design process and to provide common ground for design. Other lessons learned from these efforts include: the need to involve both educators and children in the design process, the importance of including more than one child on a participatory team, the desirability of having more than one adult on a participatory team, the value of introducing low-tech tools early, and the need for flexible goals (Druin, Bederson, Boltman, Miura, Knotts-Callahan, and Platt, 1999).

7.3 Design of the Original PCF Classroom Workstation

The PCF network classroom was one of the few classrooms where computers are on every desktop, within easy reach of students at all times. At the onset of the PCF project, the student workstations had been designed using a participatory design process that included teachers, school technologists, and researchers. As part of the design process, classroom scenarios were constructed that considered where children were to focus their attention. With these scenarios, design team members tried to anticipate how the students would collaborate and predict what resources would be used. Teachers and technologists prototyped classroom designs, using drawings with paper cutouts to produce designs which everyone could evaluate.

The intent of the original workstation design was to integrate the technology into the fabric of the classroom, making it an ever-present, but not dominating, learning tool. At the same time, the design aimed to limit the intrusiveness of the technology, thereby minimizing distractions during non-computer tasks. In order to promote collaboration, students worked in pairs at workstations, which came equipped with a networked computer. Figure 7-1 shows the workstation that was created by the original design team. The remainder of this section provides a detailed discussion of the PCF workstation and the rationale behind its design.

Figure 7-1. Shared workstation used for the PCF classroom intervention.

7.3.1 Workspace Design

The design team was cognizant of the fact that learning would require a flexible workspace that allowed reading of books, writing and drawing on paper, and creating of artwork. Using the computer was only one of many purposes for the computer desks that served as student workstations. To support multi-purpose use, the project purchased large, height-adjustable desks (30” x 60”). The desks provided a large enough workspace to seat the computer monitor and still give students desktop space that could support other learning material in the performance of non-computer work. The desks also provided sufficient space underneath to put the stackable plastic “crates” which students used to store their books and possessions. Students, however, found this arrangement cramped and often voiced their desire for a larger desktop and more storage space.

Because having sufficient desktop space was a serious concern and the design team didn’t want students distracted by the technology when engaged in non-computer work, dual retractable trays were mounted under the work surface to hold the keyboards, with computer processors placed in tower configurations on a tray under the desk. During non-computer tasks, stowing the keyboard and mouse freed up the physical desk surface and eliminated the keyboard as a distraction when the teachers demanded a student's undivided attention. This configuration was expected to allow the teacher to tell at a glance whether a student was paying attention to her or playing with the computer. However, the teacher still found students would sometimes hide behind the computer and distract themselves, either with the computer or with other material, during lessons. More than once, the teacher expressed a desire for a "master cut-off" switch with which she could disable the students' computers.

Although the computer desks were height-adjustable and ergonomic guidelines emphasize the importance of maximizing the fit between workstations and computer users, the teacher never adjusted table heights to match student dimensions. The teacher paired the students based on personality compatibility, not physical compatibility, making adjustment problematic. Further complicating the situation, other students used the room during free periods, resulting in different children using the same furniture. Additionally, as table adjustment involved moving computer equipment, the teacher considered the operation too risky. Hence, the tables were set at a standard height (28.5"), an arbitrary height determined by the principal, and never adjusted.

7.3.2 Computer Controls

Each computer workstation was equipped with two keyboards, one for each student. The design team felt that individual keyboards would give each child a sense of personal ownership and control over the computer. At first, control of a keyboard was by a custom-constructed switch box placed in front of the monitor. The students used the switch to toggle between the two keyboards. Although the researchers saw no serious incidents of resource hoarding or contention, the classroom did have several switch-box failures due to rough treatment by the students. The switch-boxes have since been replaced with commercially available digital multiplexors called Y-Key-Keys that automatically switch between the two keyboards based on signal input. Because these switches connected to the computer at the keyboard port located behind the processor, students did not fiddle with them.

Although each student had his or her own keyboard, a student pair shared a single mouse to the computer. The design team debated the questions of one keyboard versus two and one mouse versus two. The teacher's intuition was that two keyboards would prevent shuffling (the keyboard is a bulky device) and lost time, but that providing two mice as well would invite unnecessary play. The researchers agreed to try a single-mouse workstation, and if experience dictated, add a second mouse. The project did no empirical studies; however, classroom teachers observed no situation that warranted using a second mouse. The observed biases had more to do with students' personalities than gender or resource contention.

7.4 Methodology

The main goal of this research was to elicit student perceptions of shared, classroom workstations and to investigate differences in workstation preferences among classroom stakeholders, *e.g.*, students and teachers. This information was gathered using participatory methods, which were used to develop low-tech prototypes and usage scenarios for shared student workstations. Participatory techniques are central to the macroergonomic approach (Hendricks and Kleiner, 2000) and have been used successfully to design a variety of child software products (*e.g.*, Druin, Bederson, Boltman, Miura, Knotts-Callahan, and Platt, 1998; Scaife and Rogers, 1998). These techniques were expected to be equally successful in this context. This approach allows children and adults to collaboratively build workstation prototypes using commonly available classroom materials such as construction paper, tape, cardboard, crayons, and so on. Both children and adults are equally adept at using such low-tech materials, and the materials provide a common ground for generating new ideas (Druin *et al.*, 1998).

7.4.1 Participants

In all, 13 children and 12 parents participated in the design sessions. Five child teams and four parent teams were formed. Three human factors graduate students, the classroom technologist, and an extension specialist served as facilitators for the teams. None of the participants or facilitators had been involved in the design of the original workstation. At the time of the participatory design sessions, participating students and classroom staff had spent the past academic year in the network classroom. Parents had been frequent visitors in the classroom, both for school events and weekly parent computer classes.

Both the classroom teacher, who had worked on the original design and taught in the PCF classroom for three years, and the classroom technologist, who was also a teacher, individually created new workstation designs. In order to preserve the anonymity of the teacher and technologist, both will be referred to as teachers when discussing their designs.

7.4.2 Procedures

7.4.2.1 Participatory Evaluation Process

A modification of the Druin *et al.* (1998) participatory methodology was used for design sessions. Key elements of the Druin *et al.* (1998) approach include

- Child design partners in the 7-10 year old age range,
- Mixed teams of four to seven children and adults,
- More than one child on design teams,
- Playful interaction between team members to stimulate new ideas,
- Informal adult behavior, and

- An open-ended outcome for the participatory session.

Adults on the team are interface experts, typically educators, designers, or developers. A diversity of low-tech materials, *e.g.*, crayons and paper, are introduced early with prototyping beginning as quickly as possible. Team members are usually seated informally in a circle on the floor or around a large circular table.

The participatory sessions discussed here were to follow the Druin *et al.* (1998) methodology. Additionally, this study would have

1. Students gathering information related to the session topic prior to the session.
2. Parents participating with children on design teams.
3. Each team containing one or two interface experts who also functioned as facilitators to ensure equal participation among group members, as in earlier participatory sessions, parents would sometimes try to dissuade children from their more fanciful ideas or in extreme cases attempted to dominate the process.
4. At the end of the session, facilitators were to conduct a short interview with team members using a structured protocol. The structured protocol was designed to elicit scenario information from the teams and allow team members to voice concerns about the workstations found in the PCF classroom.

Previously, the PCF project had successfully explored collaborative editor design using this modified participatory methodology, and had found it an excellent means for stimulating creative discussions on educational software. Similar success was expected for the workstation sessions.

Pilot testing revealed that the dynamic of mixed student-parent teams was less successful for workstation design. Most parents had a great deal of experience using workstations and were extremely comfortable with the more concrete nature of the design problem. Despite facilitator attempts to the contrary, parents dominated much of the design session and ran roughshod over the children's less traditional ideas during pilot testing. As a result, students and parents were split into separate teams for the actual study

7.4.2.2 Participatory Sessions

The participatory sessions took place during evening meetings on two different nights. Sessions were held in art rooms at the local elementary school where the PCF project took place. The art rooms were used instead of the PCF classroom as they provided large open workspaces where study participants could work collaboratively to create their low-tech prototypes of the "ideal" shared workstation. Students typically grouped themselves on large, open areas of the floor, while adults preferred congregating around large tables. Sessions were videotaped for later review.

The starting point for design discussions was the original PCF workstation. In the week prior to the design sessions, child participants researched workstation features, created a folder of workstation related articles and photos, and made lists of issues pertaining to the existing workstations. During this period, parent leaders were recruited and briefed by PCF technologist. Then on the night of the design session, participants met as a group and briefly discussed the process and specified goals for the sessions. Students and parents next broke into separate teams, with participants determining team composition and size. In all 5 student teams and 4 parent teams were formed. Student teams worked with 1-2 facilitators on the floor, which kept team dynamics informal. For all but one parent team, parent leaders served as team facilitators. Pilot testing also indicated parents were, in general, participated more when the group didn't include adult "experts".

Once formed, each team selected prototyping materials from the communal material pile, which included construction paper, tape, cardboard, crayons, clay, office supply catalogs, and colored pens. Teams then chose a work area in the art rooms. Video cameras were moved in to place and taping started. At this time, each team was given the issues list found in the appendix titled *Workstation Designs From the Participatory Sessions* to help guide the design process. At this time, each team completed a checklist designed to elicit participants' concerns going into the participatory design process.

During the sessions, refreshments were available to all study participants, with participants free to take breaks during the session. A participatory session was considered complete, when the team members were satisfied with their workstation prototype. At the end of each session, the team facilitator conducted a short interview using the structured protocol found in the appendix titled *Workstation Designs From the Participatory Sessions.*

7.5 Results From the Participatory Sessions

Results of the participatory sessions are discussed in terms of what students want in a workstation, what parents think students need, and what teachers think students need. As part of this process, design teams used a checklist to indicate their concerns going into the participatory design process. Table 7-1 summarizes checklist results. Detailed descriptions of individual designs can be found in Appendix F. These results will be discussed further (along with results from the field experiment) in the following chapter.

Table 7-1. Summary table of problems with PCF workstation. Five child teams, four parent teams, and 2 teachers participated in the study.

Problem	Number of Child Teams Reporting Problem	Number of Parent Teams Reporting Problem	Number of Teacher Teams Reporting Problem
Insufficient storage space	All	All	None
Insufficient personal space	All	All	None
Not sized for students	4	2	All
Unaesthetic, unappealing	3	1	1
Insufficient equipment	4	3	None
Collaboration difficulties	1	0	All

7.5.1 What Students Want in a Workstation

When comparing the design prototypes from the five child design teams, three central themes related to collaboration, control, and comfort emerged from the participatory design sessions. Some gender differences were apparent. Most boys viewed the workstation as an all encompassing entertainment center, which should be equipped with cup holders, joysticks, and CD racks, while girls focused on making the workstation an effective, aesthetically pleasing tool for the classroom.

7.5.1.1 Collaboration

Students felt strongly that two students, and no more than two, should share a workstation. Sharing makes activities more fun and facilitates the development of social and team working skills. However, students thought that larger groups would slow work and made decision-making difficult. Larger groups also meant that one student could be ganged up on and that each student got less time interacting with the technology. Plus as one student noted, teachers have a hard time finding two students that regularly get along, and finding more than two students that could work together would be even harder.

7.5.1.2 Control

Students wanted more control over their space. They wanted to share the computer area, but did not want partners to hog the computer. They wanted more input devices as well as touch pads and other devices that were better suited to activities such as drawing. Students reported feeling more connected to the computer and engaged in the work if they were holding an input device.

Students also wanted places that they “owned” with sufficient space for their belongings. Individual workstations were uniformly divided into separate areas for each student. As seen in Figure 7-2, one group literally divided the work area in half, with users given the option of splitting the workstation into two functioning units. Storage areas were often enclosed thereby making them more private. One team went so far as to provide separate cubbyholes for the students who used the PCF classroom while the PCF students were at lunch.

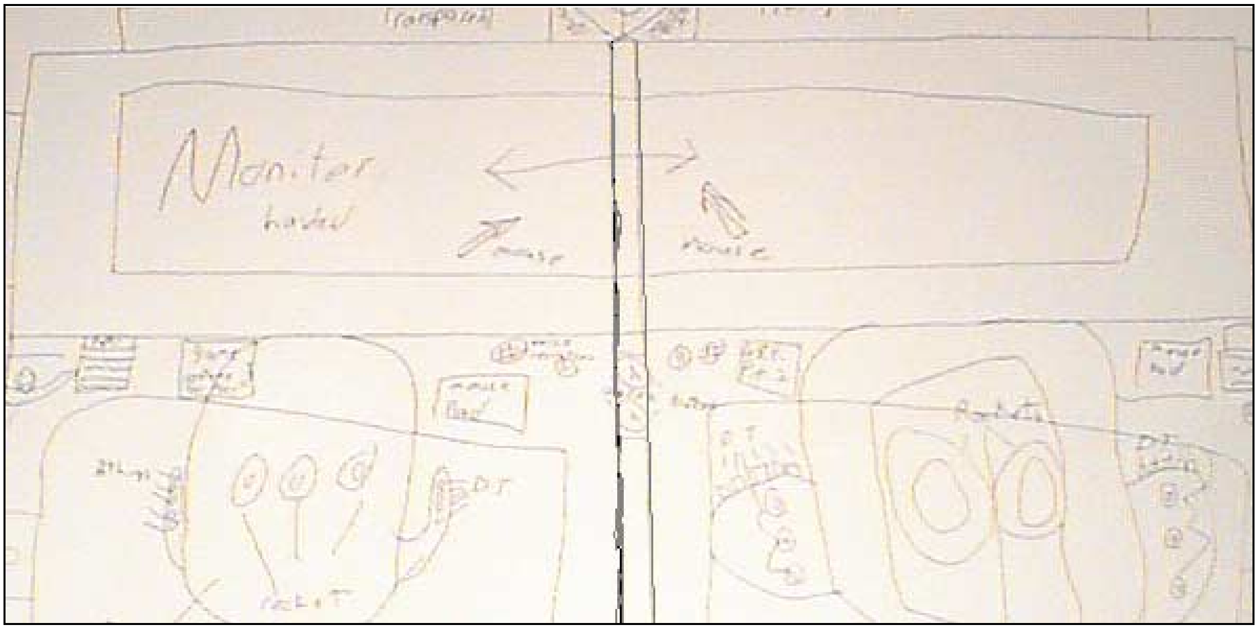

Figure 7-2. Prototype workstation that could be literally divided in half along the line shown in the photo. Each half could function independently when divided.

Students made a sharp distinction between personal and communal space. Shared spaces were areas where common equipment, *e.g.*, the monitor, resided. Only teachers could adjust these common elements, while personal elements, *e.g.*, chairs, were under the control of individual students. As shown in Figure 7-3, one team divided their work surface into three physically distinct areas, with only the teacher allowed to adjust the height of the work surface supporting the monitor. In general, teachers were to make any adjustments deemed difficult, risky, or involving common elements.

Students wanted “disappearing” technology that could be hidden away during non-computer activities thereby increasing the available workspace and decreasing instances of the technology blocking the student’s view of the teacher or blackboards. Equipment was made to disappear either by 1) dropping it down into the workstation, or 2) embedding the monitor in the workstation and viewing it through a see-through top that could be covered with materials during non-computer activities. Equipment was made more durable by covering it with see-through plastic covers, with everything from keyboards to monitors wrapped in plastic. Children wanted the equipment to demonstrate the same robustness as more traditional learning materials.

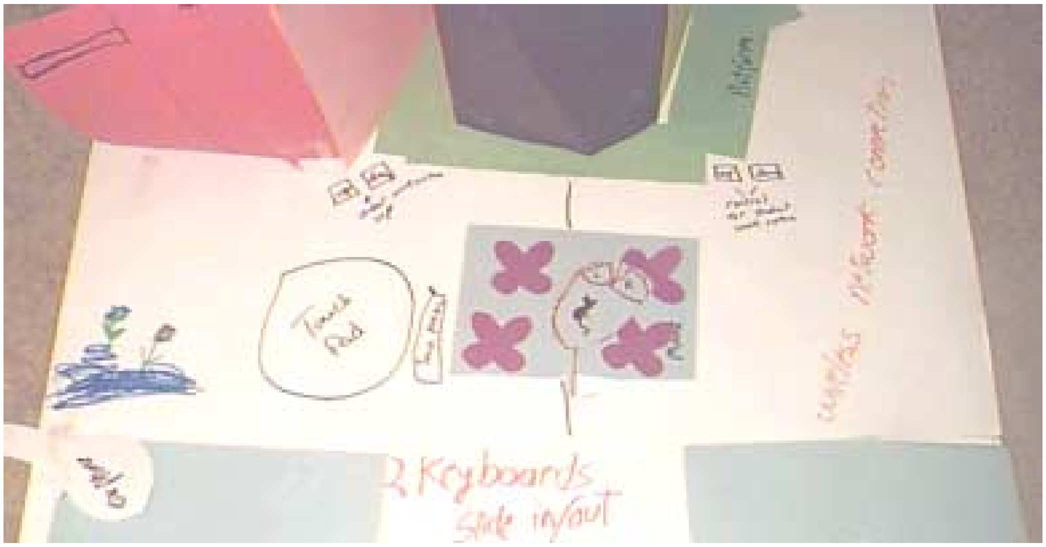

Figure 7-3. Prototype work surface that was divided into three areas: the common portion supporting the monitor and two separate student work surfaces.

Students cared deeply about how elements of the workstation looked. They cared as much about how it looked as they did about what it did or how comfortable it was. They didn't want boring, standard office furniture. Technology and furniture shouldn't look like technology or furniture; instead it should look like dolls or rocket ships. For example, one group created the doll-shaped CPU found in Figure 7-4, while several team incorporated rocket shaped controls into their design.

Figure 7-4. Doll-shaped CPU created by a team of girls during participatory sessions.

Students also wanted to personalize their space by selecting colors and accessories. Children also desired display areas for artwork and personal possessions. They wanted the visual look to be flexible and change as their interests changed. For instance, one team put a see-through cover over their work surface under which they could display items reflecting their current interests.

7.5.1.3 Comfort

Students wanted to be comfortable when working at the computer. Although often forced to assume strange positions for computer work due to improperly sized furniture, they, like adults, clearly prefer furniture that is made to their scale and well-padded. They wanted high-end features like arm rests, head rests, and wrist rests. Mouse supports were added to keyboard trays so students would not need to stretch just to reach their mouse. Chair elements were adjustable along a variety of dimensions, and foot stools were often suggested for shorter students. Students believed adjustability would affect both their comfort and ability to work.

7.5.2 What Parents Think Students Need in a Workstation

Like the students, parents thought children should be paired at the workstation and have disappearing technology. Parents wanted students to be able to put the technology away, but only because they thought it would distract the students at inappropriate times. However, parents did not give much though to workstation aesthetics or ill-fitting furniture; both of which were extremely important issues to the children.

Unlike the students, the parents believed each student should have an individual computer and a physically separate individual space for non-computer activities. Shared workstations were acceptable so long as students had lots of opportunities to work alone; parents wanted students to spend more time on individual activities. Individual workspaces were important to the parents because they gave students the opportunity to work at their own pace and prevented the technology from being monopolized by a classmate. Teacher, not student, control of classroom activities was considered crucial, with one team going so far as to scatter video cameras throughout the classroom.

7.5.3 What Teachers Think Students Need in a Workstation

Like students and parents, teachers wanted more storage space, expanded work areas, and bigger workspaces for non-technology activities. However, unlike students, teachers did not address aesthetics issues in their designs. There was much less agreement among teachers than other groups participating in the design sessions. These differences largely reflect differences in their teaching philosophies. While one teacher favors collaborative, student-centered activities, the other teacher prefers traditional pedagogies that leave her firmly in control of the classroom. As a result, although both teacher designs required one computer for every two students, the technology was used and arranged in very different ways. The more traditional teacher put students side-by-side with individual computers to better support individual work, and relegated technology activities to a single row in the back of the classroom. The more student-centered teacher integrated technology throughout the classroom and focused on supporting cooperative learning activities.

CHAPTER 8. DISCUSSION

Chapter Table of Contents

8.1 OVERVIEW 154
8.2 THE CLASSROOM SETTING 156
8.3 THE HOME ENVIRONMENT 160
8.4 THE STUDENTS 162
8.4.1 Patterns of Internet Use Among PCF Students 164
8.4.2 Patterns of Change Among PCF Students 166
8.5 THE STUDENT WORKSTATIONS 168
8.6 THE RESEARCH METHODOLOGY 170
8.7 IMPLICATIONS OF RESEARCH 173
8.8 DELIMITATIONS AND LIMITATIONS OF THIS RESEARCH 175
8.9 FUTURE DIRECTIONS 176
8.10 CONCLUSIONS 177

8.1 Overview

This research is part of the PCs for Families (PCF) project which seeks to determine what can be achieved if technology access, support, and curriculum integration could be eliminated as obstacles or constraints in the classroom and at home. During the fifth grade, students in the program were to experience constructivist teaching practices and had access to computer technology in both the classroom and home. The project sent a computer home with each child and teacher, and provided as much support as necessary to all program participants, including parents. Students, along with their parents, received training in using the technology to facilitate the learning process. After a year in the technology-rich classroom, students returned to a normal classroom but keep their home computer technology and Internet access.

The present work investigated the effects of the PCF intervention on the performance and behaviors of fifth graders and their families. This study was longitudinal in nature and can provide designers of classroom technology with in-depth information on how children interact with network technology and how that use changes over time. This research focused on the in-depth assessment of the third cohort of students to enter the PCF program and is limited to the students' first year in the project. This research investigated both the "macro" and "micro" effects of the PCF intervention during the students' first year in the project. At the "macro" level, a year-long field experiment was used to evaluate the effect of the PCF intervention on the students and to explore the relationship between student computer use and student outcomes. At the "micro" level, traditional human factors techniques were used to generate new information about how children use network technologies and to identify those aspects of the technologies that are most challenging for child users and their families. Table 8-1 summaries the research hypotheses and outcomes for this work.

Macroergonomics provided the methodological framework for this research. Although macroergonomics is frequently used to successfully design technology interventions and study their effects in adult organizations, it has not been used before as a framework for evaluating the effects of introducing computing technology in elementary schools. The macroergonomic framework facilitates systematic understanding of how classroom computer technology impacts other elements of the classroom system and how the characteristics of the classroom system impact the success of technology integration efforts.

This chapter discusses the results of this research with respect to dissimilarities between the PCF classroom and more traditional classrooms, experimental differences between the PCF participants and their control counterparts, multi-dimensional patterns of change for PCF students, patterns and predictors of computer use in the classroom and home, methodological issues related to this work, research limitations, and implications of these findings.

Table 8-1. Summary research hypotheses and expected outcomes for PCF students and parents.

Hypothesis		Data Supporting Hypothesis?
1a.	Greater academic gains	Supported only by writing standardized test results (see Section 6.2.2.1)
1b.	More efficient and reliable homework process	None (see Section 6.2.2.2)
1c.	Higher levels of computer skills and knowledge	Supported only by computer skills checklist (see Section 6.2.2.3)
1d.	Greater use of computer technology for learning	Higher use in classroom but not home (see Sections 6.3.1.1 and 6.3.2.2)
2a.	Greater attitudinal gains	SAM data only supports improvements for PCF boys (see Section 6.2.1)
2b.	More positive attitudes toward computers	None (see Section 6.2.1.3)
3a.	Parents more involved in student learning and school	Higher involvement only for the first 12 weeks of the school year based on self-reports (see Sections 6.2.3.2, 6.2.3.3)
3b.	Parents contact the school more often	None (see Section 6.2.3.1.2)
3c.	Parents use computer more to help student and contact school	None (see Sections 6.2.3.1.2, 6.2.3.1.3, and 6.2.3.2)
4a.	Student computer use increases with time	Supported only by classroom computer logs which indicated higher application usage in the last 12 weeks of the school year (see Sections 6.3.1, 6.3.2, and 6.3.3)
4b.	Parent school-related computer use increases with time	None (see Section 6.2.3.1.3)
4c.	Relationship between student characteristics and home computer use	Supported by all data analyses (see Sections 6.3.3.4 and 6.3.4.2)
4d.	Positive relationship between student home computer use and student changes	Mixed results (see Section 6.4)
4e.	Positive relationship between workstation “fit”, student computer use, and musculoskeletal complaints	Discomfort related to workstation “fit” variables and subjective measures of computer use but not objective measures (see Section 6.3.5)

8.2 The Classroom Setting

To first-time visitors walking into the PCF classroom, the classroom bore little resemblance to its more traditional counterparts. Network computers were found on every desktop, within easy reach of students at all times. Scanners, digital cameras, robots, and other technologies were scattered throughout the room. Technology was integrated into the very fabric of the classroom, making it an ever-present, easily accessible tool for both students and teachers. The classroom was led by an experienced teacher who was trained in constructivist teaching practices and technology integration by a master teacher who was her mentor early in the project. Her expertise was supplemented by that of an in-class technology specialist who was available to solve technology problems and assist in technology integration efforts.

However, the functioning of the PCF classroom was in many ways indistinguishable from that of its traditional counterparts. Observers reported the technology was seldom utilized during school hours (if at all). Computer logs lent credence to these observations. Average computer usage in the PCF classroom exceeded the three hours of computer laboratory time allotted to the control class only during the last 12 weeks of school (see Section 6.3.1.1). Much of the extra computer usage during that period could be attributed to an extended, after-school computer class project that spilled over into the normal school day and to a student teacher who experimented with the technology when left in charge of the classroom. Observers also reported the pedagogy remained steadfastly teacher-centered and didactic, with most lessons requiring little or no interaction, participation, or input on the part of the students. Student comments from participatory sessions supported adult observations, with many students commenting that they did not really get to work together during the school day. Collaboration was common only during extra-curricular computer classes.

The most visible effect of the technology's presence in the classroom was the weaving of the teacher around the equipment as she moved about the room. Given the number of students and the physical constraints of the classroom, the room layout resembled a maze of computer desks with few straight paths between areas. When the PCF program was initiated two years earlier, a participatory design process had been employed to ensure the design of a highly functional and space-efficient classroom. However, during the year this research took place, the classroom was moved to a new school as part of a district re-structuring. No satisfactory affordable design for the new classroom, with classroom layout determined largely by the positioning of the pipes and ductwork in the ceiling. Figure 8-1 shows the resulting classroom layout.

Figure 8-1. Layout of the PCF classroom in the new school. Picture taken from classroom doorway.

The teacher often commented to both the researcher and technologist that she was looking forward to the day when the project would be over and she could have fewer desks in her classroom. While this sentiment may be attributable to the constraints of her current classroom, her classroom design for the participatory design sessions reflected this sentiment. Her layout reduced the number of desks and computers in the classroom, created open spaces for floor activities, eliminated student pairing for computer work, and segregated technology to the back of the room. The master teacher who reviewed classroom videotapes for the project also commented on the cluttered nature of the classroom, and suggested decreasing the ratio of computers to students.

These findings dispute the anecdotal beliefs of many in the educational community who cite insufficient technology, training, and support as the primary reasons why teachers are unsuccessful at integrating technology into the curriculum. Certainly, these issues are substantive obstacles for any teacher trying to integrate technology. However, this research clearly illustrates that having adequate access to computer technology and classroom support is not sufficient to ensure successful integration. The reader should note that while the lack of technology integration was problematic within the context of this research, it should not be construed as a failure on the part of the teacher. She taught the class in the manner she considered best suited to support student learning. The question remains though as to why technology played such a minor role in instruction despite being so plentiful in the classroom.

In part, the answer lies in the context in which the research took place. Unlike many of the more successful technology-enabled classroom interventions, this one restricts itself to typical teachers in actual classrooms and not, for instance, to only those who are especially motivated to integrate technology into their classroom. Further, unlike the often-cited Union City project, the school lacked an articulate, committed change agent who advocated adoption of the technology and provided positive feedback to those making the transition successfully. Earlier ACOT research (David, 1992) also suggests that by adding technology to only one classroom in the school, the project inadvertently created a barrier between the teacher and her natural peer group, *i.e.*, her fellow teachers, thereby lessening the chances of successful adoption.

Another possible explanation that emerges for the lack of technology integration and constructivist teaching practices is that the goals and values of the project were not a good fit with those of the teacher. Not understanding what was involved in research, the teacher may have seen project participation as a low-cost means of expanding her influence at the school or as an opportunity to increase the technology-richness of her classroom. The teacher was visibly discomforted by the demands of the research, especially the frequent observation by the project staff, the videotaping of classroom activities, and the interest of many in the local and educational communities. Certainly, the teacher had little desire to transition to a more constructivist teaching style. When asked by the researcher, the teacher remarked that when she agreed to participate, her understanding was that she would teach as she always had in a classroom with lots of technology. To quote the teacher, "I agreed to one thing and got something completely different." From her perspective, she had a mature, successful teaching style and saw little reason to change even after the addition of classroom technology and mentoring by a constructivist, master teacher. Certainly, parents and students alike found her to be an experienced, caring teacher.

The presence of the technologist in the classroom seemed to have encouraged the classroom teacher to abdicate ownership of technology integration efforts (along with the actual technology) to the technologist. Even after three years in a technology-rich classroom, the teacher lacked many of the basic computer skills that her students acquired during the first several weeks of the school year (*e.g.,* cutting and pasting information between applications). She made minimal use of the computer for communication purposes and no use of it for classroom management. During the rare instances of technology-facilitated instruction that took place in the classroom during the year, the teacher would resist the technologist's attempts to involve her in lesson planning, often turned the classroom over the technologist during the lesson, and would generally leave the classroom while the lesson was being taught.

Other forces external to the classroom also affected this research. Upheaval in the larger elementary school may have increased the teacher's resistance towards change especially during the year this research took place. During that time, her elementary school merged with another local school and relocated to a new building. At the same time, the teacher was also trying to adjust to the principal who had replaced a previous, much-beloved principal with whom the teacher had a long-standing relationship. The teacher was visibly stressed by the situation and often vocalized her frustration to project staff. Within this time period, Virginia had also adopted a state Standards of Learning document that specified what every child at every grade level should know. A rigorous testing program was put in place with the teacher held accountable for student performance making the teacher even more reluctant to experiment with her teaching style.

8.3 The Home Environment

The highest level of education achieved by parents ranged from 10th grade to advanced university degrees. Prior to participation in the project, parental educational levels were positively correlated with ownership of home computer technology and availability of home Internet access. The majority of families participating in the field experiment had home computer technology when they volunteered for the study. Based on self-reports, 66.67% of the PCF families and 58.33% of the control families had computers prior to the onset of the intervention, with some families having access to multiple computers. Less than half that percentage, approximately 33% of each group, had home Internet access. With one exception[23], computer ownership and Internet subscriptions remained stable among the control families throughout the fifth grade, while all but two PCF families received an additional computer and a free Internet subscription as part of the intervention.[24] The prevalence of home technology among participants is attributable in part to the perception of the PCF project as primarily a technology intervention among local families. Families that had already bought into computer technology were more willing to volunteer and fulfill project pre-requisites.

Based on family self-reports, the PCF intervention had no lasting effects on the nature of home-school communication or on levels of family support for student learning (see Section 6.2.3). In the seven or eight weeks after the delivery of home network technology, PCF parents rated the quality of home-school communication higher than did the control parents. During that period, they also spent more time helping students with home learning activities. However, unlike anecdotal reports from similar home technology interventions (*e.g.,* the Buddy project), these changes were not sustained and by mid-year the behavior of the PCF parents was indistinguishable from that of the control parents. The initial surge in parental commitment and satisfaction may have been related to the delivery of home technology, and indicates the possibly of a transient novelty effect associated with the technology or of a temporary Hawthorne effect that was a by-product of the research.

Control parents were more likely to contact the school than were PCF parents (see Section 6.2.3.1.2). In part, this may have stemmed from their dissatisfaction with the lack of technology in their children's classroom. In particular, control parents were concerned that 1) rather than being randomly selected, certain children had been "picked" for

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[23] Shortly after the onset of the project, one control family without residential computer access purchased a home computer.

[24] The policy of the project was to give each participating family only one network computer and a single Internet subscription. Those PCF families not receiving computers in the 1998-1999 school year had already had a child participate in the project and as a result had already been given a free computer by the project.

inclusion in the PCF classroom, and 2) their children were somehow being shortchanged by having fewer computers in the classroom. While the second concern was understandable given media hyperbole at the time about classroom computers and the visible, technological disparities generated by the presence of the PCF project in the school, the first concern grew out of a project-level decision to employ a computer-mediated, double-blind selection process (see Section 5.4) instead of a simple lottery. While the process was meant to ensure fairness, its opaqueness and complexity was perceived by some families as providing opportunities for researchers to choose specific children. The control parents also found research demands (*e.g.,* survey completion) onerous. These issues were exacerbated by larger political storms brewing in the newly merged school and the disparities in compensation between the two groups. While PCF families were given ownership of their home technology if they completed their research commitments, control families received a token 50 dollars for the same work.

Although PCF parents universally had email access to school personnel, they were no more likely than control parents to report using email to contact school staff (see Section 6.2.3.1.2). In fact, parents from both classes expressed a strong preference for communicating face-to-face or by phone with school personnel (see Section 6.2.3.1.2). The PCF teacher echoed this sentiment on more than one occasion. The teacher's attitudes may explain in part the reluctance of PCF parents to let the technology serve as a vehicle for home-school communication. Analysis of PCF server logs indicated that email communication between parents and the classroom teacher was indeed infrequent. The reader should note that as the project only tracked email sent from the home account, the number of email sent by parents may be under-reported as parents could have sent the teacher email using a work account whose usage would not have been logged by the project server.

Further analysis of the PCF server logs uncovered distinct differences between teacher and technologist patterns of email communication with parents (see Section 6.2.3.1.3). As in classroom technology integration efforts, the teacher let the technologist take the lead. The technologist was 33 times more likely than the teacher to send email to parents. Interestingly, despite sending many more emails to parents than the teacher, she was only four times more likely than the teacher to receive a message from a parent, with many of her messages technology-related, *e.g.*, requests for help on a computer malfunction. Overall, the teacher and technologist were more likely to email parents than they were to receive email from parents. The total number of emails received by parents each week at home was positively associated with the number of emails sent by the teacher and technologist each week, however, the converse did not hold. This may be an artifact of the way the project logged email usage. Although the project server logged all email messages sent by parents (assuming they were sent from the parent's PCF account using the PCF proxy server as the mail server), teacher and technologist emails were logged only when the sender or receiver was a PCF participant.

8.4 The Students

This study was based on a group of fifth graders living in a rural community. All students had been in the local school district since at least the third grade. Half of the children received instruction in the PCF classroom and were given home network technology, while the other half attended a traditional classroom at the same school and received 50 dollars for their participation in the study. As the two classes were part of a fifth-grade pod where each teacher was responsible for a specific subject, students from the two classes were taught some subjects by the same teachers and generally changed rooms for those subjects. However, because of the field experiment, the PCF students stayed in the technology-rich classroom, and teachers were the ones to change classrooms.

Control student perceptions of the technological disparities generated by the project were largely shaped by parental reactions, with control boys particularly concerned about the inequity. Student concerns were somewhat assuaged by the 50 dollar sum given for completing research surveys; unlike parents, the children found this small sum of money motivating. At the end of the school year during informal discussions with the researcher, control students remained adamant in their belief that computers always made kids smarter and school more fun. The field experiment, however, provided only limited evidence to support control student convictions (and experimental hypotheses) about the two groups.

Although students in the PCF classroom were expected to make greater gains in learning motivation and previous research had linked technology interventions to motivation increases (*e.g.*, Honey and Henriquez, 1996; Follansbee, 1996), only the *School Attitude Measure, Second Edition, Level G/H* provided any support for the experimental hypothesis (see Section 6.2.1.1.2), with PCF boys making greater gains on this measure than control boys. However, no other differences were found suggesting the possibility that that the effects of technology, or the lack thereof, at this age may be mediated by gender. Certainly, boys in the control classroom verbalized their frustration with the lack of technology to a greater extent than the girls, with their parents being among the most vocal about its lack. Interestingly, changes on the *School Attitude Measure* were not associated with improved attendance, a common objective measure of student motivation. However, the possibility remains that changes in students' subjective attitudes towards school may be precursors of changes in objective attitudinal measures.

Students also completed shorter surveys that investigated their motivation for using the computer, writing, and writing with the computer. Of these measures, only the writing measure was significant and not in the anticipated direction. Student attitudes towards writing were assessed by the frequently used *Knudson Writing Attitude Survey* (Knudson, 1991). Although students have often experienced increased motivation for writing in technology-rich classrooms (David, 1992), control students actually made larger improvements on the *Knudson Writing Attitude Survey* than did the PCF students (see Section 6.2.1.2). As complete data was not available for all control students, a self-selection bias may have contributed to the significant result. Not surprisingly, students with more positive attitudes towards computers also reported more home computer use. Interestingly for PCF students, although not entirely unexpected given most fifth-graders' sense of time, self-reports of computer use were not associated with objective measures of Internet use (*e.g.,* number of emails sent by student).

Students in the PCF classroom were also expected to make greater gains in the academic arena. Not surprisingly given the mixed results from earlier research on technology-rich classrooms, writing was the only subject whose standardized test performance was significant (see Section 6.2.2.1.1). As with many previous technology interventions (*e.g*., Follansbee, 1996), when compared to their third grade performance, students in the technology-rich classroom made greater gains on the *Composing Written Expression* and the *Usage-Mechanics* sections of the *Virginia SOL Assessment Tests* than their control counterparts. Interestingly, students' SOL writing scores were positively correlated with their self-reports of home Internet use. Further, for the PCF students, family WWW usage was positively associated with the magnitude of their overall GPA gain. However, home network technology did not result in PCF students being more efficient at completing homework, with PCF students actually spending more time on homework than control students (see Section 6.2.2.2.2).

In keeping with the technological nature of the intervention, PCF students did out perform control students on a sequence of a computer tasks performed at the end of the year (see Section 6.2.2.3.1). PCF students were also faster and more accurate typists than their control counterparts. Interestingly, while the typing accuracy of the girls in the control class was much lower than that of either the boys or the girls in the PCF class, the typing accuracy of the control boys was indistinguishable from that of the PCF students. The performance difference may be related to the lower incidence of home computer ownership among the families of control girls. Although PCF students demonstrated a greater degree of technical skill at using the computer to complete tasks, this did not translate into higher scores on the technology section of the SOL tests taken at the end of fifth grade (see Section 6.2.2.3.2). The number of tasks in the test sequence that students successfully completed was related to student scores on two of the three technology sections from the SOL test, specifically the Basic Operational Skills and Using Technology to Solve Problems sections, thus providing some consistency between measures. The third section, Basic Understanding of Computer Technology, was associated with decreases in the number of tardies and improvements in student GPA.

Surprisingly, given the emphasis on the use of home technology in the PCF project, the average amount of home computer use reported by PCF students was no different than that of the control students with access to home computers (see Section 6.3.2.1). Nor were PCF students more likely than the control students with computers to report using the home computer for homework (see Section 6.3.2.2), which given the minimalist nature of computer use in the PCF classroom is not surprising. The only difference in self-reports of home computer use among the two groups related to computer game playing, with control students having home computers reporting that they spent much more time playing games than did the PCF students (see Section 6.3.2.1.2). The decreased game playing may have resulted from the validation of the computer as a learning tool through its presence in the PCF classroom or from the emphasis on using the computer to support learning in PCF training classes. Another potential explanation is that given the emphasis in project on using the computer to support learning, PCF students may have felt uncomfortable reporting computer game use.

What stands out in the field research is that despite the similarities in the classroom experiences of the two groups and the minimal nature of school technology use by both groups, experimental differences between the two groups were found for a subset of measures. Unfortunately, as multiple changes to the learning and home environments were implemented simultaneously, only the combined effect of the changes can be evaluated. However, given the lack of intervention buy-in by the PCF teacher, one can theorize that the changes were somehow related to the introduction of home network technology or the validation of the computer as a learning tool through its presence in the classroom. A Hawthorne effect is another strong possibility, especially in those instances where larger gains are not associated with increased computer use on the part of the PCF students. In order to better understand the role computer use played in these changes, additional correlational analyses were undertaken for the PCF group using objective measures of Internet usage.

8.4.1 Patterns of Internet Use Among PCF Students

Unlike previous research with adults (Kraut, Mukhopadhyay, Szczypula, Kiesler, and Scherlis, 1998), analyses of data from the PCF proxy server suggest that student web browsing overshadows other Internet activities, with email taking precedence over chat (see Sections 6.3.3.1 and 6.3.3.2). Further, web usage was more frequent than either email or chat use, and unlike chat or email, family web usage was sustained long after students left the PCF classroom. This pattern may be an artifact of the manner in which the project recorded web usage. While email and chat use was tracked in terms of individual students, web usage was logged in terms of family use. However, over sixty eight percent of family web usage each week was attributable to student, not family, characteristics suggesting students play a large role in determining family usage (see Section 6.3.3.4.1). Academic information finding provides a plausible explanation for these results, with family web usage declining somewhat during summer months when students were not in school. The association between weekly family web usage and weekly classroom use also lends credence to this theory. Students also relied on the web for entertainment and had favorite websites that they would return to again and again to play games or interact with fictional characters, sometimes during classroom lessons. On several occasions, the teacher expressed a desire for a “master cut-off” switch with which she could disable the student monitors. Interestingly, families of students who were absent more frequently or who had been tardy more often in the fourth grade had higher levels of web use.

Stability of both web and email use was relatively high among students with lagged usage measures accounting for a significant proportion of variance in weekly use (see Section 6.3.3.4). Lagged web use accounted for the greatest percentage of variance in weekly web use, with lagged email variables comprising the second largest source of variance in weekly email use. Only social influence variables accounted for a larger proportion of variation in email use. In keeping with critical mass theory, student email use increased when other students used email. Interestingly, parental email use had a negative association with student email use and accounted for almost ten percent of the total variance in weekly student use. Not surprisingly, social variables were not found to have a significant effect on web usage. Student individual difference variables accounted for the smallest percentage of variance in Internet usage. As in previously discussed research, girls were found to make greater use of email than boys, with this research suggesting highly visual and more intuitive students used email more often. Further, the families of students who reported little desire to write with the computer on surveys had higher levels of web usage. Also, as in a similar study of chat usage among the second cohort of PCF students (McCreary, Lisanti, and Ehrich, 1999), this study found more "judging" students favored chat.

In keeping with Internet usage metrics, students and teachers made greater use of email than chat to communicate outside the classroom (see Section 6.3.4.1.1). In particular, the average weekly density of the email network for the classroom was approximately ten times that of the chat network. As with previous research on real life networks (*e.g.,* Tietjen, 1982), students were more likely to communicate with students of the same gender using the Internet, with female students more likely than male students to email the female teacher and technologist (see Section 6.3.4.3). Interestingly, family members were more likely to contact the teacher and technologist than the students themselves although parents never really adopted email as a medium for home-school communication (see Section 6.3.4.3). Leaving the network classroom had no impact on chat communication between students as chat usage had virtually ceased long before the end of fifth grade; however, their departure from the technology-rich classroom greatly decreased email communication between students (see Section 6.3.4.1.3). Once the physical classroom community ceased to exist, the Internet-enabled community virtually disappeared.

Although neither the teacher nor the technologist utilized chat during the time students were in the network classroom, they were central to email communication with network density dropping significantly when their ties were removed (see Section 6.3.4.1.2). However, as with the parents, the teacher let the technologist take the lead in communicating with the students using email. Deletion of technologist ties had a more negative impact on network density than deletion of teacher ties. Based on their degree centrality and prestige, girls played more important roles in the email network than boys (see Section 6.3.4.2). Given their greater email usage, this is not surprising. This is consistent with previous research that suggests that the quality of relations with others is more important to girls than it is to boys and as a result they put more effort into maintaining the ties (*e.g.,* Samuelson, 1997). Additionally, those who rated higher on the MMPI thinking-feeling scale were more likely to play a central role in the email network, with this score accounting for 34 percent of the total variance in student centrality. That is, those who were more concerned with relationships and harmony were more central in the network. What stands out when considering student roles in Internet-enabled networks is the role of student motivational variables. Students who opinion of what others thought about their academic abilities decreased over the course of the year were more important in the email network (see Section 6.3.4.2.1.1). However, students who were more academically motivated and had better opinions of their academic abilities were more central to the chat network (see Section 6.3.4.2.1.2). Perhaps students who were less sure of their abilities were more comfortable engaging in a form of communication such as email that allowed them to edit and refine their ideas before presenting them in public.

Of all the available Internet technologies, chat offered the most challenges to students, which may explain their failure to adopt the technology. The project chat interface allowed students to login anonymously under different names, which resulted in a number of negative behaviors. Project chat logs showed students taking aliases and using those aliases while saying things that probably would not have been said if they knew they were identifiable. Students would also hold down the carriage return key to keep the screen scrolling to prevent other students from reading posted comments. Boys were the biggest offenders, with male disruptive use higher than all other forms of use (see Section 6.3.3.4.4). Logistically, students had difficulties finding each other in the chat room at just the right time. The fact that their classmates would log on at slightly different times for a scheduled meeting was not obvious to students. With an impatience characteristic of fifth graders, students logged on and immediately logged off if no other students were on-line. In fact, during the one year period under consideration, 178 non-connections were recorded by the project server while only 123 student conversations took place during the same period with the majority of conversations involving only two students. Additionally, parents would often interrupt their children's sessions to make telephone calls, which posed obvious problems for students working on homework or extracurricular group projects. In spite of the challenges associated with chat usage, many of the students in the class chose to take advantage of the project chat facility. However, most of those students had already proven themselves to be self-motivated and engaged learners in a wide variety of contexts, including academics and technology. As evidenced by the predictor set for chat network characteristics, students who were historically unmotivated non-performers seldom engaged in a chat (see Section 6.3.3.4.3).

8.4.2 Patterns of Change Among PCF Students

As the sample size was insufficient to attempt structural equation modeling, relationships among student measures were explored through a combination of cluster, canonical, and regression analyses. Although canonical analyses supported the experimental hypothesis that student changes were related to student technology use, they also suggested that technology use was a less homogenous construct than suggested by the research model and its relationship with student change measures was more complex than originally hypothesized (see Section 6.4.2.1). Cluster analysis provided additional support for this position (see Section 6.4.2.2), with classroom grades and attendance behaving in a manner most similar to that of web usage. Cluster analysis also indicated email usage was most similar to measures of change in standardized writing performance, while student self-reports of computer use behaved very similarly to the remaining measures of changes for standardized test performance.

Student previous achievement was by far the strongest predictor of student SOL test performance on individual categories, with computer use linked only to student performance on the writing and mathematics portions of the test (see Section 6.4.2.3.1.2). Not unexpectedly, as the number of email messages sent by the student increased, their writing performance increased with email usage accounting for almost ten percent of the total variance in the SOL writing score (see Section 6.4.2.3.1.2.2). Sending email was also strongly associated with on-time completion of student homework assignments and accounted for approximately four percent of the total variance in that value (see Section 6.4.2.3.1.1.2). The only computer use measure associated with SOL mathematics scores was student self-reports of computer use, which accounted for less than four percent of the total variance in performance. Interestingly, changes in student GPA were not related to previous student achievement; instead, motivation variables accounted for the largest percentage of total variance in this measure, with Internet use variables accounting for approximately half of that (see Section 6.4.2.3.1.1.1).

Computer use was associated more strongly with changes in student motivation (see Section 6.4.2.3.2).   Family web use and student chat usage for the year accounted for almost sixty percent of the total change in student absences, with student previous performance and MMPI extrovert-introvert score accounting for the remaining 20 percent (see Section 6.4.2.3.2.1). Interestingly, student chat usage and family web usage were strong predictors of decreased student attendance for the year, indicating perhaps that absent students frequently turned to the computer for companionship when not at school (see Section 6.4.2.3.2.1). Student self-reports of home computer use accounted for fully 30 percent of the variance in changes in the School Attitude Measure (SAM) score, with students reporting the highest use making the greatest improvements in their SAM score (see Section 6.4.2.3.2.2). Not unexpectedly, students with higher entry SAM scores made the smallest improvements suggesting highly motivated students benefit to a lesser extent. Similarly, student chat and web usage accounted for approximately ten percent of the total variance in student changes on the Knudson writing measure, with heavier web and chat users making larger improvements in their attitudes towards writing (see Section 6.4.2.3.2.3). Also, student entry Feel About Computer scores accounted for approximately another 12 percent of the total variance in Knudson changes. Again, students with more positive attitudes towards computers made correspondingly larger improvements in their attitudes towards writing.

The reader should note that although the association between student changes and student computer variables is intriguing, one cannot say unequivocally that differences in student computer variables caused the observed differences in student performance and attitudes, or that specific aspects of the PCF intervention triggered these changes given the correlational nature of these analyses.

8.5 The Student Workstations

Although the workstations currently used by children in the classroom typically look like scaled-down versions of their adult counterparts, child computer users have very different skills, dimensions, preferences, and goals than adult users. Child workstations reflect largely the tastes of adult buyers. In part, this may be because children are not involved in the design of the workstations and the research has not, to date, investigated child perceptions of workstations or the long-term impact of frequent computer use on children. Additionally, very little research has addressed the special needs of children forcing the designers of child workstations to rely primarily on guidelines developed from studies with adult users. This research adds to that body of literature by 1) investigating the musculoskeletal effects of long-term, frequent computer use on children and 2) exploring student perceptions of shared, classroom workstations and identifying differences in design preferences among classroom stakeholders.

In the PCF classroom, large height-adjustable desks served as workstations for pairs of students (see Section 7.3). Each computer workstation was equipped with two keyboards, one for each student. Control of a keyboard was determined by commercially available digital multiplexors called Y-Key-Keys that automatically switched between the two keyboards based on signal input. Computers were equipped with a single mouse that was shared by the students. Retractable trays were mounted under the tables to hold the keyboards, with computer processors placed in tower configurations on a tray under the desk. Stackable crates underneath the tables served as storage space for students. Students found this arrangement cramped and often voiced their desire for a larger desktop and more storage space, while the teacher was concerned by students sometimes hiding behind the computer monitor and distracting themselves, either with the computer or with other material, during lessons.

As with adults, ill-fitting workstations were associated with an increase in student self-reports of musculoskeletal problems among the PCF students (see Section 6.3.5). The most common site of student discomfort was the shoulders and back, with wrist pain running a close second. Leg pain was cited only slightly less frequently. Although leg pain is not particularly common in adult workstation users, its frequency is understandable given student chairs were on average 2 inches too tall for boys and 1.4 inches too tall for girls. Student ratings of musculoskeletal discomfort in the last 24 weeks of school were two to three times higher than at the start of the school year. The lower the student’s eye height in comparison to the monitor height, the larger the increase in student self-reports of discomfort. Increases in student reports of discomfort were also negatively associated with the difference between the keyboard height and student elbow height. That is, the higher the student's elbow height with respect to the keyboard height, the larger the increase in student ratings of musculoskeletal discomfort. An increase in the student's rating of musculoskeletal discomfort was also positively associated with student self-reports of home computer use. Interestingly, increases were not associated with any of the objective measures of child computer use.

Although PCF workstations were height-adjustable, school personnel never adjusted table heights to match student dimensions. As student pairings were based on personality compatibility, not physical compatibility, adjustment was problematic. Further complicating the situation, other students used the room during free periods, resulting in different children using the same furniture. Additionally, as table adjustment involved moving computer equipment, the teacher considered the operation too risky. Hence, the tables were set at a standard height (28.5"), an arbitrary height determined by the principal, and never adjusted. Students often assumed unusual positions in order to reach the mouse and their feet seldom rested flat on the floor. Not surprisingly, the adjustability of workstation furniture was an important issue in the participatory design sessions (see Section 7.5.1), although more so to students and teachers than to parents. Students made a sharp distinction between adjustment of workstation personal and communal space. Only teachers could adjust these common elements, e.g., monitors, while personal elements, *e.g.,* chairs, were to be under the control of individual students. In general, teachers were to make any adjustments deemed difficult, risky, or involving common elements.

The participatory sessions identified important differences between students, parents, and teachers, both with respect to their workstations concerns and their workstation designs (see Section 7.5). Children were interested in gaining greater control over the workstation, both in terms of individual technology and adjustability of furniture. Parents, however, focused on improving the richness of an individual student's workspace and de-emphasized collaborative work. Teacher opinions diverged more than other groups and reflected their underlying pedagogic differences. One teacher took a more student-centered approach that integrated technology throughout the classroom and created a design more in keeping with student perspectives. The other took a more teacher centered approach that afforded her greater control of classroom activities and had views better aligned with that of the parents.

Control of technology was a central issue in the majority of designs, with student and parent designs uniformly providing individual students with their own set of input devices. Both students and parents saw multiple input devices as a way of preventing one partner from dominating computer learning activities. As reflected by the parents' emphasis on individual work, parents sought to achieve this richness of devices by providing each student with a computer. Students, on the other hand were willing to share a computer if they had their own input devices. However, their willingness to share a computer may have been the result of conditioning due to their year-long exposure to the shared PCF workstation.

Students were the only group that gave serious thought to workstation aesthetics. They did not want boring, run of the mill office furniture. Workstation technology and furniture should not look like technology or furniture; instead it should look like dolls or rocket ships. For example, one group created a doll-shaped CPU, while several teams incorporated rocket shaped controls into their design. Workstation elements should be colorful and adorned with drawings of flowers or other things of interest to the children. Students wanted the look of the workstation to be flexible and change as their interests changed. For instance, one team put a see-through cover over their work surface under which they could display items reflecting their current interests.

With the exception of the classroom teacher who had students work individually and the technologist who had students work in groups of four, design session participants grouped students in pairs at the workstations. The general consensus among students and parents was that increasing the number of students grouped at the workstation would create an undesirable social situation, decrease the time an individual student spent interacting with the computer, make decision-making more difficult, and diminish performance.

8.6 The Research Methodology

Research of this type is a tremendous undertaking. Researchers must identify and measure the salient characteristics of numerous classroom stakeholders and processes. Even when the information is successfully collected, the intricate web of inter-relationships between classroom elements, the families, and the larger school environment make attributing causality problematic. Research on this scale is also a real commitment for already busy teachers and families, with research demands often taking much longer than expected. Macroergonomics is a powerful tool for understanding the often disparate perspectives of classroom stakeholders and the relationship among intervention components and changes in different elements of the classroom system.

During the second year of the PCF project, a decision was made to transition to a macroergonomic evaluation approach. By that time, the limitations of the original project approach to evaluation had become overwhelmingly apparent. The original plan was to determine whether in a 3 to 5 year period researchers would find changes in standardized test scores between PCF children and those in a matched control group selected anonymously from children across the school district. This approach, however, provided little insight into the complicated relationships between home and school and the effect of network technology on students and families. Macroergonomics provided a mechanism for systematically identifying the key differences between a standard classroom and the PCF classroom, a theoretical framework for relating student and family changes to elements of the PCF intervention, and a process for exploring both the “micro” and “macro” aspects of the PCF classroom.

As the PCF project was already in place, macroergonomics was used primarily to develop evaluation criteria for the intervention and to design new technologies, with the main focus being

- Identification of variances for the PCF classroom based on the expected results of the intervention, a comprehensive literature review, and detailed STS analyses of a standard and the PCF classroom.
- Selection of an initial set of key variances based on the strength of their linkage with PCF intervention elements. This set was further refined using project evaluation priorities.
- Development of role networks for the standard classroom and identification of changes that were expected to occur as the result of the network technology.
- Design of new technologies for the classroom and home, *e.g.*, collaborative text editors, using participatory techniques.

Conversations with students, families, and teaching staff were used to verify analyst perceptions of responsibilities in the system. Based on the previous analyses, performance criteria were created for the third year of the project. As the set of criteria was so large as to be infeasible to implement, a subset was selected based on input from school personnel and further definition of research priorities. As most objective measures of student performance would not be available once the students left the intervention classroom, care was taken to relate each of the target criteria to both subjective and objective measures.

Although macroergonomic methods and techniques were used only during the last year of the project, macroergonomics has been found to provide an effective methodology for exploring the complex relationships found in a classroom setting and a robust framework for addressing performance multi-dimensionality in both classroom and family processes. Partial results keep suggesting new issues; however, the macroergonomic measure set has so far been sufficient to address these new research questions. The macroergonomic perspective has also been helpful in understanding the mechanisms by which the forces at work in the families and larger school impact the effectiveness of research processes. In keeping with macroergonomic theory, this research suggests that the effects of the PCF intervention go far beyond that of the technology itself.

The systematic nature of the macroergonomic process lent itself to the use of multi-dimensional statistical techniques (*e.g.*, structural equation modeling). This combination is particularly powerful in situations, such as this, where the researcher is interested the inter-relationships between variables or exploring the fit of the conceptual constructs underlying an intervention. However, the utility of most multi-dimensional techniques is limited to a greater extent by population size than more traditional techniques (*e.g.,* ANOVAs), and on a small-sized project such as this, the selection of appropriate techniques can be quite limited. Interestingly, the majority of macroergonomic research has not utilized these techniques to explore system dynamics, instead relying on more traditional, and generally more familiar, statistical techniques that are often better suited to the analysis of individual or unrelated measures.

Key to the success of the macroergonomic approach has been the inclusion of school staff and families in assessment design. When willing, students and their families can be an invaluable resource for refining data collection instruments and procedures. Parents and students from the second year volunteered for usability studies of potential survey instruments and provided researchers with valuable insights related to survey design and administration. Teaching staff suggested measures related to the performance criteria and provided excellent insights into which criteria would prove to be most valuable. Teachers and school administrators also helped the researcher develop a data collection strategy that would minimize disruptions to normal classroom and family functioning.

With so many diverse groups participating in the research process, maintaining participant commitment over the course of the research was a challenging task. Participants came from varied backgrounds and generally had little concept of the research process. School staff and families also had widely differing reactions to the presence of research personnel. Some found research intrusive and were loath to participate in data collection. Others were extremely supportive and willingly completed the research tasks. Both teachers and families tended to lose sight of the fact that the existence of the project was dependent upon their responsiveness to research inquiries. Further as the attention of most participants centered on the technology aspects of the project, they were often surprised by the inclusion of measures related to non-computer aspects of the classroom and home. Participants viewed the technology as neutral and unlikely to impact the social or organizational functioning of the classroom or home. Also, the purpose of measurement was sometimes misunderstood by both teachers and students to be a means of enforcing personal accountability instead of as a mechanism for scientific study. A participatory approach to the research process helped allay participant fears, but building and maintaining participant trust takes time and effort on the part of researchers.

Researchers are also warned that the systematic nature of the macroergonomic process and the complex inter-relationships within educational systems can easily lead to the development of an overly large measure set if great care is not taken to prune measures not directly related to those aspects of the classroom which are of primary interest. Despite strong participation from intervention stakeholders, the PCF evaluation process required fine-tuning early on in the year due to feedback from control families that the data collection schedule was overly burdensome. Thus several months into the third year, survey administration was scaled back, particularly for the control parents. Fortunately, as care had been taken to associate both objective and subjective measures with each performance criteria, evaluation quality has not been compromised. However, this experience emphasizes the need for researcher follow-up with all participants to evaluate the success of a macroergonomic study and to sustain participant commitment.

8.7 Implications of Research

This research has found macroergonomics to be a powerful tool for exploring inter-relationship among classroom elements and examining issues related to the introduction of technology in the classroom and home. It provides an effective framework for researchers and educators wishing to understand how technology impacts other elements of the classroom system or how the characteristics of the classroom system impact the success of technology integration efforts. The present findings confirm that macroergonomic methodologies for analysis and design of work systems are extensible to classroom systems, and suggest that this approach will be a useful approach for studying other educational interventions.

In keeping with macroergonomic theory, this research suggests that teacher success at integrating technology into the curriculum is not merely a matter of having access to sufficient technological resources, training, and support. These findings call into question many of the assumptions underlying the recent influx of technology into U.S. schools, and should serve as a caution to the many school districts that are cutting other educational programs in order to increase the number of computers in their classrooms. Clearly, enriching classroom technology does not always change classroom pedagogies for the better, reform the educational process, increase student motivation, or improve student achievement. Before technology can be a vehicle for change in the classroom, it must be used, and as demonstrated by this research, even teachers with extraordinary access to technology and support may choose not to use it. Educators and researchers need to realize that the addition of technology does not benefit all teachers or all classrooms.

This research also demonstrates that mismatches between elements of a technological change and the characteristics of the classroom can nullify many of the potential benefits of the new technology. As this research illustrates, there is a distinct difference between technology-rich and technology-enriched classrooms. These findings strongly suggest that macroergonomics has a role to play beyond that of a framework for evaluating the impact of classroom technology. Designers of classroom technology interventions will also want to consider using macroergonomic methods and techniques to discover solutions, which fit the diverse elements of the classroom system and balance the needs of classroom stakeholders.

This research provides new insights on the effects of ubiquitous network technology in the classroom and home on students and their families, and is one of the first studies that investigates these topics experimentally. It provides indications of what the benefits of technology use would be for individual students if home computers were universally available and family barriers to home computer ownership were eliminated. Naturally, not all students reacted to the technology in the same manner. This research identified those student characteristics most strongly associated with heavier computer use under those circumstances, and then explored the link between student computer use and changes in student performance and behaviors. This research has the potential to help educators identify which students are most likely to prefer technology-enhanced instruction and provide indicators of those most likely to benefit from a technology interventions.

This work also explores in-depth longitudinal patterns of Internet use among elementary students and their families. Besides the obvious information about student patterns of Internet use and their preferences for different media, this research provides several lessons to researchers wishing to track student network use outside of the school environment. First, the logging process should never be dependent on parameters that can be modified by participants. Participants may inadvertently reset the parameters or may intentionally turn off the logging while engaging in activities that they assume the project might find inappropriate or would reflect badly on them. Second, automated processes should be in place, which regularly check that individual accounts are being successfully tracked. Third, when publishing results, discuss how these issues were addressed in the research project. The reader will need this information in order to make judgments about the reliability of the results.

This research also provides new insights into the microergonomics of shared workstation design. Repeated computer use and improperly sized workstations was linked to significant increases in reports of musculoskeletal discomfort by children in this study. Although not explored in this research, improper computer use by children is likely to carry the same long-term risks as it does for adults including vision problems, carpal tunnel syndrome, and other serious musculoskeletal problems. These findings illustrate the importance of properly sized workstations for children in both the classroom and home and provides further evidence of the need for educators and parents to check the "fit" of child workstations and to monitor child computer use. This work also demonstrates the value of participatory design, even with the youngest users, when creating or evaluating classroom technology. Children and the adults bring very different perspectives to the design of the technology. Participatory design is effective at capturing those differences and helping participants negotiate a common solution. Participatory design is especially essential in classroom settings where both students and teachers must co-exist with the same technology.

This research also highlights the costs of the research process for teachers and families and the challenges of long-term experimental research in the schools. Maintaining participant commitment over an extended period requires taking a participatory approach to the research process, follow-up with all participants to evaluate the success of the research process, eliminating inequities in compensation among research participants, good communication among participants and researchers, a willingness to modify research procedures that are not working, involvement of educators and families in selecting measures and designing data collection procedures, and a research process that ensures the privacy of all participants.

8.8 Delimitations and Limitations of this Research

Because of the age grouping of the subjects participating in this research, research results cannot be generalized to other age levels. Further, the results will not be completely generalizeable from this rural sample to the general population. Because this research evaluates changes to participants in their first year in the PCF program, conclusions about long-term differences as a result of the intervention cannot be made. Additionally, although the classroom was technology-rich, classroom processes were not visibly enriched by its presence and the classroom pedagogy remained teacher-centered. Thus, this research provides little insight into the effects of constructivist teaching practices or the impact of successfully integrating the technology into the curriculum on students. Further, this research is somewhat limited by its sample size. As multiple changes to the learning environment were implemented simultaneously, only the combined effect of the changes can be evaluated.

Since typical teachers in an actual elementary classroom (and not, for example, only those who are inordinately motivated to integrate technology into their classroom) participated in this research and standardized instruments are being used to assess changes, results should be generalizeable to other educational settings. However, limiting the selection of students and families to those who completed a short survey may have pre-disposed the sample towards achievement-minded students and slightly restricts the generalizeability of the research. Similarly, the technological nature of the intervention may have biased the sample towards more technologically aware families and slightly limits the generalizeability of these results. A more serious threat to generalizeability is the conditions under which the study takes place. As participants had access to unusual resources, *e.g.*, extensive training and help from university researchers, not typical in even technology-rich classroom settings, results may potentially not generalize to actual classrooms without such resources.

Conceivably, the project may have under-reported home Internet usage by participants as the project only tracked usage from PCF accounts. Participants, despite project requests to the contrary, may have utilized other accounts regularly without project knowledge. As the project only tracked email sent from the home account, the number of email messages sent by parents to classroom staff would be under-reported if the parents regularly contacted the classroom staff using a work account. Additionally, as the project only tracked email usage by the teacher and technologist when the sender or receiver had a PCF account, total usage for classroom staff is most likely under-reported. The dependence of the project tracking process on parameters that could be modified by the participant limits measure reliability. In some instances, fathers visiting questionable sites disabled WWW tracking, and did not always remember to re-enable it or re-enabled it incorrectly. Similarly, participants who changed their mail server to something other than the project server were not tracked by the project. Although yearly project checks of family machines provide evidence that this did occur, the project has no real knowledge of exactly when such events occurred or their duration.

Additionally, for most surveys, the completion rate of the control group was lower than that of the PCF group. While understandable due to inequities in compensation, it may have created a self-selection bias within the control group results. Hence, the more reliable participants may have been over-represented in the control treatment condition, which may have confounded the analyses of some subjective measures. The high number of families that already had home technology at the start of the intervention, particularly the high number of families in the control group, is another potential confound.

8.9 Future Directions

Like most studies, this one raises more questions than it answers. How can educators predict which teachers when given access and support will successfully integrate technology into the curriculum? How do teacher learning styles or other characteristics change the success of integration efforts? What kind of training would improve the probability of integration success? Even when integration is successful, does pedagogy always change? How are pedagogy changes linked to student outcomes? When technology is used regularly in the classroom, does student home computer use change?

Of particular concern is how the interaction between the characteristics of the teacher and technology impacts the effectiveness of classroom technology interventions. Future experiments are needed that replicate this research (or something similar) on a larger scale with multiple classrooms and look for links between teacher characteristics and the extent to which technology is successfully integrated into the curriculum as well their relationship to student outcomes. Future studies should also examine which teacher characteristics are most strongly associated with heavier computer use in the classroom and at home. Such research could potentially help school districts identify those teachers whose classrooms are most likely to benefit from increased technology.

Replicating this field experiment (or something similar) on a larger scale would also increase understanding of the role of technology in student outcomes and the effects of technology on student populations different from the one considered in this research. In particular, how does the grade level at which technology is first introduced into the classroom affect student outcomes? Future research should also investigate the effects of technology in the classroom or home for a longer period of time. In particular, does home access affect student educational outcomes? Do longer periods of immersive exposure to the technology in the classroom and home yield greater improvements for student? Are student changes sustained three or five years after leaving a technology-rich classroom?

Cost too should be investigated by future researchers. In the cost-cutting climate of today's schools, schools often cut music programs or other activities in the rush to fund technology uses (Oppenheimer, 1997). Given the mixed evidence related to computer use in the school, educators are hard pressed to justify their choices. Real questions also remain as to the cost-effectiveness of technology interventions. Could equivalent educational results have been obtained using other, possibly cheaper, non-technological methods?

Future researchers should also investigate “micro” issues related to classroom workstations. Participatory sessions with students, parents, and teachers yielded several potential design parameters for shared classroom workstations. Formal studies are needed that examine how these parameters affects student performance, well-being, and collaboration on a variety of tasks. Studies are also needed to determine how the nature of the task impacts the effectiveness of students at a shared workstation. At the least, future research should examine the benefits of individual mice versus a single shared mouse, a single keyboard versus individual keyboards, and differences related to computer tasks that rely primarily on a mouse for input versus one relying primarily on the keyboard. Future studies should also determine the extent to which students are willing to adjust workstation furniture and how their adjustments relate to student anthropometric dimensions, the input control configuration, and student perceptions. Additionally, researchers should investigate the impact of computer use on student health and comfort over a longer period of time using objective measures. Ideally, such studies would result in specific guidelines to guide designers of child workstations in both home and educational settings.

Macroergonomic methods and techniques could potentially help answer many of the questions raised by this research. However, future research is needed to explore the usefulness of the macroergonomic methodology in classroom settings. In this research, macroergonomics was used predominantly as a framework for evaluating an existing classroom intervention. Future research should also investigate the utility of the macroergonomic approach for designing classroom interventions and identify in what educational settings the macroergonomic approach is most likely to succeed. In particular, studies should examine whether classroom interventions designed using the macroergonomic process “fit” educational settings to a greater extent than those designed using more traditional, educational methodologies. Additionally, given limited time and resources, which elements of the macroergonomic process are most valuable to the educational analyst or designer? What should the roles of educators, students, and other stakeholders be at different steps in the macroergonomic process?

8.10 Conclusions

An evaluation of the impact of new classroom technology requires identifying and understanding the many elements of the classroom and their inter-relationships. Analysis of the classroom setting is complicated by the fact that classrooms are home to groups with conflicting goals, which belong to the same larger system. The sometimes divergent goals of classroom stakeholders implies that no one optimal solution may be found which is best for all classroom elements; however, that does not mean no one solution can found which optimizes overall classroom performance. Macroergonomics provides a method for discovering solutions, which fit the many elements of the classroom system and balances the often disparate needs of classroom stakeholders. Results from the field study confirm that macroergonomic methodologies for analysis and design of work systems are extensible to classroom systems, and provide a systematic framework for examining issues related to the introduction of classroom computing technology.

A critical element of any successful effort to integrate technology into the curriculum is access to adequate classroom technology and support; however, as this research illustrates, they are not sufficient to ensure successful integration. This research demonstrates other forces are at work, and that key to the success of such an effort is the "fit" between the new technology and the characteristics of the classroom system, especially those of the teacher who effectively functions as the gatekeeper for the technology. The preceding discussion raises a number of issues related to the introduction of technology into elementary school classrooms, and how the characteristics of classroom stakeholders mediate the effects of the technology on the system.

Although most children are enthusiastic about the presence of computers in the classroom and the home, the benefits of the technology are not always clear-cut. With the exception of writing standardized test performance and some subjective motivation differences, few significant differences were found between the PCF and control groups on non-technology measures. This research found little evidence that the intervention was the driver for sustained changes in family support or involvement in learning, but despite limited utilization of the computer during classroom hours, this research did find intriguing links between student home computer use and changes in student performance and motivation. Student computer use was associated with student entry characteristics and different personality type indicators. However, given the intervention design, causality cannot definitively be assigned.

CHAPTER 9. REFERENCES

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APPENDICES

Appendices Table of Contents

APPENDIX A: PCF IRB MATERIALS 204

A.1 PCF IRB PROTOCOL 205
A.2 INFORMED CONSENT FORMS FOR PCF SELECTION PROCESS 212
A.3 INFORMED CONSENT FORM FOR PARENTS 215
A.4 STUDENT ASSENT FORM 219
A.5 SIBLING ASSENT FORM 222

APPENDIX B: EVALUATION INSTRUMENTS 224

B.1 OVERVIEW 225
B.2 CHILD MUSCULOSKELETAL DISCOMFORT SURVEY 226
B.3 FAMILY HOMEWORK EFFORT 227
B.4 HOMEWORK DELIVERY TRACKING FORM 230
B.5 PARENTAL INVOLVEMENT FORM 231
B.6 TRAINING SKILLS CHECKLIST 233
B.6.1 Computer Skills Targeted by PCF Training 236

APPENDIX C: PROCEDURES USED FOR PRELIMINARY TESTING OF DATA 240

APPENDIX D: DESCRIPTIVE INFORMATION AND DETAILED ANALYSIS RESULTS 242

D.1 RESULTS FOR INDIVIDUAL MEASURES 244
D.1.1 Student Attitude and Motivation Results 244
D.1.2 Student Performance Results 261
D.1.3 Family Support Results 280
D.2 PATTERNS AND PREDICTORS OF COMPUTER USAGE 285
D.2.1 Classroom Computer Usage 285
D.2.2 Student Self-Reports of Home Computer Usage 288
D.2.3 Evolution of Electronic Social Networks 295
D.2.4 Physical Effects of PCF Student Computer Use 296
D.3 PATTERNS AND PREDICTORS OF STUDENT CHANGES 297
D.3.1 Differences in Student Academic Efficiency 297
D.3.2 Patterns of Relationships Among Experimental Measures 297

APPENDIX E: SUMMARY TABLES OF SIGNIFICANT CORRELATIONS BETWEEN EVALUATION MEASURES 304

E.1 TECHNOLOGY SKILLS 304
E.2 TECHNOLOGY USAGE 308
E.3 STUDENT ATTITUDES 310
E.4 STUDENT PERFORMANCE 312
E.4.1 Homework Process 316

APPENDIX F: WORKSTATION DESIGNS FROM THE PARTICIPATORY SESSIONS.........................317

F.1 ISSUES LIST 318
F.2 POST-SESSION STRUCTURED INTERVIEW PROTOCOL 318
F.3 DESIGN SUMMARIES 319
F.3.1 CHILD1 320
F.3.2 CHILD2 320
F.3.3 CHILD3 321
F.3.4 CHILD4 322
F.3.5 CHILD5 322
F.3.6 PARENT1 323
F.3.7 PARENT2 323
F.3.8 PARENT3 323
F.3.9 PARENT4 323
F.3.10 TEACHER1....324
F.3.11 TEACHER2....324

APPENDIX A: PCF IRB MATERIALS

Note: The field research was a subset of planned PCF research and was covered by the larger PCF Institutional Review Board (IRB) submittal.

Appendix Table of Contents

A.1 PCF IRB PROTOCOL........205
A.2 INFORMED CONSENT FORMS FOR PCF SELECTION PROCESS........212
A.3 INFORMED CONSENT FORM FOR PARENTS........215
A.4 STUDENT ASSENT FORM........219
A.5 SIBLING ASSENT FORM........222

A.1 PCF IRB Protocol

PCs For Families

Field-Initiated Studies Educational Research

Institutional Review Board Protocol

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August 3, 1998

Testing a Network-Based Approach to Home-School Coupling in Elementary Education

PCs for Families

Justification of Project

There is much concern that our children have fallen educationally behind their peers in other major world nations. Network-based computing technology has provided strong hope for K-12 educational reform; however, the Benton Foundation estimates that only 3% of all US classrooms even have Internet access. There is almost no information about how the Internet is used in these classrooms, and almost nothing is known about the effect of network access on student achievement under the best of circumstances.

We are initiating the 3rd year of a 5-year longitudinal study of the effect of a stimulating and carefully designed constructivist network-based curriculum to be implemented in the context of a networked rural community. The curriculum will be designed to require substantial parental involvement and major changes in the relationships among the participants in the educational process.

A fifth-grade classroom has been designed which has a networked computer for every two children, and a networked computer will be placed in the home of every child in that classroom. A study is to be made of family and student achievement as the students progress through the first two years of middle school, armed with the best networked computing capabilities and learning methodology we can reasonably provide. The results of this study will be fundamental to major decisions about the future of technology in the schools, not only in Montgomery County, but nationally.

General Procedures

The subject pool for this research consists of the students and their parents at Riner Elementary School in Montgomery County, Virginia, and control groups from sister schools in Montgomery County. The proposed curriculum is aimed at 5th grade, and a study will be made of both parents, students, and immediate family as the students progress through the first two years of middle school. The following subject pools will be used in the study for year 3:

- **(A)** 24 students (12 boys and 12 girls) in a specially designed fifth-grade classroom at Riner Elementary School, with teacher Ms. Susan Hood (Level 1 participants);

- **(B)** 24 students (12 boys and 12 girls) in the another fifth-grade classroom at Riner Elementary School (Level 2 participants);

- **(C)** fifth-grade students selected randomly from Montgomery County and matched by achievement scores and publicly available demographic information to those students in pool A.

Our study is primarily a 3-year longitudinal study, in which we will train students and their families in the PCs for Families program in computer and Internet usage in the first year and track their progress for another two years or until the next standardized tests are given after that by the school district. Participation in either pool A or pool B will be limited to those students who have been in the MCPS through the entire 3rd and 4th grades. This should increase the likelihood that families will remain in MCPS during the three year period needed to complete the longitudinal study.

We will track three consecutive Level 1 classes taught by Ms. Susan Hood, each for a period of three years. Thus for three consecutive years, we will randomly select new classes of 24 students and their control-group counterparts. Since we will track three consecutive classes, each for a period of three years, we will collect data for a total of five years from the date of program start. However, due to limitations of project resources, only the first class will have full technical support, including dial-up services, furnished by the project for all three years.

Every Level 1 student in Ms. Hood’s class will be provided with a personal computer to take home. Each configuration will be similar to that of the computers at school. When plugged in at home and through dial-up access provided by the program, these computers will connect the students with each other, with the schools and teachers, with the community, and with the worldwide information resources of the Internet. The students and their parents will be trained in the usage of both the computers and the Internet. Level 2 students will also be eligible to attend an after-school program to learn about computers and networking, and Level 2 parents will have the opportunity to learn the same information.

We will determine how students and their families use the Internet and the readily available personal computer. We will determine whether we can make substantive improvements in the social relationships important to the educational process and give the students a new perspective on their citizenship in a world information society.

Data will be collected from both students and their families in the PCs for Families group and the control groups. The data will cover a wide spectrum, including: student achievement and attendance records over the three years of a student's participation, questionnaires and in-class exercises, computer usage logs, automated data logging of user access, and student and family interviews.

The Subject Selection Process (Approved by IRB in May and carried out)

Each 4th-grade family will be sent a letter from Dr. Jeff Perry, principal of Riner Elementary School, inviting them to participate in the PCs for Families Program. Each family will also be sent a parental consent form, a student assent form, a parent survey, and a child survey. To be eligible for the random selection process to be held near the end of May, 1998, the families must return the signed forms, and their child must have been in the school system through the entire 3rd and 4th grades to ensure that the schools have a complete test history. Families will be told that they may withdraw from the program at any time.

Families who return the forms must appear at the drawing or designate a surrogate if they cannot attend in person. In the first drawing, 24 boy families and 24 girl families will be selected. Then we will draw 12 girls and 12 boys for Level 1, and the rest will be Level 2. Level 2 families will be the alternates for Level 1, should any families drop out.

To participate in the selection process, the families must agree

- To return the completed forms in their package;
- To complete 3 parent survey sets and to complete 3 student survey sets during the fifth-grade school year if selected for Level 1 or Level 2;
- To have their children complete short personality typing and learning styles inventories if selected for Level 1 or Level 2;
- To give a personal interview about family and computing background if selected for Level 1;
- To attend two introductory computer training sessions during the summer if selected for Level 1;
- To sign full consent forms at the beginning of the school year if selected for Level 1.

Families who fail to complete the above process may be dropped from the program.

The PCs for Families Experiment (for which IRB approval is being requested)

The following is a summary of the data that will be collected. This is very similar to the procedure approved by the IRB in the previous two years.

- Surveys for pools A and B will be administered periodically through out the year, with individual surveys being administered no more than 3 times during the year. Each administration provides information about learning and computer usage, with separate forms for parents and students;
- A child-level adaptation of the Myers-Briggs Personality-Type Indicator (Murphy Meisgeier) for pools A and B, at the beginning of the class, to determine individual student temperaments and motivations;
- Learning Styles Inventory for pools A and B, at the beginning of the class, such as that from the Center for New Discoveries in Learning **(www.howtolearn.com/personal.html)**;
- Several short cognitive tests, such as the ETS cognitive tests S-1, S-2, and SS-1;
- Interviews with several families in pool A to assess progress, not more frequently than twice each year;
- Videotapes and logs of fifth grade classroom activities for pools A and B to help assess the educational process and classroom ergonomics;
- Videotapes of family computer training sessions for assessing progress in family technology education;
- Proxy and server logs showing World Wide Web documents and images accessed by pool A;

- Mail server logs showing destinations of mail sent and sources of mail received by pool A;
- Standardized school test results for pools A and C for Kindergarten through 8-th grade.

We will be evaluating only aggregate data; in the case of pool C, individual scores will be used only to determine control group membership. We will attempt to match two fifth-grade students elsewhere in the school system with each of the 24 students in pool A. Matching will be based upon standardized school achievement tests from Kindergarten through 4th grade and upon public demographic information such as distance of homes from population centers, free lunch data, or public utilities. Pool B will serve as the control group for general school measures, survey measures, and in-class activities measures.

Should a student drop out the pool A or pool B classes, the student will have the option of staying in the class or moving to another. In the latter case, a determination will have to be made as to whether another student will be permitted to join the class at a late date, since this may compromise the primary experimental groups.

Risks and Benefits

There are only minimal risks associated with this study. The students and their family in both pool A or pool B may benefit from after-school computer training, while those in pool A may benefit from the usage of a computer and Internet access, both at school and at home. The pool A students may also benefit from a stimulating constructivist curriculum.

There is a minor risk to pool A that a family member or user of a home computer may damage the computer due to negligence and will be held responsible for repair or replacement.

There is a risk that the children in pool A might access undesirable materials through the Internet. Every parent in the Montgomery County public school system is aware of this and has signed an acceptable use agreement. In addition, mandatory site blocking software is maintained by Montgomery County Public Schools, and software will be offered free to those parents who wish to use it. Thereafter the parents will be responsible for the maintenance of the software databases and any associated fees. Through these measures, through supervision, and by encouraging parental supervision, we are making all reasonable efforts to ensure that this will not be a problem.

The composition of the students in pool C will be kept confidential. None of the students in pool C will be aware that their performance will be compared to that of pool A. MCPS personnel will assist in identifying matching students for pool C, and they will keep the actual student names confidential. All published data will be anonymous, and none will ever be traceable to a particular child. A parent may request the raw data we collect from their child. However, no other data will be revealed, aside from the published study results.

Since we will not provide computers or Internet access to students in the pools B or C, for them, there are no significant risks or benefits; they will not be aware of their participation in the study. We will apply the same safeguards related to student scores and performance for the control group as we apply to those in pools A and B.

Level 1 parents will be compensated by the computers and services they will receive.

Level 2 parents will be paid $2 for each of the first two survey sets and an additional $5 for completing the 3rd survey set during the school year.

Confidentiality/Anonymity

Since data will be based on student performance scores and other sensitive information about the students and their families, anonymity is a primary concern. All data will be backed up and secured in two places, under lock and key in a file cabinet in Dr. Ehrich's office, and in the Riner school principal's office. School officials working with the investigators will be specifically asked to keep the identity of the control group members strictly confidential.

Since the research is a study extends over five years, pool A and B anonymity cannot be maintained from the researchers. However, all data released outside the group of researchers will be analyzed and processed so that no results will ever reveal the identity of individual subjects.

All collected data is required to be kept for five years after the conclusion of the project. At the project conclusion, all names associated with the study will be removed, and collected data will be destroyed in year 2006.

Informed Consent

Since state-mandated standardized testing is routinely used for programmatic assessment, and since there is ample precedent for the use of such results in public studies, no additional consent is deemed necessary for the control groups in pool C. This will also preserve the anonymity of the control groups and prevent their contamination.

When the school year begins, students and families in pool A will be required to sign three documents, one a parental consent form, the second a student assent form, and the third an agreement with the county school system.

All participating families have been told and will continue to be told that they may withdraw from the program at any time. That is so stated on each form.

Biographical Sketches

The biographical sketches of the principal investigators are in the attachments. The principal investigators in this study who will have access to the raw data from pools A and B from this research are:

- Roger W. Ehrich (Professor, Department of Computer Science, Virginia Tech);
- Melissa Matusevich (Instructional Coordinator, Montgomery County Public Schools);
- Keith Rowland (Former Principal, Riner Elementary School).

They will be assisted and supported by the following people who will also have access to raw subject data:

- Jeff Perry (Principal, Riner Elementary School)
- Susan Hood (Teacher, Riner Elementary School);
- Melissa Lisanti (Educational Research Associate, Montgomery County Public School);
- Faith McCreary (Research Assistant, Department of Computer Science, Virginia Tech).

A.2 Informed Consent Forms for PCF Selection Process

PCs for Families Program (Level 1)

Agreement

The purpose of this letter is to request permission for your child to participate in a 3-year program sponsored by the US Department of Education and to clarify your benefits and obligations. The program's purpose is to determine how much your child's achievement improves in a home-classroom environment where he or she has convenient access to a networked personal computer. Your child has been assigned to a fifth grade class taught at Riner Elementary School taught by Susan Hood, in which all children will have access to grant-provided computers both at school and at home.

Your child will receive the same curriculum as the other fifth grade classes, but there will be more emphasis on projects and exploration using the computer at school and at home. After 5th grade, your child will continue in a regular middle school class. Although your child will no longer be in a computer-based classroom, he or she will still have computer access at school and at home. Another aspect of your child's education is that it will be strongly family-oriented. You will be encouraged to participate actively in your child's learning. Experience has shown that children learn more in a family learning environment where they are encouraged to explore, to read, to write, and to discover the world around them. The program will have the additional benefits that

- Your fifth-grade child will gain knowledge about today's information technology, such as how to locate information on the World Wide Web.
- Your child will be taught that we are always learning and that wonderful resources are available to help us learn, and he or she will be taught how to evaluate the reliability and usefulness of these resources.
- Your child may become better at making decisions because he or she will learn how to find relevant information and how to use it.
- Your family will have free use of a powerful networked computer as long as you actively participate for the next three years, after which you will receive title to the computer.

A family participating in this program will be lent a computer by Virginia Tech. A family may leave the project at any time, but must then return all computing equipment. A family that fulfills its obligations for the full three years will be given complete title to the computing equipment, and it will then belong to your family. A student who leaves the Montgomery County public school system before completing 7th grade will be considered to have left the project and will be expected to return all equipment. Support offered by this project is contingent on continued funding from the Department of Education.

Obligations of the School

- The project will provide all necessary hardware and software and will provide free networking as long as the project is funded by the US Department of Education.

- The project will provide maintenance for those computers that fail for normal reasons as long as the project is funded by the US Department of Education.

- Some parents are concerned that their children might access undesirable materials through the computer network. The project will provide site-blocking software to decrease the probability that the students will access such materials over the network.

- The project will train both students and parents about hardware, software, and networked computing.

Obligations of the Parents and Other Family Members

- Parents and caretakers agree to give participating children priority access to the home computer.

- The parents agree to attend a series of classes to learn how to use their computers and the computer network. The number of classes will depend upon previous experience. The classes will be taught at the school site in Mrs. Hood's classroom. Parents agree to permit some sessions to be video taped to help us gauge the learning process.

- The parents or caretakers agree to supervise their children's use of the computer at home and to ensure that they are using the equipment responsibly. This includes other children or adults who may use the equipment.

- Parents accept responsibility for maintaining the site-blocking software if they decide to use it. The parents assume full responsibility for materials downloaded by their children.

- Parents agree to repair damage to the equipment due to personal negligence, such as dropping equipment or pouring liquids into the keyboard. Normal computer failures will be repaired by the project staff.

- Parents and family members agree to take reasonable precautions against theft and damage from storms.

- Parents agree to return the equipment in good condition if they leave the program early or leave the Montgomery County public school system before completing 7^{th} grade.

- Parents and their children agree to permit the investigators to use the results of standardized tests anonymously to determine their progress from the time they first entered school through the 7^{th} grade.

They agree to have their children complete several short tests to help us understand how they learn.

- Parents and their children agree to complete a series of surveys. The information will be kept in strictest confidence.

- Parents and family members will participate in interviews.

- Parents and family members will allow the investigators to log network use. All such logs will be kept in strictest confidence.

- Parents will keep all passwords confidential and will not permit others to use their mail and network accounts.

Obligations of the Student

- Students will not provide their name, address, or phone number over the network without permission from a teacher, parent, or guardian.

- Students agree to respect the equipment to which they will have access and not to abuse it.

- Students agree to respect the privacy and personal property of others, and they agree not to do anything that will make it harder for others to do their work.

- Students agree not to tamper with programs that record or restrict computer use and will adhere to the code of ethics as set forth by the project staff.

- Students will participate in interviews.

- Students will allow the investigators to log their network use. All such logs will be kept in strictest confidence.

- Students will keep all passwords confidential and will not permit others to use their mail and network accounts.

Signatures

Parent or Guardian: ____________________________ Date: ____________________

Parent or Guardian: ____________________________ Date: ____________________

Child: ____________________________ Date: ____________________

Principal: ____________________________ Date: ____________________

Notary: ____________________________ Date: ____________________

A.3 Informed Consent Form For Parents

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Parents/Guardians of Student Participants (Level 1)

Title of Project: Testing a Network-Based Approach to Home-School Coupling in Elementary Education (PCs for Families)

Principal Investigators: Roger W. Ehrich, Department of Computer Science, 231-5420, ehrich@cs.vt.edu; Melissa Matusevich, Montgomery County Public Schools, 382-5100, melissa@bev.net; B. Keith Rowland, Falling Branch Elementary School, 381-6145, rowlandk@bev.net.

I. The Purpose of this Research Project
The US Department of Education is supporting the third year of a 3-year program to determine how much a child's achievement improves in a home-classroom environment where he or she has convenient access to a networked personal computer. If you agree to participate, your child will be assigned to a fifth grade class taught at Riner Elementary School taught by Susan Hood, in which all children will have access to grant-provided computers both at school and at home. You and your child have already given your consent to participate in the program. The purpose of this agreement is to clarify your obligations if you still agree to participate.

II. Procedures
Your child will receive the same curriculum as the other fifth grade classes, but there will be more emphasis on projects and exploration using the computer at school and at home. After 5th grade, your child will continue in a regular middle school class. Although your child will no longer be in a computer-based classroom, he or she will still have computer access at school and at home. Another aspect of your child's education is that it will be strongly family-oriented. You will be encouraged to participate actively in your child's learning. Experience has shown that children learn more in a family learning environment where they are encouraged to explore, to read, to write, and to discover the world around them.

We would like to observe students in the participating classrooms to better understand educational processes and classroom ergonomics. Periodically we wish to video tape these classes so that we may discuss the ways the students are working with one another. In-class performance measures, *e.g.* homework completion statistics, will also be collected.

Parents or guardians will be asked to complete survey sets at least three times a year about their attitudes and experiences related to computers and learning. Some parents of the participating students may be interviewed occasionally to learn about their reactions to the program and to ensure that they are satisfied with their educational experience.

Similarly, students will be asked to complete survey sets at least three times a year about their attitudes and experiences related to computers and learning, and we may wish to interview them. Students will also be asked to complete a Learning Styles Inventory that is used to determine how a student prefers to learn, a Murphy-Meisgeier Personality-Type Indicator to determine temperament and motivations. Students will also complete a short cognitive test to determine visualization ability. Student achievement scores, grades, and other performance measures will be used to determine if increased exposure to networked computing changes student motivation, attitudes, or performance. Such data may also be collected for siblings to determine whether the students' work is also affecting the education of brothers and sisters.

Student achievement scores, grades, and other performance measures will be used to determine if there are differences in achievement in comparison with other MCPS students who have not participated in this educational program. Such data may also be collected for siblings to determine whether the students' work is also affecting the education of brothers and sisters.

III. Risks

There are only minimal risks associated with this program. There is a risk that a family member or user of a home computer may damage the computer due to negligence and will be held responsible for repair or replacement. The computer with printer has a value of roughly $2,000.

Some parents may be concerned that their children might access undesirable materials through the computer network. Every parent in the Montgomery County public school system has signed an Acceptable Use Agreement. The school will install site blocking software on classroom computers to decrease the probability that the students will access such materials. Parents will be offered similar software free of charge for their home computers. Thereafter the parents will be responsible for the maintenance of the software databases and any associated fees.

IV. Benefits of this Project

- Your fifth-grade child may gain knowledge about today's information technology, such as how to locate information on the World Wide Web.
- Your child will be taught that we are always learning and that wonderful resources are available to help us learn, and he or she will be taught how to evaluate the reliability and usefulness of these resources;
- Your child may become better at making decisions because he or she will learn how to find relevant information and how to use it.
- Your family will have free use of a powerful networked computer as long as you actively participate for the next three years, after which you will receive title to the computer.
- You will be helping educators and government leaders at all levels make informed decisions about the use of technology in supporting public education.

V. Confidentiality

No one other than investigators and the participating teachers will have access to classroom data, logs, questionnaire data, or standardized test results without additional written consent. All students will participate anonymously; no performance or personal information will ever be revealed that will be attributable to a particular student. All physical data will be stored in locked cabinets at the school or at Virginia Tech. Electronic data will be stored on a restricted-access computer at Virginia Tech, and normal security measures will prevent unauthorized access. All data will be destroyed 5 years after the conclusion of the project.

VI. Compensation

There is no monetary compensation for your child's participation in this program. However, families participating for the full three-year period will receive title to their home computer.

VII. Freedom to Withdraw
You are free to withdraw your child from this program at any time, although your home computer must be returned in good condition.

VIII. Approval of Research
This research has been approved, as required, by the Institutional Review Board for projects involving human subjects at Virginia Polytechnic institute and State University, by the Department of Computer Science, and by the Montgomery County Public Schools.

IXa. Responsibilities of Parents, Guardians, and other Family Members
I, the parent or guardian of the child selected for the PCs for Families program, voluntarily agree to participate in this study and agree to the following responsibilities:

- The family agrees to remain in the Montgomery County Public School System until the child has completed 7th grade.
- Parents and caretakers agree to give the participating fifth grade child priority access to the home computer.
- The parents agree to attend a series of classes to learn how to use their computers and the computer network. The number of classes will depend upon previous experience. The classes will be taught at the school site in Mrs. Hood's classroom. Parents agree to permit some sessions to be video taped to help us gauge learning progress.
- The parents or caretakers agree to supervise their children's use of the computer at home and to ensure that they are using the equipment responsibly. This includes other children or adults who may use the equipment.
- Parents accept responsibility for maintaining the site-blocking software if they decide to use it. The parents assume full responsibility for materials downloaded by their children.
- Parents agree to repair damage to the equipment due to personal negligence, such as dropping equipment or pouring liquids into the keyboard. Normal computer failures will be repaired by the project staff.
- Parents and family members agree to take reasonable precautions against theft and damage from storms.
- Parents agree to return the equipment in good condition if they leave the program early or leave the Montgomery County public school system before completing 7th grade.
- Parents and their children agree to permit the investigators to use the results of standardized tests, grades, and other performance measures anonymously to determine their progress from the time they first entered school through the 7th grade. Parents agree to permit similar data to be collected for siblings. They agree to have their children complete several short tests to help us understand how they learn.
- Parents and their children agree to complete a series of surveys. The information will be kept in strictest confidence.
- Parents and family members will participate in interviews.
- Parents and family members will permit the investigators to cite observations and use quotes from interviews in publications with the understanding that their names will never be used.

- Parents and family members will allow the investigators to log network use. All such logs will be kept in strictest confidence.

- Parents will keep all passwords confidential and will not permit others to use their mail and network accounts.

IXb. Responsibilities of the Student

- Students will not provide their name, address, or phone number over the network without permission from a teacher, parent, or guardian.

- Students agree to respect the equipment to which they will have access and not to abuse it.

- Students agree to respect the privacy and personal property of others, and they agree not to do anything that will make it harder for others to do their work.

- Students agree not to tamper with programs that record or restrict computer use.

- Students will participate in interviews.

- Students will allow the investigators to log their network use. All such logs will be kept in strictest confidence.

- Students will keep all passwords confidential and will not permit others to use their mail and network accounts.

X. Subject's Permission

I have read and understand the informed consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for my child's participation in the project.

Student's Name ____

Signature of Parent/Guardian _____________________________ Date: _____________

Should I have any questions about this research or its conduct I may contact:

Dr. Roger Ehrich (Principal Investigator)	(540) 231-5420
Tom Hurd (Chair, IRB, Research Division)	(540) 231-5281

A.4 Student Assent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Assent for Student Participants

Title of Project: Testing a Network-Based Approach to Home-School Coupling in Elementary Education (PCs for Families)

Principal Investigators: Roger W. Ehrich, Department of Computer Science, 231-5420, ehrich@cs.vt.edu; Melissa Matusevich, Montgomery County Public Schools, 382-5100, melissa@bev.net; B. Keith Rowland, Falling Branch Elementary School, 381-6145, rowlandk@bev.net.

I. The Purpose of this Research Project
This is a 3-year project to learn whether networked computing helps improve long term learning and achievement.

II. Procedures
If selected for this program and you decide to participate, you and your parents will be given the opportunity during your fifth grade year to learn more about computers and networking. Some of the students in the program will have increased access to computers in their classrooms and their homes. You will be asked to take several tests to help us understand how you learn and to determine your skill at visualizing patterns. We may interview you to find out how you feel about your experiences in the program. Also, you will be asked to fill out questionnaires several times during the year to help us detect changes in your attitudes and experiences related to computers and learning. Sometimes we may want to videotape your class to see how you are using computers. We will look at your regular achievement scores for three years to see what changes occur.

III. Risks
There are no physical risks to you in this program.

IV. Benefits of the Project
If selected, you will have the opportunity to learn much about computers and information technology that will help you in school and in your career, and you will be helping school administrators make decisions about the kinds of classrooms and instructional programs that will be offered in the future.

V. Confidentiality
Your names and test scores will never be known to anyone besides the project staff, nor will any class video tapes be shown to other people. Your name will never be used

VI. Compensation
If selected, you will be given the opportunity to participate in this program. You will not get anything for participating in this study, although we hope you will have some new educational opportunities and better access to networked computers.

VII. Freedom to Withdraw
You are free to stop participating in this study at any time without penalty. You may move to one of the other classrooms if you wish.

VIII. Approval of Research
This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University and by the Montgomery County Public Schools.

IX. Subject's Responsibilities
As part of the project selection process,

- I agree to complete the initial student survey and the student assent form by the required date.

If selected for the project,

- I agree to respect the equipment to which I will have access and not to abuse it. I agree also to abide by the Acceptable Use Agreement signed by my parent or guardian.

- I agree to respect the privacy and personal property of others, and I agree not to do anything that will make it harder for others to do their work.

- I agree not to provide my name, address, or phone number over the computer network without permission from a teacher, parent, or guardian.

- I agree not to tamper with automatic logging software or with software to restrict network access.

- I agree to participate in interviews addressing the use of the computer as needed for the project, and I agree to complete the questionnaires to help the project staff understand my computer abilities and how I learn. I agree to let things I say be quoted as long as my name is never mentioned.

- I agree to keep all passwords to myself and not let anyone else use them.

X. Subject's Permission
I have read and understand the informed consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for my inclusion in the project selection process. Further, if selected for the project, I give my voluntary consent to participate in this project.

Student's Name ____

Signature of Student _____________________________________ Date: ____________

Should I have any questions about this research or its conduct I may contact:

Dr. Roger Ehrich (Principal Investigator)	(540) 231-5420
Tom Hurd (Chair, IRB, Research Division)	(540) 231-5281

A.5 Sibling Assent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Assent for Siblings of Student Participants

Title of Project: Testing a Network-Based Approach to Home-School Coupling in Elementary Education (PCs for Families)

Principal Investigators: Roger W. Ehrich, Department of Computer Science, 231-5420, ehrich@cs.vt.edu; Melissa Matusevich, Montgomery County Public Schools, 382-5100, melissa@bev.net; B. Keith Rowland, Falling Branch Elementary School, 381-6145, rowlandk@bev.net.

I. The Purpose of this Research Project
This is a 3-year project to learn whether networked computing helps improve long term learning and achievement.

II. Procedures
While your brother or sister is in our program, you will have increased access to computers in your home. You may also have your own electronic mail account if you wish. You will be able to learn more about computing, and your parents can learn more about computers in a program designed for them. You may take several short tests to help us understand how you learn and to determine your skill at visualizing patterns. We may interview you to find out how you feel about your experiences in the program. Also, you will be asked to fill out questionnaires three times during the year to help us detect changes in your attitudes and experiences related to computers and learning. We will look at your regular achievement scores for three years to see what changes occur.

III. Risks
There are no physical risks to you in this program.

IV. Benefits of the Project
If selected, you will have the opportunity to learn much about computers and information technology that will help you in school and in your career, and you will be helping school administrators make decisions about the kinds of classrooms and instructional programs that will be offered in the future.

V. Confidentiality
Your names and test scores will never be known to anyone besides the project staff, nor will any class video tapes be shown to other people. Your name will never be used

VI. Compensation
If selected, you will be given the opportunity to participate in this program. You will not get anything for participating in this study, although we hope you will have some new educational opportunities and better access to networked computers.

VII. Freedom to Withdraw
You are free to stop participating in this study at any time without penalty. You may move to one of the other classrooms if you wish.

VIII. Approval of Research
This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University and by the Montgomery County Public Schools.

IX. Subject's Responsibilities
As part of the project selection process,

- I agree to respect the equipment to which I will have access and not to abuse it. I agree also to abide by the Acceptable Use Agreement signed by my parent or guardian.

- I agree to respect the privacy and personal property of others, and I agree not to do anything that will make it harder for others to do their work.

- I agree not to provide my name, address, or phone number over the computer network without permission from a teacher, parent, or guardian.

- I agree not to tamper with automatic logging software or with software to restrict network access.

- I agree to participate in interviews addressing the use of the computer as needed for the project, and I agree to complete the questionnaires to help the project staff understand my computer abilities and how I learn. I agree to let things I say be quoted as long as my name is never mentioned.

- I agree to keep all passwords to myself and not let anyone else use them.

X. Subject's Permission
I have read and understand the informed consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for my inclusion in the project selection process. Further, if selected for the project, I give my voluntary consent to participate in this project.

Student's Name ____

Signature of Student _____________________________________ Date: ____________

Should I have any questions about this research or its conduct I may contact:

Dr. Roger Ehrich (Principal Investigator) (540) 231-5420
Tom Hurd (Chair, IRB, Research Division) (540) 231-5281

APPENDIX B: EVALUATION INSTRUMENTS

Appendix Table of Contents

B.1 OVERVIEW 225
B.2 CHILD MUSCULOSKELETAL DISCOMFORT SURVEY 226
B.3 FAMILY HOMEWORK EFFORT..227
B.4 HOMEWORK DELIVERY TRACKING FORM 230
B.5 PARENTAL INVOLVEMENT FORM..231
B.6 TRAINING SKILLS CHECKLIST 233
B.6.1 Computer Skills Targeted by PCF Training *236*

B.1 Overview

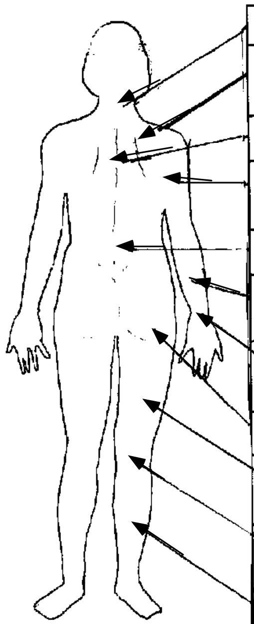
This appendix contains the instruments that were developed (or modified) for the PCF field experiment. Instruments are listed alphabetically by name. The following instruments were used in their original form and are not included here.

- Attitudes Toward Writing With the Computer Scale (Shaver, 1990)
- Harter Intrinsic vs. Extrinsic Motivation Scale
- Homework Problem Checklist (Anesko, Schoiock, Ramirez, and Levine, 1987)
- How Do You Feel About Computers Scale (Todman and File, 1990)
- Learning Styles Inventory
- Child Murphy-Meisgeiner Type Indicator
- School Attitude Measure, Level G/H (American College Testing)

B.2 Child Musculoskeletal Discomfort Survey

Note: modification of adult Cornell Musculoskeletal Discomfort Questionnaires (Human Factors and Ergonomics Laboratory at Cornell University, 1997).

The picture below shows the approximate location of the body parts listed below. Answer the questions to the right by marking the answer that is closest to how you feel.



		During the last week how often did you feel aching, pain, or discomfort in:					If you felt aching, pain, or discomfort, how uncomfortable was it?			If you experienced ache, pain, discomfort, did this keep you from working on the computer ?		
		Never	1-2 times a week	3-4 times a week	Daily	Several times a Day	Not at all	Slightly	A lot	Not at all	Slightly	A lot
Neck		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Shoulder	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Back		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Arm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Back		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Forearm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Wrist	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hip/Buttocks		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Thigh	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Knee	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Leg	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

B.3 Family Homework Effort

Student's Name: ___________________________ **Class: Hood Frye**
Date: _________________

Please complete this form AFTER the student has completed his/her homework for the evening.

1. How much time total did the student spend doing homework this evening?
   ______ hours ______ minutes

   How much of that time did the student receive help from a family member?
   ______ hours _______ minutes

   Circle the family members who helped the student with his/her homework this evening? (Circle as many as apply.)

   Father Mother Brother Sister Other family member ____________

2. How much time total was spent using the computer for homework activities this evening? ______ hours _______ minutes

   Of the time spent using the computer, how much time total was spent using the Internet for homework activities this evening? ______ hours _______ minutes

   How much time total did a family member work with the student on the computer to complete homework activities? ______ hours _______ minutes.

   Circle the family members who helped the student with his/her homework on the computer this evening?

   Father Mother Brother Sister Other family member ____________

3. How much time total did the student spend working on homework activities with a classmate this evening? ______ hours _______ minutes

   How many classmates did the student work with this evening? ______

   Circle means by which the student contacted his/her classmates (circle as many as apply).

   Face-to-Face Phone E-mail Chat Room Other __________

4. Did the student contact a teacher about homework tonight? Yes No

   Circle means by which the student contacted the teacher (circle as many as apply).

   Face-to-Face   Phone   E-mail   Chat Room   Other ___________

5. Did the parent contact a teacher about homework tonight? Yes No

   Circle means by which the parent contacted the teacher (circle as many as apply).

   Face-to-Face   Phone   E-mail   Chat Room   Other ___________

6. Check any software used for homework activities this evening.
   _ Word processing applications
   _ Drawing applications
   _ Spreadsheet applications
   _ Email
   _ Chat
   _ Net browsing application, *e.g.* Netscape.
   _ On-line Reference material, *e.g.* Encarta or dictionary.

7. How well does the student like doing homework on the computer? Place an x at the point that is closest to how the student feels.

1	2	3	4	5	6	7
Don't like			Don't care			Like a lot

8. Does the student think doing homework on a computer is easier than doing it without a computer? Place an x at the point that is closest to how the student feels.

1	2	3	4	5	6	7
Doesn't matter			Somewhat easier			Much easier

9. If the student had a choice, would the student rather

_ Do homework WITH a computer
_ Do homework WITHOUT a computer

10. Did the parent contact the homework hotline tonight? Yes No

If so, which homework hotline did the parent access? Phone Hotline Internet Hotline

11. Did the student contact the homework hotline tonight? Yes No

If so, which homework hotline did the student access? Phone Hotline Internet Hotline

Signature of Student : ___________________

Signature of Parent : ___________________

B.4 Homework Delivery Tracking Form

Class : Hood Frye

Instructions : 1) Mark date for each homework item, 2) Check whether homework required a computer (**C**) or didn't require a computer (**NC**), 3) check the names of the students who delivered the homework item on time, and 4) for those students who did not deliver the homework item on time, enter the number of days the homework item was late.

Date ⇒																				
Student ⇓	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC

B.5 Parental Involvement Form

Student's Name:__________________________ **Class : Hood Frye**
Date: ________________________________

Please take the time to complete this form. Your answers will be kept confidential.

1. How many times did you visit the school in the past week? (Do not include the times you were there for the PCF training class or for dropping/picking children up from school.) ______
2. How much time total did you spend at the school this week? (Do not include the times you were there for the PCF training class or for dropping/picking children up from school.) ______ hours ______ minutes
3. How much time total did you spend discussing school with your child this week? ______ hours ______ minutes
4. Check any reasons for your visits to the school in the last week.
   _ School event, *e.g.* concert.
   _ PTA meeting.
   _ Office visit.
   _ Teacher visit.
   _ Volunteering.
   _ Other _________________
5. How many hours this last week did you actively support your child's school? (Include time spent volunteering at the school, time spent participating in school activities, and time spent at home preparing items for bake sales, school fairs, etc.) ____ hours _____ minutes
6. How many times did you contact the school in the last week.
   _ In person
   _ Using the phone
   _ By letter
   _ By email

7. How would you rate the quality of home-school communication this last week?

1	2	3	4	5	6	7
very bad			average			very good

8. If you needed to discuss your child's progress with the school, rank the following communication methods in order of preference. Draw a line between 1 and your most liked method, 2 and your second choice, 3 and your third choice, 4 and the fourth choice, and 5 and the least liked. Draw no line to a particular communication method if you don't know what it is.

1	chat room
2	telephone
3	e-mail
4	face to face
5	letter

9. How aware were you of how your child was doing in school this last week?

1	2	3	4	5	6	7	
	Not Enough			Some			Well Informed

10. How aware were you of what your child was doing in school this last week?

1	2	3	4	5	6	7
Not Enough			Some			Well Informed

B.6 Training Skills Checklist

Student Name : ____________________________________
Date : ______________________________

Instructions : I am going to ask you to perform some tasks on the computer. The project wants to determine what you already know about the computer, so computer class can be made more interesting. If you do not know how to do a particular task, just say so. Don't worry if you cannot perform all the tasks.

<table>
<tr><th rowspan="2">Task</th><th rowspan="2">Task Instructions</th><th rowspan="2">Task Components</th><th colspan="2">Demonstrated Successfully?</th></tr>
<tr><th>Yes</th><th>No</th></tr>
<tr><td rowspan="13">1.</td><td rowspan="2">A. Please find the file Dinosaurs.doc and tell me what type of file it is.</td><td>• Find file.</td><td></td><td></td></tr>
<tr><td>• Identifies file as document.</td><td></td><td></td></tr>
<tr><td rowspan="2">B. Now open Dinosaurs.doc.</td><td>• Opens file with correct application.</td><td></td><td></td></tr>
<tr><td>• Opens correct file.</td><td></td><td></td></tr>
<tr><td rowspan="2">C. Add page numbers to bottom of each page of report.</td><td>• Identifies document footer</td><td></td><td></td></tr>
<tr><td>• Insert page numbers in footer.</td><td></td><td></td></tr>
<tr><td rowspan="5">D. Search the web for additional information on dinosaurs to put in Dinosaurs.doc</td><td>• Opens web browser.</td><td></td><td></td></tr>
<tr><td>• Uses web search engine.</td><td></td><td></td></tr>
<tr><td>• Finds a dinosaur site.</td><td></td><td></td></tr>
<tr><td>• Finds additional dinosaur sites.</td><td></td><td></td></tr>
<tr><td>• Follows a link to another site (optional).</td><td></td><td></td></tr>
</table>

Task	Task Instructions	Task Components	Demonstrated Successfully?	
			Yes	No
	E. Make a table in the dinosaur report using some of the information you just found on the web.	• Creates a table		
		• Adds information to table.		
	F. Close document.	• Saves documents to disk.		
		• Closes window		
2.	**A.** Now open the spreadsheet titled Numbers.xls	• Opens spreadsheet application.		
		• Opens spreadsheet.		
	B. Sum the first column of numbers using a formula then find the average for the first column of numbers.	• Sums first column.		
		• Calculates average		
	C. Make a pie chart using the two columns of data in the spreadsheet.	• Highlights columns.		
		• Invokes chart wizard.		
		• Makes pie chart.		
3.	**A.** Find the folder named volcanoes and copy the folder to a floppy drive.	• Finds folder.		
		• Knows which drive is the floppy drive.		
		• Copies folder to floppy drive.		
	B. Get a listing of files in the folder volcanoes.	• Creates a directory listing.		
	C. Make a subfolder called myfiles in volcanoes.	• Makes a new directory.		

Task	Task Instructions	Task Components	Demonstrated Successfully?	
			Yes	No
	E. Change the color depth of the file image.	• Opens image with correct application.		
		• Changes color depth of image.		
	F. Now crop the image.	• Selects region.		
		• Crops image.		
		• Saves image.		
	G. Print the image you just cropped.	• Print file.		
4.	**A.** Make a slide from the cropped image you were just working on.	• Opens presentation software.		
		• Creates new presentation.		
		• Creates new slide		
		• Inserts graphic.		
	B. Add some text to the slide describing the image.	• Inserts text.		
	C. Add a slide transition for the slide you just finished.	• Adds a slide transition.		

Task	Task Instructions	Task Components	Demonstrated Successfully? Yes	No
5.	Now send the presentation you just created to Mrs. Lisaniti.	• Creates new message.		
		• Inputs receiver address.		
		• Inputs subject.		
		• Types greeting/message.		
		• Attaches presentation.		
		• Sends email.		
6.	**A.** Can you tell me the difference between a disk drive and a hard drive?	• Hard drive in CPU		
		• Files stored in hard drive are not portable.		
		• Files stored on disks in disk drives can be carried around.		
		• Hard drive is usually faster than disk drive		
	B. Can you tell me how you are suppose to sit at a computer?	• Back straight.		
		• Wrists straight.		
		• Feet on floor.		

B.6.1 Computer Skills Targeted by PCF Training

(√ skills are demonstrated as part of the skills checklist)

I. **General window Operations**

A. Resize a window.

B. Close a window. √

II. **General file operations**.

A. Open an existing file. √
B. Identify a file's type without opening file. √
C. Find a particular file. √
D. Create a new file. √
E. Save an existing file. √
F. Copy an existing file to a floppy disk. √
G. Move an existing file to a different folder.
H. Rename a file.
I. Delete a file.
J. Print a file. √

III. **General folder operations.**

A. Create a listing of the files in a folder. √
B. Create a new folder. √
C. Delete a folder.
D. Rename a folder.

IV. **General software operations**.

A. Startup up a program. √
B. Exit from a program. √

V. **General computer hardware knowledge**

A. Difference between hard drive and disk drive. √
   1. hard drive is in the CPU
   2. files stored on hard drive are not portable.
   3. Files stored on disks in disk drives can be carried around.
   4. hard drive is usually faster than disk drive.
B. Can identify monitor.
C. Can identify mouse.
D. Knows correct posture for doing computer work. √

VI. **Word Processing.**

A. Finds word processing software. √
B. Open an existing word processing file. √
C. Find text. √
D. Cut and paste text. √
E. Formatting text.
   1. Change text justification.
   2. Bold or underline text.
   3. Change font size.
   4. Change color of text.
F. Add page numbers. √
G. Change document header.
H. Change document footer. √
I. Create a table. √
J. Insert information in a table. √

VII. **Spreadsheets**

A. Finds spreadsheet software. √
B. Open an existing spreadsheet.
C. Create a spreadsheet. √
D. Input data to a spreadsheet. √
E. Make a chart. √
F. Use formulas on data. √

VIII. **Presentations.**

A. Finds presentation software. √
B. Create a presentation. √
C. Creates a slide. √
D. Add text. √
E. Add a shape**,** *e.g.* circle, to a presentation.
F. Add a rotating object to a presentation.
G. Add an animated object to a presentation.
H. Add a slide transition to a presentation. √

IX. **E-mail**

A. Finds email software. √
B. read mail.
C. send mail √
D. retrieve mail
E. forward mail
F. reply to mail
G. attach a document to mail √
H. create a mail alias.

X. **Web-browsing**

A. Finds web-browsing software. √
B. Find information. √
    1. Multiple sources. √
C. Follow a link to a different page. √
D. Jump to a page using a bookmark.
E. Jump to a page by entering address.

XI. **Images**

A. finds image processing software. √
B. get basic stats for an image.
    1. Number of pixels.
    2. File type
    3. Color depth √
    4. Size
C. Resize an image.
D. Crop an image. √
E. Paint a portion of the image.
F. Use a special effect on an image.

XII. **Graphics**

A. Add graphics to a document or presentation. √
B. Add clipart to a document or presentation.

APPENDIX C: PROCEDURES USED FOR PRELIMINARY TESTING OF DATA

Hypothesis Testing Technique	**Preliminary Tests**	**Analysis Technique**
Correlation	• Independence	Rank Von Neumann (RVN) Test of Randomness
	• Normality	Ryan-Joiner modification of the Shapiro-Wilk Test
Analysis of Variance[+]	• Independence	Rank Von Neumann (RVN) Test of Randomness
	• Normality	Ryan-Joiner modification of the Shapiro-Wilk Test
	• Homogeneity of Variance (Between-Subject Variables)	Levine
	• Sphericity (Within-Subject Variables)	Bartlett's Test of Sphericity
Analysis of Covariance[+]	• ANOVA Preliminary Tests	see previous
	• Linearity	Local Linear Regression Plots Correlation
	• Homogeneity of Slopes	F statistic
Regression Analysis[+]	• ANOVA Preliminary Tests	see previous
	• Linearity	Local Linear Regression Plots Correlation
	• Multicollinearity	Variance Inflation Factor Regression coefficient variance-decomposition matrix
Multivariate Analysis of Variance (MANOVA)[+]	• ANOVA Preliminary Tests [25]	see previous

[+] Due to unequal samples sizes in the field experiment data, General Linear Models (GLMs) were used to perform this technique for the field experiment data.

[25] Assumptions for multivariate analysis are based on multivariate normal distribution and homogeneity of covariances; however, if the usual univariate ANOVA assumptions are valid for each variable, there is generally no problem with the multivariate analysis (Lindman, 1992).

Hypothesis Testing Technique	Preliminary Tests	Analysis Technique
Time Series Analysis	• Autocorrelation • Stationarity • Hetroskedasticity	graphs and Yule Walker method graphs and test of the unit-root hypothesis White Test
Time Series Cross-Sectional Regression	• Autocorrelation • Cross-sectional Correlation	Yule Walker method Correlation
Data Envelopment Analysis	• n/a	n/a
Canonical Correlation	• Normality	Ryan-Joiner modification of the Shapiro-Wilk Test
Cluster Analysis	• Normality	Ryan-Joiner modification of the Shapiro-Wilk Test

APPENDIX D: DESCRIPTIVE INFORMATION AND DETAILED ANALYSIS RESULTS

Appendix Table of Contents

D.1 RESULTS FOR INDIVIDUAL MEASURES 244
D.1.1 Student Attitude and Motivation Results 244
D.1.1.1 Student Overall Attitudes and Motivation for School....................244
D.1.1.1.1 School Attendance....................244
D.1.1.1.2 School Attitude Measure 245
D.1.1.1.2.1 Motivation For Schooling Subscale 246
D.1.1.1.2.2 Student's Sense of Control Over Performance Subscale....................246
D.1.1.1.2.3 Performance Based Academic Self-Concept Subscale....................246
D.1.1.1.2.4 Reference Based Academic Self-Concept Subscale 247
D.1.1.1.2.5 Instructional Mastery Subscale....................247
D.1.1.2 Student Writing Attitudes 247
D.1.1.2.1 Knudson Writing Survey 247
D.1.1.2.1.1 Prefers Writing Scale....................249
D.1.1.2.1.2 Positive View of Self as a Writer Scale....................250
D.1.1.2.1.3 Competent Writer Scale 252
D.1.1.2.1.4 Writing Achievement Scale....................253
D.1.1.2.1.5 Importance of Writing Scale....................255
D.1.1.2.1.6 Letter/Note Writing Scale....................256
D.1.1.3 Student Attitudes Towards Computers 258
D.1.1.3.1 Overall Computer Attitudes....................258
D.1.1.3.2 Computer Writing Attitudes 260
D.1.2 Student Performance Results 261
D.1.2.1 Academic Performance 261
D.1.2.1.1 Standardized Test Performance 261
D.1.2.1.1.1 Reading Achievement....................261
D.1.2.1.1.2 Writing Achievement 263
D.1.2.1.1.3 Mathematics Achievement 265
D.1.2.1.1.4 Social Studies Achievement 267
D.1.2.1.1.5 Science Achievement 269
D.1.2.1.2 Grade Point Average....................271
D.1.2.2 Homework Performance Results....................273
D.1.2.2.1 Homework Reliability....................273
D.1.2.2.2 Time Spent on Homework Activities....................275
D.1.2.2.3 Incidence of Problem Behaviors....................276
D.1.2.3 Technical Skills and Knowledge Results 277
D.1.2.3.1 Computer Task Performance 277
D.1.2.3.2 Technology Standards of Learning Scores 278
D.1.3 Family Support Results 280
D.1.3.1 Home-School Communication....................280
D.1.3.1.1 Perceived Quality 280
D.1.3.1.2 Parent-School Contacts 281
D.1.3.2 Email as a Medium for Parent-Teacher Communication Among PCF Families....................282
D.1.3.3 Homework Help....................283
D.1.3.4 Support For School Activities....................284
D.2 PATTERNS AND PREDICTORS OF COMPUTER USAGE....................285
D.2.1 Classroom Computer Usage 285
D.2.1.1 Total Time Spent Using the Computer 285
D.2.1.2 Analysis of PCF Classroom Computer Usage....................286
D.2.1.2.1 Category of Classroom Application Usage....................286
D.2.1.2.2 Breadth of Classroom Application Usage....................287
D.2.1.2.3 Classroom World Wide Web Usage 287
D.2.2 Student Self-Reports of Home Computer Usage 288

D.2.2.1 Overall Patterns of Home Computer Use 288
D.2.2.1.1 Time Spent Using Home Computer 288
D.2.2.1.2 Time Spent Playing Computer Games 288
D.2.2.1.3 Time Connected to the Internet 289
D.2.2.2 Homework-related Computer Use 290
D.2.2.3 Home Internet Usage by PCF Students 291
D.2.2.3.1 Dispersion of Internet Technologies 291
D.2.2.4 Relative Importance of Internet Technologies 291
D.2.2.5 Factors Influencing Internet Usage 293
D.2.2.5.1 Influences on WWW Usage 293
D.2.2.5.2 Influences on Email Usage 294
D.2.2.5.3 Influences on Chat Usage 294
D.2.2.5.4 Categories of Chat Usage 294
D.2.3 Evolution of Electronic Social Networks 295
D.2.3.1 Differences in Student Network Characteristics 295
D.2.4 Physical Effects of PCF Student Computer Use 296
D.3 PATTERNS AND PREDICTORS OF STUDENT CHANGES 297
D.3.1 Differences in Student Academic Efficiency 297
D.3.2 Patterns of Relationships Among Experimental Measures 297
D.3.2.1 Relationships Between Model Constructs 297
D.3.2.2 Similarities Among Outcome Measures 299
D.3.2.3 Factors Influencing Student Outcomes 301
D.3.2.3.1 Influences on Student Performance 301
D.3.2.3.2 Influences on Student QWL 303

D.1 Results for Individual Measures

D.1.1 Student Attitude and Motivation Results

D.1.1.1 Student Overall Attitudes and Motivation for School

D.1.1.1.1 School Attendance

Tables D-1 thru D-3 present summary descriptive information for these measures. A negative value indicates improved attendance. Tables D-4 thru D-6 summarize the analysis results.

Table D-1. Means (*M*) and standard deviations (*std*) for the CLASS effect on the attendance measures.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
Days Absent (5^{th}) - Days Absent (4^{th})	1.63	3.65	0.43	5.36
Days Tardy (5^{th}) - Days Tardy (4^{th})	2.13	6.00	-0.21	2.41

Table D-2. Means and standard deviations for the GENDER effect on the attendance measures.

	Males		Females	
	Mean	*std*	*Mean*	*std*
Days Absent (5^{th}) - Days Absent (4^{th})	0.57	4.57	1.42	4.60
Days Tardy (5^{th}) - Days Tardy (4^{th})	1.71	6.31	0.38	2.86

Table D-3. Means and standard deviations for the CLASS x GENDER interaction of the attendance measures.

	PCF Students		Control Students	
Males	*Mean*	*std*	*Mean*	*std*
Days Absent (5^{th}) - Days Absent (4^{th})	1.83	2.82	-1.11	5.97
Days Tardy (5^{th}) - Days Tardy (4^{th})	3.67	7.76	-0.89	1.83
Females	*Mean*	*std*	*Mean*	*std*
Days Absent (5^{th}) - Days Absent (4^{th})	1.42	4.44	1.42	4.89
Days Tardy (5^{th}) - Days Tardy (4^{th})	0.58	3.15	0.21	2.69

Table D-4. MANOVA Results for the effect of CLASS on attendance measures.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.91	2.03	2	42	0.145
Pillai's Trace	0.09	2.03	2	42	0.145
Hotelling-Lawley Trace	0.10	2.03	2	42	0.145
Roy's Greatest Root	0.10	2.03	2	42	0.145

* $p < 0.050$

Table D-5. MANOVA Results for the effect of GENDER on attendance measures.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.97	0.63	2	42	0.537
Pillai's Trace	0.03	0.63	2	42	0.537
Hotelling-Lawley Trace	0.03	0.63	2	42	0.537
Roy's Greatest Root	0.03	0.63	2	42	0.537

* $p < 0.050$

Table D-6. MANOVA Results for the effect of CLASS x GENDER interaction on attendance measures.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.93	1.61	2	42	0.213
Pillai's Trace	0.07	1.61	2	42	0.213
Hotelling-Lawley Trace	0.08	1.61	2	42	0.213
Roy's Greatest Root	0.08	1.61	2	42	0.213

* $p < 0.050$

D.1.1.1.2 School Attitude Measure

The mean (M) change in SAM NP for boys was 1.05 with a standard deviation (std) of 22.32, while the mean change for girls was .46 with a standard deviation of 18.16. The mean change for students from the PCF classroom was 2.75 with a standard deviation of 21.59, while the mean change for student from the standard classroom was -1.39 with a standard deviation of 18.20. Table D-7 present summary information for the overall survey and its composite scales. A positive value indicates improvement.

Table D-7. Summary descriptive information for changes in SAM scores over the course of fifth grade.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
Overall SAM Score	2.75	21.59	1.39	18.20
Motivation for Schooling Scale	-3.75	27.95	-9.17	27.34
Academic Self-Concept -- Performance Based Scale	3.08	28.20	3.47	25.81
Academic Self-Concept -- Reference Based Scale	5.17	25.31	1.69	19.69
Sense of Control over Performance Scale	6.83	22.06	9.47	35.33
Instructional Mastery Scale	1.87	33.19	8.04	29.17

A General Linear Model (GLM) was used to do an Analysis of Variance (ANOVA) for this measure. Table D-8 summarizes the analysis results.

Table D-8. ANOVA Summary Table for overall SAM measure.

Source	***df***	***SS***	***MS***	***F***	***p***
Class (CLASS)	1	201.43	201.43	0.54	0.475
Gender (GENDER)	1	0.21	.202	0.00	0.982
CLASS x GENDER	1	2081.46	2081.46	5.62	*0.022
S / CLASS GENDER	43	15930.32			
Total	46	18213.40			

* $p < 0.050$

D.1.1.1.2.1 Motivation For Schooling Subscale

The mean change for boys was -8.62 with a standard deviation of 29.32, while the mean change for girls was -4.62 with a standard deviation of 26.37. The mean change for students from the PCF classroom was -3.75 with a standard deviation of 27.95, while the mean change for student from the standard classroom was -9.17 with a standard deviation of 27.34. A GLM was used to do an ANOVA for this measure. Table D-9 summarizes the analysis results.

Table D-9. ANOVA Summary Table for the SAM / Motivation for Schooling measure.

Source	***df***	***SS***	***MS***	***F***	***p***
Class (CLASS)	1	345.51	345.51	0.49	0.488
Gender (GENDER)	1	248.76	248.76	0.35	0.557
CLASS x GENDER	1	3699.83	3699.83	5.22	*0.027
S / CLASS GENDER	43	30475.22			
Total	46	34769.32			

* $p < 0.050$

D.1.1.1.2.2 Student's Sense of Control Over Performance Subscale

The mean change for boys was 10.19 with a standard deviation of 26.73, while the mean change for girls was 6.46 with a standard deviation of 31.18. The mean change for students from the PCF classroom was 6.83 with a standard deviation of 22.06, while the mean change for students from the standard classroom was 9.47 with a standard deviation of 35.33. A GLM was used to do an ANOVA for this measure. Table D-10 summarizes the analysis results.

Table D-10. ANOVA Summary Table for the SAM / Student's Sense of Control over Performance measure.

Source	***df***	***SS***	***MS***	***F***	***p***
Class (CLASS)	1	82.16	82.16	0.10	0.759
Gender (GENDER)	1	189.97	189.97	0.64	0.641
CLASS x GENDER	1	1448.69	1448.69	1.68	0.202
S / CLASS GENDER	43	37026.41	861.07		
Total	46	38747.23			

* $p < 0.050$

D.1.1.1.2.3 Performance Based Academic Self-Concept Subscale

The mean change for boys was -0.86 with a standard deviation of 33.85, while the mean change for girls was -0.46 with a standard deviation of 20.52. The mean change for students from the PCF classroom was 3.08 with a standard deviation of 28.20, while the mean change for student from the standard classroom was -3.47 with a standard deviation of 25.81. Table D-11 summarizes the analysis results.

Table D-11. ANOVA Summary Table for the SAM / Academic Self-Concept -- Performance Based measure.

Source	*df*	*SS*	*MS*	*F*	*p*
Class (CLASS)	1	505.66	505.66	0.77	0.387
Gender (GENDER)	1	48.92	48.92	0.07	0.787
CLASS x GENDER	1	4489.56	4489.56	6.79	*0.013
S / CLASS GENDER	43	28415.10	660.82		
Total	46	33459.23			

* $p < 0.050$

D.1.1.1.2.4 Reference Based Academic Self-Concept Subscale

The mean change for boys was 5.19 with a standard deviation of 25.70, while the mean change for girls was -0.92 with a standard deviation of 20.18. The mean change for students from the PCF classroom was 5.17 with a standard deviation of 25.31, while the mean change for student from the standard classroom was -1.69 with a standard deviation of 19.69. Table D-12 summarizes the analysis results.

Table D-12. ANOVA Summary Table for the SAM / Academic Self-Concept -- Reference Based measure.

Source	*df*	*SS*	*MS*	*F*	*p*
Class (CLASS)	1	553.07	553.07	1.25	0.269
Gender (GENDER)	1	337.72	337.72	0.77	0.387
CLASS x GENDER	1	3957.41	3957.41	8.97	*0.005
S / CLASS GENDER	43	18969.08	441.14		
Total	46	23817.28			

* $p < 0.050$

D.1.1.1.2.5 Instructional Mastery Subscale

The mean change for boys was -2.95 with a standard deviation of 33.90, while the mean change for girls was -3.00 with a standard deviation of 29.81. The mean change for students from the PCF classroom was 1.87 with a standard deviation of 33.19, while the mean change for student from the standard classroom was -8.04 with a standard deviation of 29.17. Table D-13 summarizes the analysis results.

Table D-13. ANOVA Summary Table for the SAM / Student's Instructional Mastery measure.

Source	*df*	*SS*	*MS*	*F*	*p*
Class (CLASS)	1	1155.40	1155.40	1.23	0.274
Gender (GENDER)	1	12.77	12.77	0.01	0.908
CLASS x GENDER	1	3550.24	3550.24	3.77	0.0509
S / CLASS GENDER	43	40490.57	941.64		
Total	46	45208.98			

* $p < 0.050$

D.1.1.2 Student Writing Attitudes

D.1.1.2.1 Knudson Writing Survey

The maximum Knudson Writing Survey score was 95. The overall score was formed by adding scores from the individual scales that make up the Knudson Writing survey. The mean cumulative change in the overall Knudson Writing Score at the end of the first semester was -0.52 with a standard deviation of 8.60 and at the end of the year was 0.83 with a standard deviation of 9.64. The mean change in the overall score for boys was -1.69 with a standard deviation of 9.33, while the mean change for girls was 1.81 with a standard deviation of 8.66. The mean change for students from the PCF classroom was -2.47 with a standard deviation of 8.23, while the mean change for student from the standard classroom was 4.98 with a standard deviation of 8.73. Tables D-14 thru D-17 presents descriptive information for this measure. Table D-18 summarizes the analysis results.

Table D-14. Descriptive information for the CLASS x GENDER interaction of cumulative change in the Knudson Writing Attitude Survey Score.

	Males		Females	
	Mean	*std*	*Mean*	*std*
PCF Classroom	-4.36	8.37	-0.58	7.83
Standard Classroom	4.17	9.02	5.56	8.84

Table D-15. Descriptive information for the CLASS x PERIOD interaction of cumulative changes in the Knudson Writing Attitude Survey Score.

	Mid-year		Year End	
	Mean	*std*	*Mean*	*std*
PCF Classroom	-3.10	7.98	-1.84	8.62
Standard Classroom	4.22	7.89	5.75	9.81

Table D-16. Descriptive information for the GENDER x PERIOD interaction of cumulative changes in the Knudson Writing Attitude Survey Score.

	Mid-year		Year End	
	Mean	*std*	*Mean*	*std*
Males	-2.41	8.26	-0.98	10.52
Females	1.17	8.76	2.45	8.76

Table D-17. Descriptive information for the CLASS x GENDER x PERIOD interaction of cumulative changes in the Knudson Writing Attitude Survey Score.

	Mid-year		Year End	
	Mean	*std*	*Mean*	*std*
Males				
PCF Classroom	-4.81	7.59	-3.91	9.42
Standard Classroom	2.84	7.84	5.50	10.81
Females				
PCF Classroom	-1.40	8.34	0.23	7.59
Standard Classroom	5.20	8.49	5.93	9.92

Table D-18. ANOVA Summary Table for cumulative changes in the Knudson Writing Score.

Source	*df*	*SS*	*MS*	*F*	*p*
Between					
Classroom (CLASS)	1	820.60	820.60	7.08	*0.012
Gender (GENDER)	1	106.01	106.01	0.91	0.347
GENDER x CLASS	1	21.73	21.73	0.19	0.668
S / GENDER CLASS	30	3476.84	115.89		
Within					
Period (PERIOD)	1	33.35	33.35	1.01	0.322
PERIOD x GENDER	1	1.34	1.34	0.04	0.841
PERIOD x CLASS	1	0.71	0.71	0.02	0.884
PERIOD x GENDER x CLASS	1	6.83	6.83	0.21	0.652
PERIOD x S / GENDER CLASS	30	988.34	32.94		
Total	67	5455.75			

* $p < 0.050$

D.1.1.2.1.1 Prefers Writing Scale

Items from the Prefers Writing Scale reflects the students' interest in writing (Knudson, 1991). The maximum score for the scale was 20. The mean cumulative change in the Prefers Writing scale at mid-year was 0.61 with a standard deviation of 3.85, while the mean change at the end of the year was 0.38 with a standard deviation of 4.31. The mean change in the overall score for boys was 0.23 with a standard deviation of 4.43, while the mean change for girls was 0.73 with a standard deviation of 3.75. The mean change for students from the PCF classroom was -0.59 with a standard deviation of 3.85, while the mean change for student from the standard classroom was 2.48 with a standard deviation of 3.74. Tables D-19 thru D-22 present descriptive information for this measure. Table D-23 summarizes the analysis results.

Table D-19. Descriptive information for the CLASS x GENDER interaction of cumulative changes in the Prefers Writing Scale Score.

	Males		Females	
	Mean	*std*	*Mean*	*std*
PCF Classroom	-1.18	4.12	0.00	3.55
Standard Classroom	3.33	3.52	1.86	3.89

Table D-20. Descriptive information for the CLASS x PERIOD interaction of cumulative changes in the Prefers Writing Scale Survey Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
PCF Classroom	-0.12	3.97	-1.05	3.39
Standard Classroom	1.95	2.29	3.00	4.14

Table D-21. Descriptive information for the GENDER x PERIOD interaction of cumulative changes in the Prefers Writing Scale Survey Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
Males	0.61	3.84	-0.14	5.05
Females	0.61	3.98	0.84	3.62

Table D-22. Descriptive information for the CLASS x GENDER x PERIOD interaction of cumulative changes in the Prefers Writing Scale Survey Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
Males				
PCF Classroom	-0.53	3.82	-1.18	4.50
Standard Classroom	3.12	2.71	3.54	4.51
Females				
PCF Classroom	0.29	4.26	-0.29	2.86
Standard Classroom	1.11	3.76	2.61	4.17

Table D-23. ANOVA Summary Table for Prefers Writing Scale Cumulative Changes.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	153.91	153.91	6.77	*0.014
Gender (GENDER)	1	0.19	0.19	0.01	0.927
GENDER x CLASS	1	26.63	26.63	1.17	0.288
S / GENDER CLASS	30	682.43	22.74		
Within					
Period (PERIOD)	1	0.00	0.00	0.00	0.984
PERIOD x GENDER	1	3.01	3.01	0.39	0.535
PERIOD x CLASS	1	13.64	13.64	1.78	0.182
PERIOD x GENDER x CLASS	1	0.14	0.14	0.02	0.894
PERIOD x S / GENDER CLASS	30	229.45	7.65		
Total	67	1109.4			

* $p < 0.050$

D.1.1.2.1.2 Positive View of Self as a Writer Scale

Items from the Positive View of Self as a Writer scale relate to how students feel about themselves as writers. The maximum score for this scale was 15. The mean change in the Positive View of Self as a Writer scale at mid-year was -0.30 with a standard deviation of 2.11, while the mean change in the second semester was -0.43 with a standard deviation of 1.76. The mean change in the overall score for boys was -0.21 with a standard deviation of 1.74, while the mean change for girls was -0.50 with a standard deviation of 2.09. The mean change for students from the PCF classroom was -0.71 with a standard deviation of 1.98, while the mean change for student from the standard classroom was

0.27 with a standard deviation of 1.69. Tables D-24 thru D-27 present descriptive information for this measure. Table D-28 summarizes the analysis results.

Table D-24. Descriptive information for the CLASS x GENDER interaction of cumulative changes in the Positive View of Self as a Writer Scale Score.

	Males		Females	
	Mean	*std*	*Mean*	*std*
PCF Classroom	-0.44	1.68	-0.98	2.24
Standard Classroom	0.28	1.86	0.26	1.63

Table D-25. Descriptive information for the CLASS x PERIOD interaction of cumulative changes in the Positive View of Self as a Writer Scale Survey Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
PCF Classroom	-0.70	2.10	-0.73	1.90
Standard Classroom	0.42	2.01	0.13	1.37

Table D-26. Descriptive information for the GENDER x PERIOD interaction of cumulative changes in the Positive View of Self as a Writer Scale Survey Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
Males	-0.19	1.79	-0.23	1.76
Females	-0.40	2.40	-0.60	1.80

Table D-27. Descriptive information for the CLASS x GENDER x PERIOD interaction of cumulative changes in the Positive View of Self as a Writer Scale Survey Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
Males				
PCF Classroom	-0.45	1.47	-0.42	1.94
Standard Classroom	0.38	2.44	0.18	1.35
Females				
PCF Classroom	-0.94	2.64	-1.04	1.90
Standard Classroom	0.44	1.85	0.09	1.50

Table D-28. ANOVA Summary Table for Positive View of Self as a Writer Scale Cumulative Changes.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	14.85	14.85	2.77	0.107
Gender (GENDER)	1	1.30	1.30	0.24	0.627
GENDER x CLASS	1	1.09	1.09	0.20	0.656
S / GENDER CLASS	30	160.80	5.36		
Within					
Period (PERIOD)	1	0.37	0.37	0.16	0.693
PERIOD x GENDER	1	0.08	0.08	0.04	0.852
PERIOD x CLASS	1	0.23	0.23	0.10	0.754
PERIOD x GENDER x CLASS	1	0.00	0.00	0.00	0.989
PERIOD x S / GENDER CLASS	30	69.35	2.31		
Total	67	248.07			

* $p < 0.050$

D.1.1.2.1.3 Competent Writer Scale

Items from the Competent Writer scale reflect the students' confidence in writing compositions (Knudson, 1991). The maximum score for this scale was 20. The mean change in the Competent Writer scale at mid-year was 0.16 with a standard deviation of 2.25, while the mean change at the end of the year was 0.30 with a standard deviation of 2.79. The mean change in the overall score for boys was 0.14 with a standard deviation of 2.42, while the mean change for girls was 0.30 with a standard deviation of 2.63. The mean change for students from the PCF classroom was -0.49 with a standard deviation of 2.38, while the mean change for students from the standard classroom was 1.56 with a standard deviation of 2.23. Tables D-29 thru D-32 present descriptive information for this measure. Table D-33 summarizes the analysis results.

Table D-29. Descriptive information for the CLASS x GENDER interaction of cumulative changes in the Competent Writer Scale Score.

	Males		Females	
	Mean	*std*	*Mean*	*std*
PCF Classroom	-0.55	2.21	-0.43	2.59
Standard Classroom	1.70	2.21	1.46	2.33

Table D-30. Descriptive information for the CLASS x PERIOD interaction of cumulative changes in the Competent Writer Scale Survey Score.

	Fall Semester		Spring Semester	
	Mean	*std*	*Mean*	*std*
PCF Classroom	-0.67	1.99	-0.33	2.75
Standard Classroom	1.68	1.95	1.45	2.57

Table D-31. Descriptive information for the GENDER x PERIOD interaction of cumulative changes in the Competent Writer Scale Survey Score.

	Fall Semester		Spring Semester	
	Mean	*std*	*Mean*	*std*
Males	0.09	2.38	0.21	2.53
Females	0.22	2.20	0.37	3.07

Table D-32. Descriptive information for the CLASS x GENDER x PERIOD interaction of cumulative changes in the Competent Writer Scale Survey Score.

	Fall Semester		Spring Semester	
	Mean	*std*	*Mean*	*std*
Males				
PCF Classroom	-0.73	1.84	-0.39	2.60
Standard Classroom	1.88	2.62	1.52	2.00
Females				
PCF Classroom	-0.60	2.21	-0.27	3.03
Standard Classroom	1.53	1.52	1.40	3.07

Table D-33. ANOVA Summary Table for Competent Writer Scale Cumulative Changes.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	65.98	65.98	6.87	*0.014
Gender (GENDER)	1	0.04	0.04	0.00	0.948
GENDER x CLASS	1	0.49	0.49	0.050	0.822
S / GENDER CLASS	30	288.23	9.61		
Within					
Period (PERIOD)	1	0.03	0.03	0.01	0.910
PERIOD x GENDER	1	0.050	0.050	0.02	0.887
PERIOD x CLASS	1	1.27	1.27	0.56	0.461
PERIOD x GENDER x CLASS	1	0.06	0.06	0.02	0.877
PERIOD x S / GENDER CLASS	30	67.87	2.26		
Total	67	424.02			

* $p < 0.050$

D.1.1.2.1.4 Writing Achievement Scale

Items from the Writing Achievement scale reflect the students’ thoughts about writing achievement and achievement through writing (Knudson, 1991). The maximum score for this scale was 10. The mean change in the scale at mid-year was -0.26 with a standard deviation of 1.96, while the mean change at the end of the year was 0.25 with a standard deviation of 1.63. The mean change in the overall score for boys was -0.93 with a standard deviation of 1.27, while the mean change for girls was 0.81 with a standard deviation of 1.84. The mean change for students from the PCF classroom was -0.21 with a standard deviation of 1.79, while the mean change for students from the standard classroom was 0.38 with a standard deviation of 1.81. Tables D-34 thru D-37 present descriptive information for this measure. Table D-38 summarizes the analysis results.

Table D-34. Descriptive information for the CLASS x GENDER interaction of cumulative changes in the Writing Achievement Scale Score.

	Males		Females	
	Mean	*std*	*Mean*	*std*
PCF Classroom	-1.29	1.26	0.86	1.59
Standard Classroom	-0.12	0.90	0.72	2.22

Table D-35. Descriptive information for the CLASS x PERIOD interaction of cumulative changes in the Writing Achievement Scale Survey Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
PCF Classroom	-0.46	2.01	0.04	1.55
Standard Classroom	0.12	1.89	0.63	1.78

Table D-36. Descriptive information for the GENDER x PERIOD Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
Males	-1.41	1.19	-0.44	1.19
Females	0.76	1.97	0.86	1.75

Table D-37. Descriptive information for the CLASS x GENDER x PERIOD interaction of cumulative changes in the Writing Achievement Scale Survey Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
Males				
PCF Classroom	-1.85	1.05	-0.72	1.25
Standard Classroom	-0.42	0.91	0.18	0.87
Females				
PCF Classroom	0.93	1.77	0.80	1.48
Standard Classroom	0.50	2.36	0.96	2.38

Table D-38. ANOVA Summary Table for Writing Achievement Scale Cumulative Changes.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	4.01	4.01	1.05	0.314
Gender (GENDER)	1	35.64	35.64	9.33	*0.005
GENDER x CLASS	1	6.50	6.50	1.70	0.202
S / GENDER CLASS	30	114.56	3.82		
Within					
Period (PERIOD)	1	4.03	4.03	3.42	0.074
PERIOD x GENDER	1	1.86	1.86	1.58	0.219
PERIOD x CLASS	1	0.00	0.00	0.00	0.959
PERIOD x GENDER x CLASS	1	1.18	1.18	1.00	0.325
PERIOD x S / GENDER CLASS	30	35.34	1.18		
Total	67	203.12			

* $p < 0.050$

D.1.1.2.1.5 Importance of Writing Scale

Items from the Importance of Writing scale reflects student opinions of the significance pf writing (Knudson, 1991). The maximum score for this scale was 10. The mean change in the Importance of Writing scale at mid-year was -0.38 with a standard deviation of 1.86, while the mean change at the end of the year was -0.02 with a standard deviation of 1.85. The mean change in the overall score for boys was -0.63 with a standard deviation of 1.88, while the mean change for girls was 0.18 with a standard deviation of 1.75. The mean change for students from the PCF classroom was -0.43 with a standard deviation of 1.62, while the mean change for student from the standard classroom was 0.21 with a standard deviation of 2.18. Tables D-39 thru D-42 present descriptive information for this measure. Table D-43 summarizes the analysis results.

Table D-39. Descriptive information for the CLASS x GENDER interaction of cumulative changes in the Importance of Writing Scale Score.

	Males		Females	
	Mean	*std*	*Mean*	*std*
PCF Classroom	-0.65	1.58	-0.20	1.67
Standard Classroom	-0.60	2.51	0.79	1.78

Table D-40. Descriptive information for the CLASS x PERIOD interaction of cumulative changes in the Importance of Writing Scale Survey Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
PCF Classroom	-0.45	1.64	-0.40	1.64
Standard Classroom	-0.25	2.25	0.68	2.07

Table D-41. Descriptive information for the GENDER x PERIOD interaction of cumulative changes in the Importance of Writing Scale Survey Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
Males	-0.83	1.89	-0.44	1.91
Females	0.02	1.79	0.34	1.76

Table D-42. Descriptive information for the CLASS x GENDER x PERIOD interaction of cumulative changes in the Importance of Writing Scale Survey Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
Males				
PCF Classroom	-0.56	1.54	-0.72	1.70
Standard Classroom	-1.40	2.61	0.20	2.38
Females				
PCF Classroom	-0.33	1.81	-0.08	1.59
Standard Classroom	0.57	1.74	1.01	1.93

Table D-43. ANOVA Summary Table for Importance of Writing Scale Cumulative Changes.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	4.22	4.22	0.95	0.337
Gender (GENDER)	1	12.68	12.68	2.86	0.101
GENDER x CLASS	1	3.45	12.68	0.78	0.384
S / GENDER CLASS	30	132.86	4.43		
Within					
Period (PERIOD)	1	4.30	4.30	1.89	0.179
PERIOD x GENDER	1	0.53	0.53	0.23	0.632
PERIOD x CLASS	1	3.66	3.66	1.61	0.214
PERIOD x GENDER x CLASS	1	2.34	2.34	1.03	0.319
PERIOD x S / GENDER CLASS	30	68.28	2.28		
Total	67	232.32			

* $p < 0.050$

D.1.1.2.1.6 Letter/Note Writing Scale

Items from the Letter/Note Writing scale relate to students' writing notes in and out of class (Knudson, 1991). The maximum score for this scale was 10. The mean change in the scale at mid-year was -0.35 with a standard deviation of 2.42, while the mean change at the end of the year was 0.37 with a standard deviation of 2.04. The mean change in the overall score for boys was -0.31 with a standard deviation of 2.33, while the mean change for girls was 0.29 with a standard deviation of 2.17. The mean change for students from the PCF classroom was -0.04 with a standard deviation of 1.89, while the mean change for student from the standard classroom was 0.09 with a standard deviation of 2.84.

Tables D-44 thru D-47 present descriptive information for this measure. Table D-48 summarizes the analysis results.

Table D-44. Descriptive information for the CLASS x GENDER interaction of cumulative changes in the Letter/Note Writing Scale Score.

	Males		Females	
	Mean	*std*	*Mean*	*std*
PCF Classroom	-0.25	1.74	0.18	2.05
Standard Classroom	-0.42	3.41	0.45	2.42

Table D-45. Descriptive information for the CLASS x PERIOD interaction of cumulative changes in the Letter/Note Writing Scale Survey Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
PCF Classroom	-0.71	1.96	0.64	1.60
Standard Classroom	0.31	3.10	-0.13	2.67

Table D-46. Descriptive information for the GENDER x PERIOD interaction of cumulative changes in the Letter/Note Writing Scale Survey Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
Males	-0.69	2.52	0.08	2.14
Females	-0.06	2.37	0.63	1.96

Table D-47. Descriptive information for the CLASS x GENDER x PERIOD interaction of cumulative changes in the Letter/Note Writing Scale Survey Score.

	Mid-Year		End-of-Year	
	Mean	*std*	*Mean*	*std*
Males				
PCF Classroom	-0.67	2.00	0.16	1.40
Standard Classroom	-0.72	3.70	-0.12	3.50
Females				
PCF Classroom	-0.75	2.00	1.19	1.71
Standard Classroom	1.04	2.63	-0.14	2.22

Table D-48. ANOVA Summary Table for Letter/Note Scale Cumulative Changes.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	0.04	0.04	0.01	0.940
Gender (GENDER)	1	6.49	6.49	0.86	0.361
GENDER x CLASS	1	0.72	0.72	0.09	0.760
S / GENDER CLASS	30	226.73	7.56		
Within					
Period (PERIOD)	1	4.30	4.30	1.67	2.06
PERIOD x GENDER	1	0.54	0.54	0.21	0.652
PERIOD x CLASS	1	10.35	10.35	4.02	0.0504
PERIOD x GENDER x CLASS	1	7.59	7.59	2.95	0.096
PERIOD x S / GENDER CLASS	30	77.29	2.58		
Total	67	334.05			

* $p < 0.050$

D.1.1.3 Student Attitudes Towards Computers

D.1.1.3.1 Overall Computer Attitudes

The mean score for boys was 63.19 with a standard deviation of 9.18, while the mean score for girls was 59.04 with a standard deviation of 9.22. The mean score for students from the PCF classroom was 62.46 with a standard deviation of 8.70, while the mean score for student from the standard classroom was 59.08 with a standard deviation of 9.94. Tables D-49 thru D-53 present additional descriptive information for this measure. Table D-54 summarizes the ANOVA analysis results for this measure.

Table D-49. Descriptive information for the PERIOD main effect of the Student Computer Attitudes measure.

	Mean	*std*
Period 1 (start of the school year)	61.72	8.26
Period 2 (middle of the school year)	61.73	9.27
Period 3 (end of the school year)	59.44	10.58

Table D-50. Descriptive information for the CLASS x GENDER interaction of the Student Computer Attitudes measure.

	Males		Females	
	Mean	*std*	*Mean*	*std*
PCF Classroom	65.56	7.68	59.36	8.64
Standard Classroom	59.62	10.21	58.70	9.89

Table D-51. Descriptive information for the CLASS x PERIOD interaction of the Student Computer Attitudes measure.

	Period					
	Start		Middle		End	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
PCF Classroom	61.87	7.55	63.37	8.57	62.15	10.10
Standard Classroom	61.56	9.11	59.10	10.03	56.33	10.49

Table D-52. Descriptive information for the PERIOD x GENDER interaction of the Student Computer Attitudes measure.

	Period					
	Start		Middle		End	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
Males	64.03	8.18	65.29	7.65	60.31	11.04
Females	59.85	7.99	58.34	9.57	58.74	10.37

Table D-53. Descriptive information for the CLASS x GENDER x PERIOD interaction of the Student Computer Attitudes measure.

	Period					
	Start		Middle		End	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
Males						
PCF Classroom	64.47	6.96	66.55	8.21	65.68	8.36
Standard Classroom	63.44	10.00	63.14	6.62	52.25	8.65
Females						
PCF Classroom	59.27	7.47	60.19	8.00	58.63	10.78
Standard Classroom	60.36	8.65	55.56	11.54	58.85	10.42

Table D-54. ANOVA Summary Table for Student Computer Attitudes.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	246.01	246.01	1.99	0.167
Gender (GENDER)	1	305.39	305.39	2.47	0.125
GENDER x CLASS	1	215.50	215.50	1.74	0.196
S / GENDER CLASS	34	4200.93	123.56		
Within					
12 week period (PERIOD)	2	162.74	81.37	1.64	0.200
PERIOD x GENDER	2	242.74	121.37	2.19	0.119
PERIOD x CLASS	2	210.48	105.24	2.12	0.127
PERIOD x GENDER x CLASS	2	321.38	160.69	2.94	0.051
PERIOD x S / GENDER CLASS	68	3802.01	55.92		
Total	113	9707.18			

* 0 < 0.050

D.1.1.3.2 Computer Writing Attitudes

The mean score for students from the PCF classroom was 36.06 with a standard deviation of 5.09, while the mean score for student from the standard classroom was 34.03 with a standard deviation of 4.75. Tables D-55 thru D-56 present additional descriptive information for this measure. Table D-57 summarizes the ANOVA analysis results for this measure. The reader should note that gender was not included as an effect of this model as insufficient numbers of control students completed the survey.

Table D-55. Descriptive information for the PERIOD main effect of the Student Computer Writing Attitudes measure.

	Mean	*std*
Period 1 (start of the school year)	34.63	6.13
Period 2 (middle of the school year)	35.46	4.49
Period 3 (end of the school year)	35.39	4.22

Table D-56. Descriptive information for the CLASS x PERIOD interaction of the Student Computer Writing Attitudes measure.

	Period					
	Start		Middle		End	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
PCF Classroom	34.81	6.83	36.40	3.84	37.02	3.94
Standard Classroom	34.44	5.41	33.95	5.14	33.68	3.88

Table D-57. ANOVA Summary Table for Student Computer Writing Attitudes.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	2.59	2.59	0.050	0.834
S / CLASS	29	1490.96	51.07		
Within					
12 week period (PERIOD)	2	2.10	1.05	0.07	0.932
PERIOD x CLASS	2	52.63	26.31	1.76	0.181
PERIOD x S / CLASS	58	865.35	14.92		
Total	92	2413.63			

* $p < 0.050$

D.1.2 Student Performance Results

D.1.2.1 Academic Performance

D.1.2.1.1 Standardized Test Performance

D.1.2.1.1.1 Reading Achievement

Reading achievement was assessed by scaled scores from the English: Reading / Literature and Research category of the SOLs. This category was comprised of the following sections: a) use word analysis strategies, b) understand a variety of printed materials / resource materials, and c) understand elements of literature. The Total Reading SS from the third grade Stanford 9 test served as the covariate for these variables.[26] Tables D-58 thru D-60 present descriptive information for these measures. Table D-61 thru D-664 summarize the analysis results.

Table D-58. Means and standard deviations for the CLASS effect of SOL English: Reading / Literature and Research Scaled Scores.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
Use Word Analysis Strategies	40.87	10.32	39.05	9.22
Understand a Variety of Printed Materials / Resource Materials	38.96	8.05	34.43	6.71
Understand Elements of Literature	35.13	5.86	36.67	6.47

Table D-59. Means and standard deviations for the GENDER effect of SOL English: Teaching / Literature and Research Scaled Scores.

	Males		Females	
	Mean	*std*	*Mean*	*std*
Use Word Analysis Strategies	39.33	10.93	40.61	8.72
Understand a Variety of Printed Materials / Resource Materials	35.33	8.50	38.13	6.81
Understand Elements of Literature	33.90	5.37	37.65	6.34

[26] Elements of the Stanford 9 reading section relate to reading vocabulary and reading comprehension.

Table D-60. Means and standard deviations for the CLASS x GENDER interaction of SOL English: Teaching / Literature and Research Scaled Scores.

	PCF Students		Control Students	
Males	*Mean*	*std*	*Mean*	*std*
Use Word Analysis Strategies	41.17	11.51	36.89	10.24
Understand a Variety of Printed Materials / Resource Materials	37.08	7.93	33.00	9.14
Understand Elements of Literature	33.50	6.04	34.44	4.64
Females	*Mean*	*std*	*Mean*	*std*
Use Word Analysis Strategies	56.63	40.55	40.67	8.47
Understand a Variety of Printed Materials / Resource Materials	41.00	8.04	35.50	4.27
Understand Elements of Literature	36.91	5.36	38.33	7.30

Table D-61. MANOVA Results for the effect of the covariate on scaled scores from the SOL English: Teaching / Literature and Research category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.40	18.52	3	37	*0.000
Pillai's Trace	0.60	18.52	3	37	*0.000
Hotelling-Lawley Trace	1.50	18.52	3	37	*0.000
Roy's Greatest Root	1.50	18.52	3	37	*0.000

* $p < 0.050$

Table D-62. MANOVA Results for the effect of CLASS on scaled scores from the SOL English: Teaching / Literature and Research category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.87	1.72	3	37	0.179
Pillai's Trace	0.12	1.72	3	37	0.179
Hotelling-Lawley Trace	0.14	1.72	3	37	0.179
Roy's Greatest Root	0.14	1.72	3	37	0.179

* $p < 0.050$

Table D-63. MANOVA Results for the effect of GENDER on scaled scores from the SOL English: Teaching / Literature and Research category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.94	0.77	3	37	0.521
Pillai's Trace	0.06	0.77	3	37	0.521
Hotelling-Lawley Trace	0.06	0.77	3	37	0.521
Roy's Greatest Root	0.06	0.77	3	37	0.521

* $p < 0.050$

Table D-64. MANOVA Results for the effect of CLASS x GENDER interaction on scaled scores from the SOL English: Reading / Literature and Research category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.94	0.74	3	37	0.536
Pillai's Trace	0.06	0.74	3	37	0.536
Hotelling-Lawley Trace	0.06	0.74	3	37	0.536
Roy's Greatest Root	0.06	0.74	3	37	0.536

* $p < 0.050$

D.1.2.1.1.2 Writing Achievement

Writing achievement was assessed by scaled scores from the English: Writing category of the SOLs. This category was comprised of the following sections: a) composing written expression, and b) usage-mechanics. The Total Language SS from the third grade Stanford 9 test served as the covariate for these variables. Tables D-65 thru D-67 present descriptive information for each of the sections. Tables D-68 thru D-73 summarize the analysis results.

Table D-65. Means and standard deviations for the CLASS effect of SOL English: Writing Scaled Scores.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
Composing Written Expression	40.52	7.35	33.76	5.29
Usage-Mechanics	38.87	7.48	34.43	5.37

Table D-66. Means and standard deviations for the GENDER effect of SOL English: Writing Scaled Scores.

	Males		Females	
	Mean	*std*	*Mean*	*std*
Composing Written Expression	35.52	6.41	38.91	7.69
Usage-Mechanics	36.43	7.37	37.04	6.51

Table D-67. Means and standard deviations for the CLASS x GENDER interaction of SOL English: Writing Scaled Scores.

	PCF Students		Control Students	
Males	*Mean*	*std*	*Mean*	*std*
Composing Written Expression	38.17	6.21	32.00	5.02
Usage-Mechanics	39.08	8.48	32.89	6.62
Females	*M*	*std*	*M*	*std*
Composing Written Expression	43.09	7.91	35.08	5.30
Usage-Mechanics	38.64	3.52	35.58	6.33

Table D-68. MANOVA Results for the effect of the covariate on scaled scores from the SOL English: Writing category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.69	8.38	2	38	*0.001
Pillai's Trace	0.31	8.38	2	38	*0.001
Hotelling-Lawley Trace	0.44	8.38	2	38	*0.001
Roy's Greatest Root	0.44	8.38	2	38	*0.001

* $p < 0.050$

Table D-69. MANOVA Results for the effect of CLASS on scaled scores from the SOL English: Writing category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.72	7.52	2	38	*0.002
Pillai's Trace	0.28	7.52	2	38	*0.002
Hotelling-Lawley Trace	0.40	7.52	2	38	*0.002
Roy's Greatest Root	0.40	7.52	2	38	*0.002

* $p < 0.050$

Table D-70. MANOVA Results for the effect of GENDER on scaled scores from the SOL English: Writing category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.88	2.53	2	38	0.093
Pillai's Trace	0.12	2.53	2	38	0.093
Hotelling-Lawley Trace	0.13	2.53	2	38	0.093
Roy's Greatest Root	0.13	2.53	2	38	0.093

* $p < 0.050$

Table D-71. MANOVA Results for the effect of CLASS x GENDER interaction on scaled scores from the SOL English: Writing category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.92	1.61	2	38	0.214
Pillai's Trace	0.08	1.61	2	38	0.214
Hotelling-Lawley Trace	0.08	1.61	2	38	0.214
Roy's Greatest Root	0.08	1.61	2	38	0.214

* $p < 0.050$

Table D-72. ANOVA Summary Table for the SOL Composing Written Expression Scaled Score.

Source	***df***	***SS***	***MS***	***F***	***p***
Stanford 9 Covariate	1	451.54	451.54	15.89	*0.000
Class (CLASS)	1	426.90	426.90	15.03	*0.000
Gender (GENDER)	1	72.30	72.30	2.54	0.119
CLASS x GENDER	1	8.54	8.54	0.30	0.587
S / CLASS GENDER	39	1107.95	28.41		
Total	43	3026.51			

* $p < 0.050$

Table D-73. ANOVA Summary Table for the SOL Writing Usage-Mechanics Scaled Score.

Source	***df***	***SS***	***MS***	***F***	***p***
Stanford 9 Covariate	1	430.94	430.94	12.56	0.001
Class (CLASS)	1	160.35	160.35	4.67	0.037
Gender (GENDER)	1	0.46	0.46	0.01	0.909
CLASS x GENDER	1	27.88	27.88	0.78	0.373
S / CLASS GENDER	39	1338.33	34.31		
Total	43	1957.96			

* $p < 0.050$

D.1.2.1.1.3 Mathematics Achievement

Mathematics achievement was assessed by scaled scores from the Mathematics category of the SOLs. Tables D-74 thru D-76 present descriptive information for each of the sections. This category was comprised of the following sections: a) number and number sense, b) computation and estimation, c) measurement and geometry, d) probability and statistics, and e) patterns functions and algebra. Tables D-77 thru D-80 summarize the analysis results.

Table D-74. Means and standard deviations for the CLASS effect of SOL Mathematics Scaled Scores.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
Number and Number Sense	34.43	11.83	32.95	8.55
Computation and Estimation	39.00	10.18	35.33	8.27
Measurement and Geometry	31.39	6.47	29.33	7.44
Probability and Statistics	38.30	10.44	32.76	8.18
Patterns, Functions, and Algebra	35.52	8.95	31.52	5.88

Table D-75. Means and standard deviations for the GENDER effect of SOL Mathematics Scaled Scores.

	Males		Females	
	Mean	*std*	*Mean*	*std*
Number and Number Sense	35.19	10.00	32.39	10.61
Computation and Estimation	36.29	9.08	38.13	9.80
Measurement and Geometry	29.67	6.73	31.09	7.22
Probability and Statistics	36.57	10.55	34.83	9.07
Patterns, Functions, and Algebra	32.71	6.89	34.43	8.66

Table D-76. Means and standard deviations for the CLASS x GENDER interaction of SOL Mathematics Scaled Scores.

	PCF Students		Control Students	
Males	*Mean*	*std*	*Mean*	*std*
Number and Number Sense	36.25	10.23	33.78	10.11
Computation and Estimation	36.67	9.78	35.78	8.60
Measurement and Geometry	31.08	7.57	27.78	5.24
Probability and Statistics	36.83	10.79	36.22	10.86
Patterns, Functions, and Algebra	34.17	7.07	30.78	6.51
Females	*Mean*	*std*	*Mean*	*std*
Number and Number Sense	32.45	13.58	32.33	7.58
Computation and Estimation	41.55	10.45	35.00	8.39
Measurement and Geometry	31.73	5.37	30.50	8.79
Probability and Statistics	39.91	10.30	30.17	4.32
Patterns, Functions, and Algebra	37.00	10.81	32.08	5.58

Table D-77. MANOVA Results for the effect of the covariate on scaled scores from the SOL Mathematics category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.46	8.28	5	35	*0.000
Pillai's Trace	0.54	8.28	5	35	*0.000
Hotelling-Lawley Trace	1.18	8.28	5	35	*0.000
Roy's Greatest Root	1.18	8.28	5	35	*0.000

* $p < 0.050$

Table D-78. MANOVA Results for the effect of CLASS on scaled scores from the SOL Mathematics category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.93	0.50	5	35	0.773
Pillai's Trace	0.07	0.50	5	35	0.773
Hotelling-Lawley Trace	0.07	0.50	5	35	0.773
Roy's Greatest Root	0.07	0.50	5	35	0.773

* $p < 0.050$

Table D-79. MANOVA Results for the effect of GENDER on scaled scores from the SOL Mathematics category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.87	1.05	5	35	0.407
Pillai's Trace	0.13	1.05	5	35	0.407
Hotelling-Lawley Trace	0.15	1.05	5	35	0.407
Roy's Greatest Root	0.15	1.05	5	35	0.407

* $p < 0.050$

Table D-80. MANOVA Results for the effect of CLASS x GENDER interaction on scaled scores from the SOL Mathematics category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.81	1.68	5	35	0.165
Pillai's Trace	0.19	1.68	5	35	0.165
Hotelling-Lawley Trace	0.24	1.68	5	35	0.165
Roy's Greatest Root	0.24	1.68	5	35	0.165

* $p < 0.050$

D.1.2.1.1.4 Social Studies Achievement

Social studies achievement was assessed by scaled scores from the History and Social Studies category of the SOLs. Tables D-81 thru D-83 present descriptive information for each of the sections. This category was comprised of the following sections: a) history, b) geography, c) economics, and d) civics. The Total Social Studies SS from the third grade Stanford 9 test served as the covariate for these variables. Tables D-84 thru D-91 summarize the analysis results.

Table D-81. Means and standard deviations for the CLASS effect of SOL History and Social Studies Scaled Scores.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
History	34.22	5.63	30.90	7.62
Geography	34.52	7.62	33.14	6.92
Economics	32.83	9.11	32.24	5.58
Civics	34.26	8.24	32.90	6.29

Table D-82. Means and standard deviations for the GENDER effect of SOL History and Social Studies Scaled Scores.

	Males		Females	
	Mean	*std*	*Mean*	*std*
History	31.91	6.37	33.30	7.21
Geography	35.95	7.75	31.96	6.32
Economics	32.57	9.06	32.52	6.06
Civics	35.33	8.72	32.04	5.50

Table D-83. Means and standard deviations for the CLASS x GENDER interaction of SOL History and Social Studies Scaled Scores.

	PCF Students		Control Students	
Males	*Mean*	*std*	*Mean*	*std*
History	33.00	5.17	30.44	7.78
Geography	35.67	8.15	36.33	7.65
Economics	32.17	10.30	33.11	7.67
Civics	35.92	10.14	34.56	6.89
Females	*Mean*	*std*	*Mean*	*std*
History	35.55	6.06	31.25	7.82
Geography	33.27	7.17	30.75	5.46
Economics	33.55	8.04	31.58	3.55
Civics	32.45	5.41	31.67	5.79

Table D-84. MANOVA Results for the effect of the covariate on scaled scores from the SOL History and Social Studies category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.57	6.76	4	36	*0.000
Pillai's Trace	0.43	6.76	4	36	*0.000
Hotelling-Lawley Trace	0.75	6.76	4	36	*0.000
Roy's Greatest Root	0.75	6.76	4	36	*0.000

* $p < 0.050$

Table D-85. MANOVA Results for the effect of CLASS on scaled scores from the SOL History and Social Studies category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.95	0.43	4	36	0.783
Pillai's Trace	0.050	0.43	4	36	0.783
Hotelling-Lawley Trace	0.050	0.43	4	36	0.783
Roy's Greatest Root	0.050	0.43	4	36	0.783

* $p < 0.050$

Table D-86. MANOVA Results for the effect of GENDER on scaled scores from the SOL History and Social Studies category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.72	3.50	4	36	*0.016
Pillai's Trace	0.28	3.50	4	36	*0.016
Hotelling-Lawley Trace	0.39	3.50	4	36	*0.016
Roy's Greatest Root	0.39	3.50	4	36	*0.016

* $p < 0.050$

Table D-87. MANOVA Results for the effect of CLASS x GENDER interaction on scaled scores from the SOL History and Social Studies category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.91	0.85	4	36	0.503
Pillai's Trace	0.09	0.85	4	36	0.503
Hotelling-Lawley Trace	0.09	0.85	4	36	0.503
Roy's Greatest Root	0.09	0.85	4	36	0.503

* $p < 0.050$

Table D-88. ANOVA Summary Table for the SOL History Scaled Score.

Source	***df***	***SS***	***MS***	***F***	***p***
Stanford 9 Covariate	1	611.66	611.66	19.79	0.000
Class (CLASS)	1	28.37	28.37	0.92	0.344
Gender (GENDER)	1	9.02	9.02	0.29	0.592
CLASS x GENDER	1	56.47	56.47	1.83	0.184
S / CLASS GENDER	39	1205.54	30.91		
Total	43	1911.06			

* $p < 0.050$

Table D-89. ANOVA Summary Table for the SOL Geography Scaled Score.

Source	***df***	***SS***	***MS***	***F***	***p***
Stanford 9 Covariate	1	473.44	473.44	11.78	*0.001
Class (CLASS)	1	4.01	4.01	0.10	0.753
Gender (GENDER)	1	232.85	232.85	5.79	*0.021
CLASS x GENDER	1	86.35	86.35	2.15	0.151
S / CLASS GENDER	39	1567.66	40.20		
Total	43	2364.31			

* $p < 0.050$

Table D-90. ANOVA Summary Table for the SOL Economics Scaled Score.

Source	***df***	***SS***	***MS***	***F***	***p***
Stanford 9 Covariate	1	432.49	432.49	8.47	*0.006
Class (CLASS)	1	9.77	9.77	0.19	0.664
Gender (GENDER)	1	5.45	5.45	0.11	0.746
CLASS x GENDER	1	74.87	74.87	1.47	0.233
S / CLASS GENDER	39	1991.71	51.07		
Total	43	2514.29			

* $p < 0.050$

Table D-91. ANOVA Summary Table for the SOL Civics Scaled Score.

Source	***df***	***SS***	***MS***	***F***	***p***
Stanford 9 Covariate	1	390.53	390.53	8.55	*0.006
Class (CLASS)	1	1.16	1.16	0.03	0.874
Gender (GENDER)	1	153.61	153.61	3.35	0.074
CLASS x GENDER	1	8.01	8.01	0.18	0.890
S / CLASS GENDER	39	1782.00	45.69		
Total	43				

* $p < 0.050$

D.1.2.1.1.5 Science Achievement

Science achievement was assessed by scaled scores from the Science category of the SOLs. This category was comprised of the following sections: a) scientific investigation, b) force, motion, energy, and matter, c) life processes and living systems, and d) earth/space systems and cycles. Scores on the sections could range from 0 to 50. Tables D-92 thru D-94 present descriptive information for each of the sections. The Total Science scaled score from the third grade Stanford 9 test served as the covariate for these variables. Tables D-95 thru D-98 summarize the analysis results.

Table D-92. Means and standard deviations for the CLASS effect of SOL Science Scaled Scores.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
Scientific Investigation	39.17	9.52	37.76	8.73
Force, Motion, Energy, and Matter	36.13	9.16	36.76	9.27
Life Processes and Living Systems	37.52	8.13	36.57	7.88
Earth/Space Systems and Cycles	37.00	8.08	36.95	7.81

Table D-93. Means and standard deviations for the GENDER effect of SOL Science Scaled Scores.

	Males		Females	
	Mean	*std*	*Mean*	*std*
Scientific Investigation	40.38	9.05	36.78	8.94
Force, Motion, Energy, and Matter	36.11	9.64	36.17	8.80
Life Processes and Living Systems	37.57	8.08	36.61	7.69
Earth/Space Systems and Cycles	37.43	7.22	36.57	8.54

Table D-94. Means and standard deviations for the CLASS x GENDER interaction of SOL Science Scaled Scores.

	PCF Students		Control Students	
Males	*Mean*	*std*	*Mean*	*std*
Scientific Investigation	41.08	9.88	39.44	8.31
Force, Motion, Energy, and Matter	36.17	8.38	37.44	11.62
Life Processes and Living Systems	36.67	7.70	38.78	8.89
Earth/Space Systems and Cycles	36.75	6.90	38.33	7.95
Females	*Mean*	*std*	*Mean*	*std*
Scientific Investigation	37.09	9.11	36.50	9.18
Force, Motion, Energy, and Matter	36.09	10.36	36.25	7.58
Life Processes and Living Systems	38.45	8.85	34.92	6.96
Earth/Space Systems and Cycles	37.27	9.54	35.92	7.89

Table D-95. MANOVA Results for the effect of the covariate on scaled scores from the SOL Science category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.43	11.84	4	36	*0.000
Pillai's Trace	0.57	11.84	4	36	*0.000
Hotelling-Lawley Trace	1.32	11.84	4	36	*0.000
Roy's Greatest Root	1.32	11.84	4	36	*0.000

* $p < 0.050$

Table D-96. MANOVA Results for the effect of CLASS on scaled scores from the SOL Science category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.89	0.85	5	35	0.523
Pillai's Trace	0.11	0.85	5	35	0.523
Hotelling-Lawley Trace	0.12	0.85	5	35	0.523
Roy's Greatest Root	0.12	0.85	5	35	0.523

* $p < 0.050$

Table D-97. MANOVA Results for the effect of GENDER on scaled scores from the SOL Science category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.90	0.97	4	36	0.434
Pillai's Trace	0.10	0.97	4	36	0.434
Hotelling-Lawley Trace	0.11	0.97	4	36	0.434
Roy's Greatest Root	0.11	0.97	4	36	0.434

* $p < 0.050$

Table D-98. MANOVA Results for the effect of CLASS x GENDER interaction on scaled scores from the SOL Science category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.87	1.30	4	36	0.290
Pillai's Trace	0.13	1.30	4	36	0.290
Hotelling-Lawley Trace	0.14	1.30	4	36	0.290
Roy's Greatest Root	0.14	1.30	4	36	0.290

* $p < 0.050$

D.1.2.1.2 Grade Point Average

Tables D-99 thru D-101 present descriptive information for this measure, while Tables D-102 thru D-104 summarize the MANOVA analysis for subject grades. Tables D-105 thru D-108 summarize the ANOVA analyses for subject grades.

Table D-99. Means and standard deviations for the CLASS effect on subject grade changes.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
Language Arts	-0.20	0.32	-0.14	0.66
Mathematics	-0.28	0.76	-0.22	0.82
Science	-0.35	0.41	-0.21	0.56
Social Studies	-0.24	0.36	-0.46	0.43

Table D-100. Means and standard deviations for the GENDER effect on subject grade changes.

	Males		Females	
	Mean	*std*	*Mean*	*std*
Language Arts	-0.33	0.38	-0.04	0.57
Mathematics	-0.29	0.48	-0.22	0.97
Science	-0.16	0.40	-0.38	0.54
Social Studies	-0.37	0.37	-0.32	0.44

Table D-101. Means and standard deviations for the CLASS x GENDER interaction on subject grade changes.

	PCF Students		Control Students	
Males	*Mean*	*std*	*Mean*	*std*
Language Arts	-0.31	0.22	-0.36	0.55
Mathematics	-0.32	0.46	-0.26	0.53
Science	-0.26	0.29	-0.04	0.49
Social Studies	-0.37	0.27	-0.38	0.49
Females	*Mean*	*std*	*Mean*	*std*
Language Arts	-0.09	0.38	0.01	0.70
Mathematics	-0.25	0.99	-0.19	0.98
Science	-0.44	0.49	-0.32	0.60
Social Studies	-0.11	0.40	-0.50	0.40

Table D-102. MANOVA Results for the effect of CLASS on subject grade changes.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.77	2.95	4	40	*0.032
Pillai's Trace	0.23	2.95	4	40	*0.032
Hotelling-Lawley Trace	0.30	2.95	4	40	*0.032
Roy's Greatest Root	0.30	2.95	4	40	*0.032

* $p < 0.050$

Table D-103. MANOVA Results for the effect of GENDER on subject grade changes.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.83	2.02	4	40	0.110
Pillai's Trace	0.17	2.02	4	40	0.110
Hotelling-Lawley Trace	0.20	2.02	4	40	0.110
Roy's Greatest Root	0.20	2.02	4	40	0.110

* $p < 0.050$

Table D-104. MANOVA Results for the effect of CLASS x GENDER interaction on subject grade changes.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.84	1.84	4	40	0.141
Pillai's Trace	0.15	1.84	4	40	0.141
Hotelling-Lawley Trace	0.18	1.84	4	40	0.141
Roy's Greatest Root	0.18	1.84	4	40	0.141

* $p < 0.050$

Table D-105. ANOVA Summary Table for changes in the language arts GPA.

Source	***df***	***SS***	***MS***	***F***	***p***
Class (CLASS)	1	0.00	0.00	0.02	0.892
Gender (GENDER)	1	1.00	1.00	3.95	0.051
CLASS x GENDER	1	0.06	0.06	0.23	0.632
S / CLASS GENDER	43	10.87	0.25		
Total	46	11.99			

* $p < 0.050$

Table D-106. ANOVA Summary Table for changes in the mathematics GPA.

Source	***df***	***SS***	***MS***	***F***	***p***
Class (CLASS)	1	0.050	0.050	0.050	0.816
Gender (GENDER)	1	0.050	0.050	0.08	0.776
CLASS x GENDER	1	0.00	0.00	0.00	0.999
S / CLASS GENDER	43	27.82	0.65		
Total	46	27.92			

* $p < 0.050$

Table D-107. ANOVA Summary Table for changes in the science GPA.

Source	***df***	***SS***	***MS***	***F***	***p***
Class (CLASS)	1	0.33	0.33	1.39	0.245
Gender (GENDER)	1	0.64	0.64	2.71	0.110
CLASS x GENDER	1	0.03	0.03	0.13	0.724
S / CLASS GENDER	43	10.11	0.24		
Total	46	11.11			

* $p < 0.050$

Table D-108. ANOVA Summary Table for changes in the science GPA.

Source	***df***	***SS***	***MS***	***F***	***p***
Class (CLASS)	1	0.47	0.47	3.04	0.089
Gender (GENDER)	1	0.050	0.050	0.33	0.569
CLASS x GENDER	1	0.43	0.43	2.79	0.102
S / CLASS GENDER	43	7.00	0.15		
Total	46	7.95			

* $p < 0.050$

D.1.2.2 Homework Performance Results

D.1.2.2.1 Homework Reliability

The mean percentage of homework assignments delivered on-time was 84.71 for boys with a standard deviation of 21.05, while the mean percentage for girls was 93.81 with a standard deviation of 9.13. The mean percentage for students from the PCF classroom was 91.00 with a standard deviation of 16.24, while the mean percentage for students from the standard classroom was 88.54 with a standard deviation of 16.19. Tables D-109 thru D-113 present descriptive information for this measure. Table D-114 summarizes the analysis results.

Table D-109. Descriptive information for the PERIOD main effect on the percentage of homework assignments delivered on-time.

	Mean	*std*
Period 1 (start of the school year)	83.87	12.48
Period 2 (middle of the school year)	94.10	17.24
Period 3 (end of the school year)	91.28	17.02

Table D-110. Descriptive information for the CLASS x GENDER interaction on the percentage of homework assignments delivered on-time.

	Males		Females	
	Mean	*std*	*Mean*	*std*
PCF Classroom	84.50	19.94	92.58	10.04
Standard Classroom	85.00	22.83	94.86	8.26

Table D-111. Descriptive information for the CLASS x PERIOD interaction on the percentage of homework assignments delivered on-time.

	Period					
	Start		Middle		End	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
PCF Classroom	83.25	14.37	92.38	21.26	90.00	10.22
Standard Classroom	84.52	10.44	95.87	11.93	92.61	22.20

Table D-112. Descriptive information for the PERIOD x GENDER interaction on the percentage of homework assignments delivered on-time.

	Period					
	Start		Middle		End	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
Males	81.67	15.84	87.24	24.28	85.24	22.72
Females	85.65	8.86	99.62	1.96	96.15	8.04

Table D-113. Descriptive information for the CLASS x GENDER x PERIOD interaction on the percentage of homework assignments delivered on-time.

	Period					
	Start		Middle		End	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
Males						
PCF Classroom	81.25	7.73	85.58	18.91	86.67	9.85
Standard Classroom	82.22	13.94	89.44	17.76	83.33	33.91
Females						
PCF Classroom	85.25	10.44	99.17	2.89	93.33	9.85
Standard Classroom	86.00	7.66	100.00	0.00	98.57	5.34

Table D-114. ANOVA Summary Table for the ranks of the percentage of homework assignments delivered on-time.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	3057.48	3057.48	1.81	0.186
Gender (GENDER)	1	9467.61	9467.61	5.59	*0.023
GENDER x CLASS	1	7.28	7.28	0.00	0.948
S / GENDER CLASS	43	72788.20	1692.75		
Within					
Period (PERIOD)	2	50555.89	25277.94	45.04	*0.000
PERIOD x GENDER	2	2957.01	1478.51	2.68	0.074
PERIOD x CLASS	2	4527.41	2263.71	4.10	*0.020
PERIOD x GENDER x CLASS	2	455.15	227.57	0.41	0.663
PERIOD x S / GENDER CLASS	86	47427.10	551.48		
Total	140	191243.13			

* $p < 0.050$

D.1.2.2.2 Time Spent on Homework Activities

The mean reported time for the first 12 weeks of the school year was 65.73 minutes with a standard deviation of 28.16, while the mean time for the last 12 weeks was 48.27 minutes with a standard deviation of 26.27. The mean time for boys was 60.79 minutes with a standard deviation of 29.61, while the mean time for girls was 53.41 minutes with a standard deviation of 27.62. The mean time for students from the PCF classroom was 65.57 minutes with a standard deviation of 27.02, while the mean time for students from the standard classroom was 44.46 minutes with a standard deviation of 26.64. Tables D-115 thru D-118 present descriptive information for this measure. Table D-119 summarizes the analysis results.

Table D-115. Descriptive information for the CLASS x GENDER interaction of average daily time spent on homework activities (minutes).

	Males		Females	
	Mean	*std*	*Mean*	*std*
PCF Classroom	69.83	26.04	61.29	27.91
Standard Classroom	46.61	30.19	42.57	23.97

Table D-116. Descriptive information for the CLASS x PERIOD interaction of average daily time spent on homework activities (minutes).

	First 12-week Period		Last 12-week Period	
	Mean	*std*	*Mean*	*std*
PCF Classroom	72.16	26.61	58.95	26.38
Standard Classroom	56.30	28.57	32.61	18.81

Table D-117. Descriptive information for the GENDER x PERIOD interaction of average daily time spent on homework activities (minutes).

	First 12-week Period		Last 12-week Period	
	Mean	*std*	*Mean*	*std*
Males	70.83	28.36	50.76	28.07
Females	60.89	27.84	45.93	25.98

Table D-118. Descriptive information for the CLASS x GENDER x PERIOD interaction of average daily time spent on homework activities (minutes).

	First 12-week Period		Last 12-week Period	
	Mean	*std*	*Mean*	*std*
Males				
PCF Classroom	77.73	23.63	61.92	26.99
Standard Classroom	60.00	33.54	33.21	20.75
Females				
PCF Classroom	66.59	29.33	55.98	26.72
Standard Classroom	53.06	25.35	32.08	18.36

Table D-119. ANOVA Summary Table for average daily time spent on homework activities.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	7817.87	7817.87	10.10	*0.003
Gender (GENDER)	1	713.23	713.23	0.92	0.344
GENDER x CLASS	1	90.21	90.21	0.12	0.735
S / GENDER CLASS	33	25546.64	774.14		
Within					
Period (PERIOD)	1	6117.00	6117.00	10.49	*0.003
PERIOD x GENDER	1	134.63	134.63	0.23	0.634
PERIOD x CLASS	1	507.11	507.11	0.87	0.358
PERIOD x GENDER x CLASS	1	0.413	0.413	0.00	0.979
PERIOD x S / GENDER CLASS	33	19253.65	583.44		
Total	73	60180.75			

* $p < 0.050$

D.1.2.2.3 Incidence of Problem Behaviors

The mean change for boys was 1.05 with a standard deviation of 9.41, while the mean change for girls was 0.08 with a standard deviation of 2.38. The mean change for students from the PCF classroom was 0.47 with a standard deviation of 8.10, while the mean change for student from the standard classroom was 0.79 with a standard deviation of 3.70. Table D-120 presents descriptive information for this measure. Table D-121 summarizes the analysis results.

Table D-120. Descriptive information for the CLASS x GENDER interaction of the Homework Behavior Checklist measure.

	Males		Females	
	Mean	*std*	*Mean*	*std*
PCF Classroom	0.62	11.53	1.81	4.53
Standard Classroom	0.32	2.50	-4.75	2.31

Table D-121. Summary of non-parametric tests preformed on the Homework Problem Checklist measure.

	Test	***Test Statistic***	***p*** *(adjusted for ties)*
Class (CLASS)	Mann-Whitney-Wilcoxon	W = 249.00	0.898
Gender (GENDER)	Mann-Whitney-Wilcoxon	W = 211.50	0.467
CLASS x GENDER	Kruskal-Wallis One-Way Analysis of Variance by Ranks	H = 1.50	0.683

* $p < 0.050$

D.1.2.3 Technical Skills and Knowledge Results

D.1.2.3.1 Computer Task Performance

Tables D-122 thru D-124 present descriptive information for the computer task measures. Based on preliminary tests of the data, a multivariate analysis was undertaken to assess the effect of project participation on student computer task scores. Tables D-125 thru D-127 summarize the analysis results, with Tables D-128 thru D-130 presenting the post-hoc ANOVAs for the multivariate analysis.

Table D-122. Means and standard deviations for the CLASS effect on student computer task scores.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
Training Skills Checklist Score	34.45	6.38	13.64	6.74
Typing Accuracy	94.41	5.53	87.59	8.68
Typing Speed	14.91	6.16	11.55	4.02

Table D-123. Means and standard deviations for the GENDER effect on student computer task scores.

	Males		Females	
	Mean	*std*	*Mean*	*std*
Training Skills Checklist Score	26.61	12.85	22.10	11.88
Typing Accuracy	92.68	5.40	89.72	9.39
Typing Speed	12.42	5.28	13.84	5.53

Table D-124. Means and standard deviations for the CLASS x GENDER interaction on student computer task scores.

	PCF Students		Control Students	
Males	*Mean*	*std*	*Mean*	*std*
Training Skills Checklist Score	36.00	5.24	13.69	7.49
Typing Accuracy	93.27	5.88	91.88	4.91
Typing Speed	13.55	5.72	10.88	4.52
Females	*Mean*	*std*	*Mean*	*std*
Training Skills Checklist Score	32.91	7.27	13.61	6.57
Typing Accuracy	95.55	5.16	85.14	9.53
Typing Speed	16.27	6.54	11.93	3.83

Table D-125. MANOVA Results for the effect of CLASS on student computer task scores.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.26	35.97	3	38	*0.000
Pillai's Trace	0.74	35.97	3	38	*0.000
Hotelling-Lawley Trace	2.84	35.97	3	38	*0.000
Roy's Greatest Root	2.84	35.97	3	38	*0.000

* $p < 0.050$

Table D-126. MANOVA Results for the effect of GENDER on student computer task scores.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.91	1.24	3	38	0.310
Pillai's Trace	0.09	1.24	3	38	0.310
Hotelling-Lawley Trace	0.10	1.24	3	38	0.310
Roy's Greatest Root	0.10	1.24	3	38	0.310

* $p < 0.050$

Table D-127. MANOVA Results for the effect of CLASS x GENDER interaction on student computer task scores.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.82	2.72	3	38	0.0508
Pillai's Trace	0.18	2.72	3	38	0.0508
Hotelling-Lawley Trace	0.21	2.72	3	38	0.0508
Roy's Greatest Root	0.21	2.72	3	38	0.0508

* $p < 0.050$

Table D-128. ANOVA Summary Table for student training skills score.

Source	***df***	***SS***	***MS***	***F***	***p***
Class (CLASS)	1	4767.36	4767.36	104.23	*0.000
Gender (GENDER)	1	28.61	28.61	0.61	0.441
CLASS x GENDER	1	23.96	23.96	0.55	0.465
S / CLASS GENDER	40	1756.97	43.92		
Total	43	6576.90			

* $p < 0.050$

Table D-129. ANOVA Summary Table for student typing accuracy.

Source	***df***	***SS***	***MS***	***F***	***p***
Class (CLASS)	1	368.14	368.14	7.50	*0.010
Gender (GENDER)	1	52.76	52.76	1.07	0.370
CLASS x GENDER	1	214.38	214.38	4.37	*0.043
S / CLASS GENDER	40	1963.50	49.09		
Total	43	2598.78			

* $p < 0.050$

Table D-130. ANOVA Summary Table for student typing speed.

Source	***df***	***SS***	***MS***	***F***	***p***
Class (CLASS)	1	130.09	130.09	4.78	*0.035
Gender (GENDER)	1	37.79	37.79	1.39	0.246
CLASS x GENDER	1	7.40	7.40	0.27	0.605
S / CLASS GENDER	40	1088.71	27.22		
Total	43	1263.99			

* $p < 0.050$

D.1.2.3.2 Technology Standards of Learning Scores

Tables D-131 thru D-133 present descriptive information for each of the sections from the technology portion of the SOLs. Tables D-133 thru D-136 summarize the analysis results.

Table D-131. Means and standard deviations for the CLASS effect of SOL Computer / Technology Category Scaled Scores.

	PCF Students		Control Students	
	Mean	*std*	*Mean*	*std*
Basic Understanding of Computer Technology	40.04	10.10	44.86	8.33
Basic Operational Skills	39.96	7.13	37.05	6.17
Using Technology to Solve Problems	40.48	7.84	38.10	6.62

Table D-132. Means and standard deviations for the GENDER effect of SOL Computer / Technology Category Scaled Scores.

	Males		Females	
	Mean	*std*	*Mean*	*std*
Basic Understanding of Computer Technology	41.43	9.21	43.17	9.90
Basic Operational Skills	38.10	6.60	39.00	7.04
Using Technology to Solve Problems	39.71	7.48	39.00	7.28

Table D-133. Means and standard deviations for the CLASS x GENDER interaction of SOL Computer / Technology Category Scaled Scores.

	PCF Students		Control Students	
Males	*Mean*	*std*	*Mean*	*std*
Basic Understanding of Computer Technology	38.00	8.86	46.00	7.94
Basic Operational Skills	39.33	7.61	36.44	4.90
Using Technology to Solve Problems	40.42	7.60	38.78	7.68
Females	*Mean*	*std*	*Mean*	*std*
Basic Understanding of Computer Technology	42.26	11.30	44.00	8.86
Basic Operational Skills	40.64	6.86	37.50	7.15
Using Technology to Solve Problems	40.54	8.48	37.58	6.01

Table D-134. MANOVA Results for the effect of CLASS on scaled scores from the SOL Computer / Technology category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.84	2.42	3	38	0.081
Pillai's Trace	0.16	2.42	3	38	0.081
Hotelling-Lawley Trace	0.19	2.42	3	38	0.081
Roy's Greatest Root	0.19	2.42	3	38	0.081

* $p < 0.050$

Table D-135. MANOVA Results for the effect of GENDER on scaled scores from the SOL Computer / Technology category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.97	0.39	3	38	0.760
Pillai's Trace	0.03	0.39	3	38	0.760
Hotelling-Lawley Trace	0.03	0.39	3	38	0.760
Roy's Greatest Root	0.03	0.39	3	38	0.760

* $p < 0.050$

Table D-136. MANOVA Results for the effect of CLASS x GENDER interaction on scaled scores from the SOL Computer / Technology category.

Statistic	*Value*	*F*	*Hypothesis Df*	*Error Df*	*p*
Wilks' Lambda	0.97	0.42	3	38	0.738
Pillai's Trace	0.03	0.42	3	38	0.738
Hotelling-Lawley Trace	0.03	0.42	3	38	0.738
Roy's Greatest Root	0.03	0.42	3	38	0.738

* $p < 0.050$

D.1.3 Family Support Results

D.1.3.1 Home-School Communication

D.1.3.1.1 Perceived Quality

The number of self-report forms returned varied from parent to parent, thus the basic unit of analysis for this measure was the average quality rating for a given period. The mean rating for PCF parents was 4.63 with a standard deviation of 1.50, while the mean rating for parents from the standard classroom was 4.12 with a standard deviation of 1.39. Tables D-137 thru D-138 present descriptive information for this measure. Table D-139 summarizes the analysis results.

Table D-137. Descriptive information for PERIOD effect of parent ratings of home-school communication.

	Mean	*std*
Weeks 1-12	5.21	1.48
Weeks 13-24	4.29	1.47
Weeks 25-36	4.02	1.28

Table D-138. Descriptive information for the CLASS x PERIOD interaction on parent ratings of home-school communication.

	Start		Middle		End	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
PCF Classroom	5.50	1.41	4.48	1.40	3.91	1.30
Standard Classroom	4.26	1.38	3.72	1.63	4.35	1.25

Table D-139. ANOVA Summary Table for parent ratings of home-school communication.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	4.11	4.11	1.23	0.277
S / CLASS	27	90.29	3.34		
Within					
Period (PERIOD)	2	1469.73	734.87	2.18	0.123
PERIOD x CLASS	2	2430.37	1215.19	3.60	*0.034
PERIOD x S / CLASS	54	18219.21	337.39		
Total	86	22213.71			

* $p < 0.050$

D.1.3.1.2 Parent-School Contacts

The mean number of weekly school contacts for control parents was 1.27 with a standard deviation of 1.81, while the mean number for PCF parents was 0.49 with a standard deviation of 0.98. The mean number of traditional contacts was 1.22 with a standard deviation of 1.59, while the mean number of Internet contacts was 0.16 with a standard deviation of 0.48. Tables D-140 thru D-144 present descriptive information for this measure. Table 145 summarizes the analysis results.

Table D-140. Descriptive information for PERIOD effect of Average Weekly Parental School Contacts.

	Mean	*std*
Weeks 1-12 of School Year	0.69	1.44
Weeks 13-24	0.83	1.22
Weeks 25-36	0.55	1.19

Table D-141. Descriptive information for the PERIOD x MODE interaction of Average Weekly Parental School Contacts.

	Weeks 1-12		Weeks 13-24		Weeks 25-36	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
Traditional	1.24	1.81	1.45	1.40	0.97	1.54
Internet	0.14	0.58	0.21	0.49	0.13	0.35

Table D-142. Descriptive information for the CLASS x MODE interaction of Average Weekly Parental School Contacts.

	Traditional		Internet	
	Mean	*std*	*Mean*	*std*
PCF Classroom	0.86	1.25	0.12	1.25
Standard Classroom	2.27	2.00	0.27	0.77

Table D-143. Descriptive information for the CLASS x PERIOD interaction of Average Weekly Parental School Contacts.

	Weeks 1-12		Weeks 13-24		Weeks 25-36	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
PCF Classroom	0.38	0.81	0.75	1.20	0.34	0.86
Standard Classroom	1.64	2.37	1.07	1.26	1.13	1.71

Table D-144. Descriptive information for the CLASS x PERIOD x MODE interaction of Average Weekly Parental School Contacts.

	Weeks 1-12		Weeks 13-24		Weeks 25-36	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
PCF Classroom						
Traditional	0.73	1.03	1.32	1.46	0.55	1.14
Internet	0.050	0.21	0.18	0.39	0.14	0.35
Standard Classroom						
Traditional	2.85	2.73	1.86	1.21	2.13	1.96
Internet	0.43	1.13	0.28	0.76	0.13	0.35

Table D-145. ANOVA Summary Table for the ranks of the Average Weekly Parental School Contacts.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	15787.53	15787.53	4.48	*0.022
S / CLASS	27	95056.30	3520.60		
Within					
Communication Mode (MODE)	1	60177.39	60177.39	36.19	*0.000
MODE x CLASS	1	8442.88	8442.88	5.08	*0.016
MODE x S / CLASS	27	44893.31	1662.72		
Period (PERIOD)	2	5704.39	2852.20	4.91	*0.009
PERIOD x CLASS	2	1023.14	511.57	0.88	0.421
PERIOD x S / CLASS	54	31392.38	581.34		
MODE x PERIOD	2	2295.50	1147.75	1.40	0.256
MODE x PERIOD x CLASS	2	1441.67	720.84	0.88	0.421
MODE x PERIOD x S / CLASS	54	44331.33	820.95		
Total	175	310545.83			

* $p < 0.050$

D.1.3.2 Email as a Medium for Parent-Teacher Communication Among PCF Families

The mean percentage of parents emailing teaching staff each week was 5.9028 with a standard deviation of 9.531. The mean percentage of parents that receive e-mail from a member of the teaching staff each week was 44.734 with a standard deviation of 48.571. The mean percentage of parents in e-mail contact with the teacher each week was 3.299 with a standard deviation of 11.949. The mean percentage of parents in e-mail contact with the technologist was 47.338 with a standard deviation of 45.698. Table D-146 presents descriptive information for the DIRECT x ROLE interaction. Table D-147 summaries the analysis for this variable.

Table D-146. Descriptive information for the DIRECT x ROLE interaction of parent-teacher E-mail communication among PCF participants.

	Teacher		Technologist	
	Mean	*std*	*Mean*	*std*
Sent	4.745	16.641	84.722	34.918
Received	1.852	2.894	9.954	11.922

Table D-147. ANOVA of Ranks Summary Table for parent-teacher E-mail communication among PCF participants.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Staff role (ROLE)	1	69820.722	69820.722	185.73	*0.001
Weeks / ROLE	70	31319.203	447.417		
Within					
Direction of Communication (DIRECT)	1	54282.528	54282.528	144.39	*0.001
DIRECT x ROLE	1	46494.141	46494.141	123.68	*0.001
DIRECT x ROLE x Weeks / ROLE	70	26315.345	375.934		
Total	143	228231.940			

* $p < 0.050$

D.1.3.3 Homework Help

The mean reported time for the first 12 weeks of the school year was 13.17 minutes with a standard deviation of 12.25, while the mean time for the last 12 weeks was 10.92 minutes with a standard deviation of 15.24. The mean time for boys was 13.17 minutes with a standard deviation of 14.56, while the mean time for girls was 10.97 minutes with a standard deviation of 13.16. The mean time for students from the PCF classroom was 13.64 minutes with a standard deviation of 15.44, while the mean time for students from the standard classroom was 9.57 minutes with a standard deviation of 10.62. Tables D-147 thru D-151 present descriptive information for this measure. Table 152 summarizes the analysis results.

Table D-148. Descriptive information for the CLASS x GENDER interaction of average daily parental homework time (minutes).

	Males		Females	
	Mean	*std*	*Mean*	*std*
PCF Classroom	16.71	16.44	10.57	14.08
Standard Classroom	7.19	8.11	11.51	12.02

Table D-149. Descriptive information for the CLASS x PERIOD interaction of average daily parental homework time (minutes).

	First 12-week Period		Last 12-week Period	
	Mean	*std*	*Mean*	*std*
PCF Classroom	15.86	13.05	10.18	11.61
Standard Classroom	8.92	9.84	11.42	17.54

Table D-150. Descriptive information for the GENDER x PERIOD interaction of average daily parental homework time (minutes).

	First 12-week Period		Last 12-week Period	
	Mean	*std*	*Mean*	*std*
Males	13.41	12.38	12.95	16.72
Females	12.95	12.46	8.99	13.87

Table D-151. Descriptive information for the CLASS x GENDER x PERIOD interaction of average daily parental homework time (minutes).

	First 12-week Period		Last 12-week Period	
	Mean	*std*	*Mean*	*std*
Males				
PCF Classroom	18.00	12.02	15.42	20.47
Standard Classroom	5.00	8.37	9.07	8.02
Females				
PCF Classroom	13.73	14.25	7.42	13.83
Standard Classroom	11.87	10.33	11.15	14.56

Table D-152. ANOVA Summary Table for of average daily parental homework time.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	426.52	426.52	0.71	0.405
Gender (GENDER)	1	61.16	61.16	0.10	0.751
GENDER x CLASS	1	944.24	944.24	1.58	0.218
S / GENDER CLASS	33	19736.39	598.07		
Within					
Period (PERIOD)	1	579.23	579.23	2.47	0.126
PERIOD x GENDER	1	413.33	413.33	1.76	0.194
PERIOD x CLASS	1	1197.19	1197.19	5.10	*0.031
PERIOD x GENDER x CLASS	1	205.97	205.97	0.88	0.356
PERIOD x S / GENDER CLASS	33	7504.60	234.51		
Total	73	31068.63			

* $p < 0.050$

D.1.3.4 Support For School Activities

The mean amount of time for PCF parents was with a standard deviation of , while the mean amount for parents from the standard classroom was with a standard deviation of .

Tables D-153 thru D-154 present descriptive information for this measure. Table 155 summarizes the analysis results.

Table D-153. Descriptive information for PERIOD effect on parent self-reports of time spent supporting school activities.

	Mean	*std*
Weeks 1-12	49.14	86.99
Weeks 13-24	67.40	97.11
Weeks 25-36	42.88	90.39

Table D-154. Descriptive information for the CLASS x PERIOD interaction on parent self-reports of time spent supporting school activities.

	Start		Middle		End	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
PCF Classroom	46.36	94.29	70.43	95.59	20.614	40.41
Standard Classroom	57.86	63.89	57.85	109.01	112.86	157.74

Table D-155. ANOVA Summary Table for the ranks of parental self-reports of time spent supporting school activities.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	1118.71	1118.71	1.22	0.279
S / CLASS	27	24704.95	914.99		
Within					
Period (PERIOD)	2	202.70	101.35	0.33	0.717
PERIOD x CLASS	2	1013.11	506.56	1.67	0.197
PERIOD x S / CLASS	54	16340.94	302.61		
Total	86	43380.41			

* $p < 0.050$

D.2 Patterns and Predictors of Computer Usage

D.2.1 Classroom Computer Usage

D.2.1.1 Total Time Spent Using the Computer

The mean amount of computer use per week in the network classroom was 256.51 minutes for the year, with a standard deviation of 147.72 minutes.

D.2.1.2 Analysis of PCF Classroom Computer Usage

D.2.1.2.1 Category of Classroom Application Usage

Tables D-156 thru D-158 present descriptive information for each application category by 12 week periods. Table 159 summarizes the analysis results.

Table D-156. Descriptive Statistics for Classroom Weekly Internet Application Use by 12-Week Period. Minutes are the unit of measurement.

	Mean	Median	Standard Deviation	Minimum	Maximum
Period 1 (weeks 1-12)	97.02	103.40	70.61	0.00	192.10
Period 2 (weeks 13-24)	56.41	40.43	51.60	0.00	186.60
Period 3 (weeks 25-36)	120.81	139.11	82.10	0.00	283.40

Table D-157. Descriptive Statistics for Classroom Weekly Production Application Use by 12-Week Period. Minutes are the unit of measurement

	Mean	Median	Standard Deviation	Minimum	Maximum
Period 1 (weeks 1-12)	101.80	74.16	91.10	0.00	272.10
Period 2 (weeks 13-24)	56.41	42.91	66.73	0.00	251.40
Period 3 (weeks 25-36)	77.01	59.80	69.70	0.00	272.10

Table D-158. Descriptive Statistics for Classroom Weekly Application Use in the Other Category by 12-Week Period. Minutes are the unit of measurement.

	Mean	Median	Standard Deviation	Minimum	Maximum
Period 1 (weeks 1-12)	58.60	46.80	51.44	0.00	189.40
Period 2 (weeks 13-24)	82.61	71.33	61.80	0.00	281.10
Period 3 (weeks 25-36)	111.70	106.50	75.31	0.00	257.50

Table D-159. ANCOVA of Ranks Summary Table for Classroom Application Use by Category.

Source	***df***	***SS***	***MS***	***F***	***p***
Days per Week (DAYS)	1	1828.07	1828.07	0.46	0.501
Between					
12-week Period (PERIOD)	2	54439.86	27219.93	4.11	*0.022
S / PERIOD	53	350748.82	6617.90		
Within					
Category (CAT)	2	10223.73	5111.87	1.28	0.283
CAT x PERIOD	4	38487.52	6617.90	2.40	0.051
CAT x S / PERIOD	108	432496.44	4004.60		
Total	170	888224.44			

* $p < 0.050$

D.2.1.2.2 Breadth of Classroom Application Usage

Table D-160 presents descriptive information for this measure by 12 week periods. Table D-161 summarizes the analysis results.

Table D-160. Descriptive Statistics for the Classroom Breadth of Application Use Measure by 12-Week Period.

	Mean	Median	Standard Deviation	Minimum	Maximum
Period 1 (weeks 1-12)	14.42	16.00	7.14	0.00	26.00
Period 2 (weeks 13-24)	14.52	15.00	7.42	0.00	28.00
Period 3 (weeks 25-36)	15.54	15.50	6.04	0.00	32.00

Table D-161. ANCOVA Summary Table for Classroom Application Breadth Measure.

Source	***df***	***SS***	***MS***	***F***	***p***
Days per Week (DAYS)	1	36.87	36.87	0.79	0.377
Period of Use (PERIOD)	2	21.61	10.81	0.23	0.793
S / PERIOD	53	2463.24	46.48		
Total	56	2521.72			

* $p < 0.050$

D.2.1.2.3 Classroom World Wide Web Usage

Table D-162 presents descriptive information for this measure by 12 week periods. Table D-163 summarizes the analysis results.

Table D-162. Descriptive Statistics for Weekly Classroom Web Usage by 12-Week Period.

	Mean	Median	Standard Deviation	Minimum	Maximum
Period 1 (weeks 1-12)	70.70	77.5	59.40	0.00	148.00
Period 2 (weeks 13-24)	48.50	20.0	82.00	0.00	367.00
Period 3 (weeks 25-36)	56.00	43.0	61.60	0.00	257.00

Table D-163. ANCOVA Summary Table for Classroom Web Usage.

Source	***df***	***SS***	***MS***	***F***	***p***
Days per Week (DAYS)	1	29230	29230	6.70	*0.012
Period of Use (PERIOD)	2	9822	4911	1.13	0.332
S / PERIOD	53	231249	4363		
Total	56	270301			

* $p < 0.050$

D.2.2 Student Self-Reports of Home Computer Usage

D.2.2.1 Overall Patterns of Home Computer Use

D.2.2.1.1 Time Spent Using Home Computer

The mean usage reported by students from the PCF classroom was 57.66 minutes with a standard deviation of 41.93, while the mean usage for students from the standard classroom was 84.69 minutes with a standard deviation of 89.50. Tables D-164 thru D-165 present descriptive information for this measure.

Table D-164. Descriptive information for PERIOD effect of time spent using home computer.

	Mean	*std*
Weeks 1-12	63.16	33.82
Weeks 13-24	84.78	83.36
Weeks 25-36	45.32	36.68

Table D-165. Descriptive information for the CLASS x PERIOD interaction on time spent using home computer.

	Weeks 1-12		Weeks 13-24		Weeks 25-36	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
PCF Classroom	65.63	32.36	65.54	56.08	41.81	29.04
Standard Classroom	55.75	39.28	142.50	123.95	55.83	60.72

D.2.2.1.2 Time Spent Playing Computer Games

Tables D-166 thru D-167 present descriptive information for this measure. Table D-168 summarizes the analysis results.

Table D-166. Descriptive information for PERIOD effect of time spent playing games on home computer.

	Mean	*std*
Weeks 1-12	26.05	40.48
Weeks 13-24	19.69	24.43
Weeks 25-36	20.68	41.68

Table D-167. Descriptive information for the CLASS x PERIOD interaction on time spent playing games on home computer.

	Weeks 1-12		Weeks 13-24		Weeks 25-36	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
PCF Classroom	12.29	14.91	15.42	17.44	8.58	11.71
Standard Classroom	67.31	62.71	32.50	37.32	56.80	72.36

Table D-168. ANOVA Summary Table for the ranks of time spent playing games on home computer.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	7381.13	7381.13	6.63	*0.015
S / CLASS	30	33422.38	1114.08		
Within					
Period (PERIOD)	2	1444.10	722.05	1.81	0.173
PERIOD x CLASS	2	1764.57	882.28	2.21	0.119
PERIOD x S / CLASS	60	24001.29	400.03		
Total	95	68013.46			

* $p < 0.050$

D.2.2.1.3 Time Connected to the Internet

The mean usage reported by students from the PCF classroom was 28.22 minutes with a standard deviation of 32.50, while the mean usage for students from the standard classroom was 42.10 minutes with a standard deviation of 68.56. Tables D-169 thru D-170 present descriptive information for this measure. Table D-171 summarizes the analysis results.

Table D-169. Descriptive information for PERIOD effect of time connected to the Internet from home.

	Mean	*std*
Weeks 1-12	23.43	21.73
Weeks 13-24	49.61	67.65
Weeks 25-36	22.26	22.19

Table D-170. Descriptive information for the CLASS x PERIOD interaction on time connected to the Internet from home.

	Weeks 1-12		Weeks 13-24		Weeks 25-36	
	Mean	std	*Mean*	std	Mean	std
PCF Classroom	23.62	24.13	74.29	110.02	29.17	33.88
Standard Classroom	22.85	24.13	41.38	47.57	20.07	17.55

Table D-171. ANOVA Summary Table for ranks of time connected to the Internet from home.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	63.73	63.73	0.06	0.809
S / CLASS	28	30068.72			
Within					
Period (PERIOD)	2	138.26	69.13	0.14	0.872
PERIOD x CLASS	2	130.10	65.05	0.13	0.879
PERIOD x S / CLASS	56	25570.71	501.39		
Total	89	55971.52			

* $p < 0.050$

D.2.2.2 Homework-related Computer Use

The mean usage reported for the first 12-week period was 11.42 minutes with a standard deviation of 16.92, and the mean usage for the third period year was 16.95 minutes with a standard deviation of 13.60. The mean usage reported by students from the PCF classroom was 14.84 minutes with a standard deviation of 14.15, while the mean usage for students from the standard classroom was 12.59 minutes with a standard deviation of 18.69. Table D-172 presents descriptive information for this measure. Table D-173 summarizes the analysis results.

Table D-172. Descriptive information for the CLASS x PERIOD interaction of daily average homework-related computer usage (minutes).

	First 12-weeks		Last 12-weeks	
	Mean	*std*	*Mean*	*std*
PCF Classroom	10.18	14.23	19.49	12.73
Standard Classroom	14.44	22.97	10.74	14.39

Table D-173. ANOVA of Ranks Summary Table for daily average homework-related computer usage.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Classroom (CLASS)	1	64.35	64.35	0.32	0.578
S / CLASS	29	5895.39	203.29		
Within					
Period (PERIOD)	1	100.39	100.39	0.38	0.541
PERIOD x CLASS	1	540.89	540.89	2.05	0.162
PERIOD x S / CLASS	29	7636.36	263.32		
Total	61	14237.38			

* $p < 0.050$

D.2.2.3 Home Internet Usage by PCF Students

D.2.2.3.1 Dispersion of Internet Technologies

The mean percentage of girls utilizing the technology for a given week was 60.95 with a standard deviation of 38.43, while the mean percentage of boys was 60.79 with a standard deviation of 39.10. The mean percentage for chat was 12.98 with a standard deviation of 20.60, while the mean percentage for e-mail was 80.050 with a standard deviation of 18.67. Table D-174 presents additional descriptive information for this measure. Table D-175 summarizes the analysis results.

Table D-174. Descriptive information for the GENDER x MEDIUM interaction of technology utilization percentage by PCF students.

	Female		Male	
	Mean	*std*	*Mean*	*std*
Chat	11.54	20.15	14.42	21.14
Email	83.33	17.62	76.76	19.27
Web	87.50	14.53	91.67	15.66

Table D-175. ANOVA Summary Table for the ranks of Technology Utilization Percentage by PCF Students.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Gender (GENDER)	1	525.72	525.72	0.11	0.744
WEEK / GENDER	102	501384.45	4915.53		
Within					
Internet Medium (Medium)	2	1579693.64	789846.82	447.13	*0.001
MEDIUM x GENDER	2	30344.39	15172.19	8.59	*0.001
MEDIUM x WEEK / GENDER	204	360362.31	1766.48		
Total	311	2472310.50			

* $p < 0.050$

D.2.2.4 Relative Importance of Internet Technologies

The mean percentage of days each month girls used Internet technologies was 34.01 with a standard deviation of 32.41, while the mean percentage for boys was 31.34 with a standard deviation of 20.32. Tables D-176 thru D-180 present additional descriptive information for this measure. Table D-181 summarizes the analysis results.

Table D-176. Descriptive information for MEDIUM effect on the percentage of days each month PCF students used Internet technologies.

	Mean	*std*
Chat	3.15	6.97
Email	35.44	23.84
Web	59.43	27.31

Table D-177. Descriptive information for MONTH effect on the percentage of days each month PCF students used Internet technologies.

	Mean	*std*
October	41.03	34.83
November	40.85	25.61
December	35.97	29.22
January	38.75	33.35
February	40.23	33.39
March	42.07	33.95
April	28.86	32.49
May	30.17	28.93
June	28.85	29.51
July	24.79	28.50
August	19.92	27.76
September	20.63	28.00

Table D-178. Descriptive information for the MONTH x GENDER interaction of the percentage of days each month PCF students used Internet technologies.

	Males		Females	
	Mean	*std*	*Mean*	*std*
October	40.02	33.79	42.04	36.29
November	39.63	25.79	42.07	25.73
December	33.15	27.71	38.77	30.79
January	32.88	28.95	44.62	36.69
February	38.01	31.51	42.46	35.49
March	42.20	32.74	41.94	35.59
April	30.42	32.57	27.31	32.80
May	28.78	27.65	31.55	30.49
June	29.22	30.56	28.46	28.76
July	23.61	27.57	25.97	29.79
August	18.82	28.41	21.02	27.46
September	19.38	28.50	21.89	27.84

Table D-179. Descriptive information for the GENDER x MEDIUM interaction of the percentage of days each month PCF students used Internet technologies.

	Chat		Email		Web	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
Males	3.69	7.67	31.28	21.29	59.06	26.74
Female	2.61	6.19	39.61	25.54	59.82	27.95

Table D-180. Descriptive information for the MEDIUM x MONTH interaction of the percentage of days each month PCF students used Internet technologies.

	Chat		Email		Web	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
October	0.81	3.95	47.62	22.28	74.66	17.86
November	15.83	10.78	51.53	23.81	55.20	18.83
December	6.05	9.19	38.97	19.07	62.86	22.11
January	1.07	2.26	46.37	21.18	68.82	22.22
February	2.38	6.46	50.00	19.84	68.32	24.27
March	5.24	6.58	49.46	24.21	71.52	23.51
April	3.75	6.97	16.46	8.25	66.38	29.24
May	2.41	4.39	36.02	23.60	52.06	25.85
June	0.14	0.68	33.89	19.70	52.51	28.80
July	0.13	0.66	25.00	20.45	49.23	28.83
August	0.00	0.00	16.40	14.48	43.36	34.20
September	0.00	0.00	13.61	15.38	48.29	29.83

Table D-181. ANOVA Summary Table for the ranks of the percentage of days each month PCF students used Internet technologies.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Gender (GENDER)	1	36986.58	36986.58	0.186	0.862
S / GENDER	22	4371936.03	198724.36		
Within					
Internet Medium (MEDIUM)	2	32172019.23	16086009.62	163.32	*0.001
MEDIUM x GENDER	2	196984.33	98492.17	1.38	0.423
MEDIUM x S / GENDER	44	3131354.37	71167.14		
Month (MONTH)	11	3450235.32	313657.76	22.76	*0.001
MONTH x GENDER	11	172331.51	15666.50	1.13	0.261
MONTH x S / GENDER	242	3335585.39	13783.41		
MEDIUM x MONTH	22	1826128.64	83005.85	10.35	*0.001
MEDIUM x MONTH x GENDER	22	164972.01	7498.73	0.93	0.549
MEDIUM x MONTH x S / GENDER	484	3883131.59	8023.00		
Total	863	52741665.00			

* $p < 0.050$

D.2.2.5 Factors Influencing Internet Usage

D.2.2.5.1 Influences on WWW Usage

Table D-182 summarizes the time series cross-sectional (TSCS) regression analysis used to determine which factors most influenced student WWW use.

Table D-182. Fit Statistics for family WWW Usage Model.

Number of Cross Sections	24
Time Series Length	52
SS Error	1215.61
MS Error	0.980
df Error	1240

D.2.2.5.2 Influences on Email Usage

Table D-183 summarizes the time series regression analysis used to determine which factors most influenced student e-mail use.

Table F-183. Fit Statistics for Student Email Usage Model.

Number of Cross Sections	24
Time Series Length	52
SS Error	1226.13
MS Error	0.990
df Error	1239

D.2.2.5.3 Influences on Chat Usage

Males entered an average of 1382 lines with a standard deviation of 1339, while girls entered an average of 738 with a standard deviation of 702. Given the discrete and non-normal nature of the data, a RGLM was used to analyze the data. The analysis results are summarized in Table D-193.

Table D-184. ANOVA Summary Table for the ranks of chat usage model.

Source	***df***	***SS***	***MS***	***F***	***p***
Regression	4	671.98	167.98	6.69	*0.002
Error	19	477.07	25.11		
Total	23	1149.00			

* $p < 0.050$

D.2.2.5.4 Categories of Chat Usage

The mean score for boys was 36.06 with a standard deviation of 5.09, while the mean score for girls was 34.03 with a standard deviation of 4.75. Tables D-185 thru D-186 present additional descriptive information for this measure. Table D-187 summarizes the ANOVA analysis results for this measure.

Table D-185. Descriptive information for the CATEGORY main effect of the Chat Categories of Use analysis.

	Mean	*std*
Social Use	336.38	329.33
School Use	1.25	3.87
Disruptive	723.08	883.78

Table D-186. Descriptive information for the GENDER x CATEGORY interaction of the Chat Categories of Use Analysis.

	Period					
	Social Use		School Use		Disruptive	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
Males	277.67	316.39	0.00	0.00	1104.25	1067.38
Females	395.08	345.19	2.50	5.28	341.92	420.52

Table D-187. ANOVA Summary Table for the Chat Categories of Use.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Gender (GENDER)	1	14.22	14.22	0.13	0.716
S / GENDER	22	8484.28			
Within					
Category of use (CATEGORY)	2	15091.58	7545.79	71.38	*0.001
GENDER x CATEGORY	2	1394.11	697.06	6.59	*0.003
CATEGORY x S / GENDER	44	4651.31			
Total	71	29635.50			

* $p < 0.050$

D.2.3 Evolution of Electronic Social Networks

D.2.3.1 Differences in Student Network Characteristics

Table D-188. ANOVA Summary Table for the ranks of email centrality model.

Source	***df***	***SS***	***MS***	***F***	***p***
Regression	3	598.925	199.642	10.67	*0.001
Error	20	318.146	18.714		
Total	23	917.071			

* $p < 0.050$

Table D-189. ANOVA Summary Table for the ranks of email prestige model.

Source	***df***	***SS***	***MS***	***F***	***p***
Regression	3	681.78	227.26	14.43	*0.001
Error	20	267.72	15.75		
Total	23	949.50			

* $p < 0.050$

Table D-190. ANOVA Summary Table for chat centrality model.

Source	***df***	***SS***	***MS***	***F***	***p***
Regression	6	45.875	7.645	48.87	*0.001
Error	17	2.190	0.156		
Total	23	28.065			

* $p < 0.050$

D.2.4 Physical Effects of PCF Student Computer Use

The mean score for boys was 9.21 with a standard deviation of 13.96, while the mean score for girls was 6.66 with a standard deviation of 16.56. Tables D-200 thru D-201 present additional descriptive information for this measure. Table D-202 summarizes the ANOVA of Ranks analysis results for this measure. The reader should note that gender was not included as an effect of this model as insufficient numbers of control students completed the survey.

Table D-191. Descriptive information for the PERIOD main effect of the Student Discomfort measure.

	Mean	*std*
Period 1 (start of the school year)	4.00	8.19
Period 2 (middle of the school year)	7.45	8.93
Period 3 (end of the school year)	12.36	23.15

Table D-192. Descriptive information for the GENDER x PERIOD interaction of the Student Discomfort measure.

	Period					
	Start		Middle		End	
	Mean	*std*	*Mean*	*std*	*Mean*	*std*
Males	5.27	8.17	9.55	9.62	12.82	20.81
Females	2.73	8.40	5.36	8.09	11.91	26.30

Table D-193. ANOVA of Ranks Summary Table for Student Discomfort measure.

Source	***df***	***SS***	***MS***	***F***	***p***
Between					
Gender (GENDER)	1	453.47	453.47	0.62	0.439
S / GENDER	20	14569.03	728.45		
Within					
12 week period (PERIOD)	2	1413.82	706.91	5.78	0.006
PERIOD x GENDER	2	355.48	177.74	1.45	0.246
PERIOD x S / GENDER	40	4892.70	122.32		
Total	65	21684.50			

* $p < 0.050$

D.3 Patterns and Predictors of Student Changes

D.3.1 Differences in Student Academic Efficiency

Table D-194. ANOVA Summary Table for of DEA Academic Efficiency Scores.

Source	***df***	***SS***	***MS***	***F***	***p***
Classroom (CLASS)	1	54.09	54.10	1.96	0.169
Gender (GENDER)	1	8.73	8.73	0.32	0.577
GENDER x CLASS	1	68.24	68.24	2.47	0.124
S / GENDER CLASS	39	1076.48			
Total	42	1207.55			

* $p < 0.050$

Table D-195. Regression Summary Table for DEA Efficiency Scores of PCF Students.

Source	***df***	***SS***	***MS***	***F***	***p***
Model	7	496.82	38.22	25.74	*0.001
Error	14	11.88	1.48		
Total	21	508.69			

* $p < 0.050$

D.3.2 Patterns of Relationships Among Experimental Measures

D.3.2.1 Relationships Between Model Constructs

Table D-196. Standardized canonical coefficients for Technology Use, Technology Use - QWL Canonical Analysis.

	Variable 1*	Variable 2	Variable 3
Average Daily Computer Use (self-report)	-0.218	-1.544	-0.545
Average Daily Internet Use (self-report)	0.490	1.008	1.091
Number of Email Messages Sent	0.066	0.268	-0.721
Number of WWW Pages Accessed	0.884	0.217	-0.337
Number of Chat Lines Entered	-0.205	-0.180	-0.256

* $p < 0.050$

Table D-197. Standardized canonical coefficients for QWL, Technology Use - QWL Canonical Analysis.

	Variable 1*	Variable 2	Variable 3
Absent Change	0.433	-0.337	-0.623
Tardy Change	0.880	0.265	0.360
Sam Change	0.082	-0.669	0.722
Feel About Computers Change	-0.272	0.468	0.260
Knudson Writing Change	-0.101	0.674	0.641

* $p < 0.050$

Table D-198. Standardized canonical coefficients for Technology Use, Technology Use - Student Performance Canonical Analysis.

	Variable 1*	Variable 2	Variable 3
Average Daily Computer Use (self-report)	0.285	-0.389	-1.113
Average Daily Internet Use (self-report)	0.066	0.384	1.468
Number of Email Messages Sent	0.0504	0.809	-0.521
Number of WWW Pages Accessed	-1.094	0.097	-0.017
Number of Chat Lines Entered	0.081	0.275	0.031

* $p < 0.050$

Table D-199. Standardized canonical coefficients for Student Performance, Technology Use - Student Performance Canonical Analysis.

	Variable 1*	Variable 2	Variable 3
GPA Gain	-0.514	-0.178	-0.290
Reading Standardized Test Ratio	-0.472	0.289	0.021
Math Standardized Test Ratio	-0.266	-0.256	-0.187
Writing Standardized Test Ratio	0.239	0.586	0.792
Science Standardized Test Ratio	0.386	1.103	-0.830
Social Studies Standardized Test Ratio	0.104	-0.327	0.440
SOL Technology SS	0.285	-0.484	0.554
Percentage Homework Completed On-time	0.718	0.049	-0.699

* $p < 0.050$

Table D-200. Standardized canonical coefficients for QWL, QWL - Student Performance Canonical Analysis.

	Variable 1*	Variable 2	Variable 3
Absent Change	0.673	0.941	-0.096
Tardy Change	0.588	-0.807	0.270
Sam Change	-0.373	-0.300	-0.309
Feel About Computers Change	-0.216	-0.387	0.387
Knudson Writing Change	-0.520	-0.523	1.061

* $p < 0.050$

Table D-201. Standardized canonical coefficients for Student Performance, QWL - Student Performance Canonical Analysis.

	Variable 1*	Variable 2	Variable 3
GPA Gain	0.414	0.732	0.010
Reading Standardized Test Ratio	-0.094	-0.526	0.710
Math Standardized Test Ratio	0.210	0.249	-0.148
Writing Standardized Test Ratio	0.025	0.154	0.711
Science Standardized Test Ratio	-0.119	0.045	0.186
Social Studies Standardized Test Ratio	-0.324	-0.488	0.152
SOL Technology SS	0.224	0.126	-0.518
Percentage Homework Completed On-time	-0.806	0.734	-0.074

Significant at $p < 0.050$

D.3.2.2 Similarities Among Outcome Measures

Table D-202. Measure set used for R-analysis of outcome measures. * indicates measures that were converted to rank data prior to analysis.

Measures	Related Conceptual Construct
1. Change in student GPA *	Student Performance
2. Average number web pages loaded by family each week	Student Technology Use
3. Change in the number of days student was absent	Student QWL
4. Change in Feel About Computer RS	Student QWL
5. Average minutes of daily home computer use (self-report)	Student Technology Use
6. Change in the number of days student was tardy *	Student QWL
7. Average number of minutes of homework help student receives each day (self-report) *	Home-School Partnership
8. Average number of email messages sent by students each week *	Student Technology Use
9. Average number of chat lines sent by students each week *	Student Technology Use
10. Average number of minutes parents discuss school with child each day (self-report) *	Home-School Partnership
11. Average number of weekly home-school contacts (self-report) *	Home-School Partnership
12. Average minutes of daily home Internet use (self-report)	Student Technology Use
13. Change in SAM RS	Student QWL
14. Ratio of SOL SS for a subject to Stanford-9 SS for reading	Student Performance
15. Ratio of SOL SS for a subject to Stanford-9 SS for mathematics	Student Performance
16. Ratio of SOL SS for a subject to Stanford-9 SS for writing	Student Performance
17. Ratio of SOL SS for a subject to Stanford-9 SS for science	Student Performance
18. Ratio of SOL SS for a subject to Stanford-9 SS for social studies	Student Performance
19. SOL Technology SS	Student Performance
20. Change in Knudson Writing RS	Student QWL
21. Average percentage of homework assignments delivered on-time each week	Student QWL
22. Parent rating of home-school communication	Home-School Partnership
23. Average number of minutes student spends on homework each day (self-report)	Home-School Partnership

Table D-203. Resemblence matrix for R-analysis of outcome measures. Numbers correspond to specific measures in the previous table.

Measure	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1.		.477	.424	-.250	-.074	.485	-.400	.078	-.103	-.017	.224	.028
2.	.477		.740	.080	.068	.362	.102	-.168	-.158	.231	-.195	-.147
3.	.424	.740		.372	.170	.277	.068	-.116	.047	.108	-.352	.170
4.	-.250	.080	.372		-.148	-.019	.063	-.035	-.032	-.208	-.584	-.202
5.	-.074	.068	.170	-.148		-.231	-.129	-.198	-.125	.190	-.064	.684
6.	.485	.362	.277	-.019	-.231		-.099	.295	-.335	.138	.156	-.186
7.	-.400	.102	.068	.063	-.129	-.099		-.171	.367	.236	.028	.030
8.	.078	-.168	-.116	-.035	-.198	.295	-.171		.283	.235	.296	.088
9.	-.103	-.158	.047	-.032	-.125	-.335	.367	.283		-.047	-.009	.153
10.	-.017	.231	.108	-.208	.190	.138	.236	.235	-.047		-.058	.292
11.	.224	-.195	-.352	-.584	-.064	.156	.028	.296	-.009	-.058		.151
12.	.028	-.147	.170	-.202	.684	-.186	.030	.088	.153	.292	.151	
13.	-.172	.093	.049	.095	.552	-.235	-.031	-.488	-.059	-.001	-.348	.247
14.	.474	.187	.184	-.025	-.176	-.088	-.292	.152	.031	.089	.136	-.034
15.	.069	-.182	.259	.297	.199	-.058	-.174	.109	.025	-.098	-.157	.227
16.	.203	-.080	.210	-.015	-.115	-.014	.218	.331	.299	.045	.296	.368
17.	.456	-.046	.173	-.003	.120	.146	-.485	.325	.135	-.274	.192	.154
18.	.236	-.223	-.131	-.233	.265	-.106	-.278	-.097	-.081	-.278	.290	.197
19.	.529	-.230	.145	.008	.084	.113	-.582	.020	-.114	-.296	.042	.226
20.	.279	.169	.221	-.467	.028	.008	.117	.268	.254	.482	.325	.356
21.	-.171	-.367	-.309	-.110	.170	-.418	.029	.027	.084	.207	-.010	.282
22.	.030	.144	-.060	-.487	-.139	-.001	.057	.133	.213	.226	.188	-.166
23.	-.505	-.208	-.036	.168	.184	-.282	.452	-.242	.010	.105	-.140	.073

Measure	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.
1.	-.172	.474	.069	.203	.456	.236	.529	.279	-.171	.030	-.505
2.	.093	.187	-.182	-.080	-.046	-.223	-.230	.169	-.367	.144	-.208
3.	.049	.184	.259	.210	.173	-.131	.145	.221	-.309	-.060	-.036
4.	.095	-.025	.297	-.015	-.003	-.233	.008	-.467	-.110	-.487	.168
5.	.552	-.176	.199	-.115	.120	.265	.084	.028	.170	-.139	.184
6.	-.235	-.088	-.058	-.014	.146	-.106	.113	.008	-.418	-.001	-.282
7.	-.031	-.292	-.174	.218	-.485	-.278	-.582	.117	.029	.057	.452
8.	-.488	.152	.109	.331	.325	-.097	.020	.268	.027	.133	-.242
9.	-.059	.031	.025	.299	.135	-.081	-.114	.254	.084	.213	.010
10.	-.001	.089	-.098	.045	-.274	-.278	-.296	.482	.207	.226	.105
11.	-.348	.136	-.157	.296	.192	.290	.042	.325	-.010	.188	-.140
12.	.247	-.034	.227	.368	.154	.197	.226	.356	.282	-.166	.073
13.		-.004	.122	-.494	-.005	.325	.004	-.211	.373	.036	-.113
14.	-.004		.354	.265	.438	.400	.492	.497	.408	.080	-.378
15.	.122	.354		.321	.562	.443	.565	.111	.366	-.035	.146
16.	-.494	.265	.321		.118	-.090	.248	.334	.060	-.165	.280
17.	-.005	.438	.562	.118		.517	.615	.177	-.072	.084	-.315
18.	.325	.400	.443	-.090	.517		.482	.299	.381	.086	-.335
19.	.004	.492	.565	.248	.615	.482		.066	.225	-.271	-.269
20.	-.211	.497	.111	.334	.177	.299	.066		.177	.328	-.227
21.	.373	.408	.366	.060	-.072	.381	.225	.177		.024	.024
22.	.036	.080	-.035	-.165	.084	.086	-.271	.328	.024		-.203
23.	-.113	-.378	.146	.280	-.315	-.335	-.269	-.227	.024	-.203	

Table D-204. Standardized canonical coefficients for Group1, Group1 - Group 3 Canonical Analysis.

	Variable 1*	Variable 2	Variable 3
WWW Weekly Usage	-1.158	-0.110	0.251
Absent Change	0.190	0.492	-0.496
Tardy Change	0.220	-0.290	-0.808
GPA Gain	0.360	-0.296	1.045
Parents discuss school with child (self-report)	-0.166	0.701	0.487
Rating of Home-School Communication (self-report)	0.095	0.148	-0.461

* $p < 0.050$

Table D-205. Standardized canonical coefficients for Group 3, Group1 - Group 3 Canonical Analysis.

	Variable 1*	Variable 2	Variable 3
SAM RS Change	-0.110	0.273	-0.481
Daily Computer Use (self-report)	-0.396	0.374	0.681
Internet Use (self-report)	-0.038	-0.189	0.214
Reading Standardized Test Ratio	-0.634	-0.035	0.862
Math Standardized Test Ratio	-0.165	0.369	-0.737
Science Standardized Test Ratio	0.53	-0.089	-0.0509
Social Studies Standardized Test Ratio	0.114	-0.716	0.001
SOL Technology SS	0.538	-0.246	0.309
Knudson RS Change	0.114	0.753	-0.232
Percentage of Homework Items Delivered On-time	0.625	0.324	0.550

* $p < 0.050$

D.3.2.3 Factors Influencing Student Outcomes

D.3.2.3.1 Influences on Student Performance

Table D-206. Regression Summary Table for GPA Changes of PCF Students.

Source	***df***	***SS***	***MS***	***F***	***p***
Model	7	944.73	134.96	30.33	*0.001
Error	13	57.84	4.45		
Total	20	1002.57			

* $p < 0.050$

Table D-207. Regression Summary Table for the Average Weekly Percentage of Homework Assignments Delivered On-Time by PCF Students.

Source	***df***	***SS***	***MS***	***F***	***p***
Model	10	1252.10	125.21	98.52	*0.001
Error	10	12.71	1.27		
Total	20	1264.80			

* $p < 0.050$

Table D-208. Regression Summary Table for SOL Reading SS of PCF Students.

Source	***df***	***SS***	***MS***	***F***	***p***
Model	3	49482.00	12370.00	23.03	*0.001
Error	17	8594.17	537.14		
Total	20	58076.00			

* $p < 0.050$

Table D-209. Regression Summary Table for SOL Writing SS of PCF Students.

Source	***df***	***SS***	***MS***	***F***	***p***
Model	4	22361.00	5590.34	19.66	*0.001
Error	16	4549.31	284.33		
Total	20	26911.21			

* $p < 0.050$

Table D-210. Regression Summary Table for SOL Science SS of PCF Students.

Source	***df***	***SS***	***MS***	***F***	***p***
Model	2	51496.00	25748.00	48.98	*0.001
Error	18	9462.93	525.72		
Total	20	60959.93			

* $p < 0.050$

Table D-211. Regression Summary Table for SOL Mathematics SS of PCF Students.

Source	***df***	***SS***	***MS***	***F***	***p***
Model	4	67864.00	16966.00	26.74	*0.001
Error	16	10152.00	634.49		
Total	20	78016.00			

* $p < 0.050$

Table D-212. Regression Summary Table for SOL Technology SS of PCF Students.

Source	***df***	***SS***	***MS***	***F***	***p***
Model	6	59360.00	9893.30	15.73	*0.001
Error	14	88808.01	629.14		
Total	20	68168.00			

* $p < 0.050$

D.3.2.3.2 Influences on Student QWL

Table D-213. Regression Summary Table for Absence Change of PCF Students.

Source	***df***	***SS***	***MS***	***F***	***p***
Model	4	220.429	55.11	16.09	*0.001
Error	16	54.809	3.43		
Total	20	275.238			

* $p < 0.050$

Table D-214. Regression Summary Table for SAM NP Change of PCF Students.

Source	***df***	***SS***	***MS***	***F***	***p***
Model	5	7766.22	1553.24	8.22	*0.001
Error	15	2835.02	189.00		
Total	20	19691.24			

* $p < 0.050$

Table D-215. Regression Summary Table for Knudson Writing Survey Change of PCF Students.

Source	***df***	***SS***	***MS***	***F***	***p***
Model	9	1051.24	116.80	17.94	*0.001
Error	11	71.63	6.52		
Total	20	1122.87			

* $p < 0.050$

APPENDIX E: SUMMARY TABLES OF SIGNIFICANT CORRELATIONS BETWEEN EVALUATION MEASURES

Given the disparate nature of the field study data (*e.g.*, normal vs. non-normal), Spearman's correlation coefficient (r_s) was used to initially explore the relationship between field study measures. Spearman's correlation is a simplification of Pearson's correlation for ranks and does not assume normality. Only significant correlations ($p < 0.050$) are presented here. Each of the correlation tables along with its starting page number are listed below. Dashes in a table cell indicate the correlation was not significant ($p > 0.050$). For survey instruments comprised of multiple scales, only the overall instrument score (gain) was included in correlational analyses summarized here. Similarly for standardized test scores, only the overall subject scores were included here.

SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR THE COMPUTER TASK PERFORMANCE MEASURES. 305
SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR THE SOL TECHNOLOGY MEASURES........................ 306
SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR STUDENT SELF-REPORTS OF HOME COMPUTER USE.308
SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR PCF STUDENT NETWORK USAGE. 309
SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR THE STUDENT ATTITUDE SURVEY CHANGES.......... 310
SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR THE ATTENDANCE CHANGES................................... 311
SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR THE SOL SUBJECT SCALED SCORES........................ 312
SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR STUDENT GRADE GAINS... 314
SIGNIFICANT SPEARMAN'S RANK CORRELATIONS FOR THE SOL HOMEWORK PROCESS MEASURES.......... 316

Technology Skills

Table E-1. Significant Spearman's rank correlations for the computer task performance measures.

	Training Skills Score	Training Skills Gain	Typing Speed	Typing Accuracy
Training Skills Gain	$r_s = 0.569$, $p < 0.005$			
Typing Speed	$r_s = 0.449$, $p < 0.002$	--		
Typing Accuracy	$r_s = 0.486$, $p < 0.001$	--	--	
Both Classes				
Number of home computers	$r_s = 0.554$, $p < 0.001$	$r_s = 0.588$ $p < 0.003$	$r_s = 0.485$, $p < 0.001$	$r_s = 0.305$, $p < 0.044$
Number of home Internet connections	$r_s = 0.549$, $p < 0.001$	n/a	$r_s = 0.396$, $p < 0.008$	--
Maximum years of education for parents	$r_s = 0.456$, $p < 0.002$	n/a	--	--
Entry SAM Overall NP	--	--	$r_s = 0.357$ $p < 0.018$	--
Language Arts 4th Grade GPA	$r_s = 0.619$, $p < 0.001$	--	$r_s = 0.705$, $p < 0.001$	--
Math 4th Grade GPA	$r_s = 0.585$, $p < 0.001$	--	$r_s = 0.511$ $p < 0.001$	$r_s = 0.330$ $p < 0.029$
Science 4th Grade GPA	$r_s = 0.641$ $p < 0.001$	--	$r_s = 0.751$ $p < 0.001$	$r_s = 0.353$ $p < 0.019$
Social Studies 4th Grade GPA	$r_s = 0.581$ $p < 0.018$	--	$r_s = 0.732$ $p < 0.001$	$r_s = 0.306$ $p < 0.044$
4th Grade GPA	$r_s = 0.658$ $p < 0.001$	--	$r_s = 0.758$ $p < 0.001$	$r_s = 0.335$ $p < 0.026$
SOL Reading SS	$r_s = 0.394$, $p < 0.009$	--	$r_s = 0.595$, $p < 0.001$	--
SOL Math SS	$r_s = 0.431$, $p < 0.004$	--	$r_s = 0.586$, $p < 0.001$	--
SOL History and Social	$r_s = 0.458$,	--	$r_s = 0.585$,	--

	Training Skills Score	Training Skills Gain	Typing Speed	Typing Accuracy
Science SS	$p < 0.002$		$p < 0.001$	
SOL Science SS	$r_s = 0.381$, $p < 0.011$	--	$r_s = 0.452$, $p < 0.002$	--
SOL Technology SS	$r_s = 0.397$, $p < 0.009$	--	$r_s = 0.554$, $p < 0.001$	--
SOL Technology: Basic Operational Skills	$r_s = 0.442$, $p < 0.003$	--	$r_s = 0.505$, $p < 0.001$	--
SOL Technology: Using Technology to Solve Problems	$r_s = 0.363$, $p < 0.017$	--	$r_s = 0.489$, $p < 0.001$	--
SOL Writing	$r_s = 0.507$, $p < 0.001$	--	$r_s = 0.603$, $p < 0.001$	--
Stanford 9 Overall NP	$r_s = 0.618$, $p < 0.001$		$r_s = 0.628$, $p < 0.001$	
Homework Assignments Delivered On-time	--	--	$r_s = 0.336$, $p < 0.026$	--
Time Spent on the Internet	$r_s = 0.410$, $p < 0.005$	--	$r_s = 0.348$, $p < 0.023$	--
Parental Homework Help	--	--	$r_s = 0.323$, $p < 0.042$	--
Homework-related Computer Use	$r_s = 0.332$, $p < 0.028$	--	--	--
PCF Class				
Email Sent	--	--	$r_s = 0.619$, $p < 0.002$	--
Email Received	--	--	$r_s = 0.475$, $p < 0.026$	--

Table E-2. Significant Spearman's rank correlations for the SOL technology measures.

	Basic Understanding of Computer Technology	Basic Operational Skills	Using Technology to Solve Problems
Number of home computers	--	$r_s = 0.335$, $p < 0.017$	$r_s = 0.403$, $p < 0.006$
Number of home Internet connections	--	$r_s = 0.375$, $p < 0.041$	$r_s = 0.351$, $p < 0.018$

	Basic Understanding of Computer Technology	Basic Operational Skills	Using Technology to Solve Problems
Maximum years of education for parents	--	$r_s = 0.318$, $p < 0.035$	$r_s = 0.452$, $p < 0.002$
Sensing - Intuitive MMPI Score	--	$r_s = 0.334$, $p < 0.029$	--
Days Absent in 4th Grade	--	$r_s = -0.365$, $p < 0.014$	
Days Tardy (5^{th}) - Days Tardy (4^{th})	$r_s = -0.326$, $p < 0.029$	--	--
Entry SAM NP	--	$r_s = 0.454$, $p < 0.002$	$r_s = 0.361$, $p < 0.015$
Training Skills Score	--	$r_s = 0.442$, $p < 0.003$	$r_s = 0.363$, $p < 0.017$
Typing Speed	--	$r_s = 0.505$, $p < 0.001$	$r_s = 0.489$, $p < 0.001$
Language Arts GPA Gain	--	--	$r_s = 0.420$, $p < 0.004$
Language Arts 4th Grade GPA	--	$r_s = 0.533$, $p < 0.001$	$r_s = 0.536$, $p < 0.001$
Math GPA Gain	--	$r_s = 0.393$, $p < 0.008$	$r_s = 0.515$, $p < 0.001$
Math 4th Grade GPA	--	--	$r_s = 0.401$, $p < 0.006$
Science GPA Gain	--	--	$r_s = 0.415$, $p < 0.005$
Science 4th Grade GPA	--	$r_s = 0.631$, $p < 0.001$	$r_s = 0.574$, $p < 0.001$
Social Studies 4th Grade GPA	--	$r_s = 0.519$, $p < 0.001$	$r_s = 0.520$, $p < 0.001$
GPA Gain	$r_s = 0.319$, $p < 0.033$	$r_s = 0.414$, $p < 0.005$	$r_s = 0.556$, $p < 0.001$
4th Grade GPA	--	$r_s = 0.583$, $p < 0.001$	$r_s = 0.568$, $p < 0.001$
SOL Reading	$r_s = 0.318$, $p < 0.033$	--	$r_s = 0.702$, $p < 0.001$
SOL Math	$r_s = 0.574$, $p < 0.001$	$r_s = 0.669$, $p < 0.001$	$r_s = 0.697$, $p < 0.001$
SOL History and Social Science SS	--	$r_s = 0.582$, $p < 0.001$	$r_s = 0.738$, $p < 0.001$
SOL Science	$r_s = 0.376$, $p < 0.001$	$r_s = 0.531$, $p < 0.001$	$r_s = 0.641$, $p < 0.001$
SOL Writing	--	--	$r_s = 0.480$, $p < 0.001$
Daily Home Computer Use	--	$r_s = 0.349$, $p < 0.019$	--
Daily Home Internet	--	$r_s = 0.353$, $p < 0.018$	--

	Basic Understanding of Computer Technology	Basic Operational Skills	Using Technology to Solve Problems
Parental Homework Help	$r_s = -0.431$, $p < 0.005$	$r_s = -0.461$, $p < 0.002$	--
Percentage Homework Completed	--	$r_s = -0.136$, $p < 0.037$	--

Technology Usage

Table E-3. Significant Spearman's rank correlations for student self-reports of home computer use.

	Time Spent Using Home Computer	Time Spent Game Playing	Time Spent on the Internet	Homework-related Computer Use
Time Spent Game Playing	$r_s = 0.621$, $p < 0.001$			
Time Spent on the Internet	$r_s = 0.735$, $p < 0.001$	$r_s = 0.474$, $p < 0.001$		
Homework-related Computer Use	$r_s = 0.539$, $p < 0.001$	$r_s = 0.505$, $p < 0.001$	--	
Number of home computers	$r_s = 0.530$, $p < 0.001$	--	$r_s = 0.538$, $p < 0.001$	
Number of home Internet connections	$r_s = 0.446$, $p < 0.002$	--	$r_s = 0.497$, $p < 0.001$	$r_s = 0.431$, $p < 0.003$
Entry Feel About Computers Score	$r_s = 0.353$, $p < 0.015$	--	--	--
Knudson Writing Gain	--	$r_s = 0.406$, $p < 0.001$	--	--
Judging - Perceiving MMPI Score	--	$r_s = 0.303$, $p < 0.048$	--	
Training Skills Score	--	--	$r_s = 0.410$, $p < 0.005$	$r_s = 0.332$, $p < 0.028$
Typing Speed	--	--	$r_s = 0.348$, $p < 0.021$	--
Language Arts 4th Grade GPA	--	--	$r_s = 0.297$, $p < 0.043$	--
Math 4th Grade GPA	--	--	$r_s = 0.330$,	--

	Time Spent Using Home Computer	Time Spent Game Playing	Time Spent on the Internet	Homework-related Computer Use
			$p < 0.024$	
Science 4th Grade GPA	$r_s = 0.424$, $p < 0.003$	--	$r_s = 0.391$, $p < 0.007$	--
Social Studies 4th Grade GPA	--	--	$r_s = 0.304$, $p < 0.038$	--
4th Grade GPA	$r_s = 0.312$, $p < 0.033$	--	$r_s = 0.359$, $p < 0.013$	--
SOL Math SS	--	--	$r_s = 0.300$, $p < 0.045$	--
SOL History and Social Science SS	$r_s = 0.438$, $p < 0.003$	$r_s = 0.410$, $p < 0.005$	$r_s = 0.303$, $p < 0.043$	--
SOL Science SS	--	$r_s = 0.310$, $p < 0.036$	--	--
SOL Technology SS	$r_s = 0.349$, $p < 0.019$	--	$r_s = 0.332$, $p < 0.026$	--
SOL Writing SS	--	--	$r_s = 0.442$, $p < 0.002$	--

Table E-4. Significant Spearman's rank correlations for PCF student network usage.

	Family home web usage (total)	Emails sent by students (total)	Emails received by students (total)	Chat Lines (total)
Emails received by students (total)		$r_s = 0.697$, $p < 0.001$		
Number of home Internet connections	--	$r_s = 0.465$, $p < 0.021$	--	--
Days Absent (5^{th}) - Days Absent (4^{th})	$r_s = 0.445$, $p < 0.029$	--	--	--
Entry SAM NP	$r_s = 0.409$, $p < 0.047$	$r_s = 0.430$, $p < 0.036$	$r_s = 0.488$, $p < 0.016$	
SAM Overall Gain	--	$r_s = -0.494$, $p < 0.014$	--	--
Feel About Computers Gain	--	--	$r_s = -0.466$, $p < 0.022$	--

	Family home web usage (total)	Emails sent by students (total)	Emails received by students (total)	Chat Lines (total)
Homework Delivered On-Time	$r_s = -0.433$, $p < 0.029$	--	--	--
Homework Completed	$r_s = -0.438$, $p < 0.032$	--	--	--
Typing Speed	--	$r_s = 0.619$, $p < 0.002$	$r_s = 0.475$, $p < 0.026$	--
Language Arts GPA Gain	--	--	$r_s = 0.509$, $p < 0.011$	
Science GPA Gain	$r_s = 0.434$, $p < 0.034$	--	--	$r_s = 0.569$, $p < 0.004$
Math 4th Grade GPA	--	--	--	$r_s = 0.419$, $p < 0.042$
GPA Gain	$r_s = 0.481$ $p < 0.017$			

Student Attitudes

Table E-5. Significant Spearman's rank correlations for the student attitude survey changes.

	SAM Change	Knudson Writing Change	Computer Writing Change	Feel About Computers Change
Both Classes				
Sensing - Intuitive MMPI Score	--	--	--	$r_s = -0.318$, $p < 0.043$
Entry SAM NP	$r_s = -0.405$, $p < 0.005$	--	--	--
Entry Feel About Computers	--	--	--	$r_s = -0.482$ $p < 0.001$
Daily Game Playing	--	$r_s = 0.406$ $p < 0.001$	--	--
PCF Class				
Email Sent	$r_s = -0.494$, $p < 0.014$	--	--	--
Email	--	--	--	$r_s = -0.466$

	SAM Change	Knudson Writing Change	Computer Writing Change	Feel About Computers Change
Received				$p < 0.022$

Table E-6. Significant Spearman's rank correlations for the attendance changes.

	Days Absent (5th) - Days Absent (4th)	Days Tardy (5th) - Days Tardy (4th)
Both Classes		
Classroom computer usage	--	$r_s = 0.343$, $p < 0.018$
SOL Technology: Basic Understanding of Computer Technology	--	$r_s = -0.326$, $p < 0.029$
Average Percentage of Homework Items Completed	$r_s = -0.335$, $p < 0.021$	--
PCF Class		
Family home web usage (total)	$r_s = 0.445$, $p < 0.029$	--
Emails sent by parents (total)	$r_s = 0.552$, $p < 0.009$	--
Emails received by parents (total)	$r_s = 0.475$, $p < 0.019$	--

Table E-7. Significant Spearman's rank correlations for the SOL subject scaled scores.

	Reading SS	Writing SS	Mathematics SS	Science SS	History and Social Science SS
Writing SS	$r_s = 0.611$, $p < 0.001$				
Mathematics SS	$r_s = 0.751$, $p < 0.001$	$r_s = 0.657$, $p < 0.001$			
Science SS	$r_s = 0.303$, $p < 0.040$	$r_s = 0.389$, $p < 0.008$	$r_s = 0.742$, $p < 0.001$		
Social Studies SS	$r_s = 0.746$, $p < 0.001$	$r_s = 0.456$, $p < 0.002$	$r_s = 0.736$, $p < 0.001$	--	
SOL Technology	$r_s = 0.689$, $p < 0.001$	$r_s = 0.550$, $p < 0.001$	$r_s = 0.724$, $p < 0.001$	$r_s = 0.631$, $p < 0.001$	$r_s = 0.696$, $p < 0.001$
Number of home computers	$r_s = 0.374$, $p < 0.011$	$r_s = 0.350$, $p < 0.018$	--	$r_s = 0.303$, $p < 0.040$	$r_s = 0.450$, $p < 0.002$
Maximum years of education for parents	$r_s = 0.331$, $p < 0.028$	--	$r_s = 0.380$, $p < 0.111$	$r_s = 0.345$, $p < 0.021$	$r_s = 0.474$, $p < 0.001$
Sensing - Intuitive MMPI Score	$r_s = 0.411$, $p < 0.007$	$r_s = 0.427$, $p < 0.005$	$r_s = 0.373$, $p < 0.015$	--	--
Entry SAM NP	$r_s = 0.376$, $p < 0.011$	$r_s = 0.352$, $p < 0.018$	$r_s = 0.398$, $p < 0.007$	$r_s = 0.325$, $p < 0.027$	$r_s = 0.404$, $p < 0.006$
Training Skills Score	$r_s = 0.394$, $p < 0.009$	$r_s = 0.507$, $p < 0.001$	$r_s = 0.431$, $p < 0.004$	$r_s = 0.381$, $p < 0.011$	$r_s = 0.458$, $p < 0.002$
Typing Speed	$r_s = 0.595$, $p < 0.001$	$r_s = 0.603$, $p < 0.001$	$r_s = 0.586$, $p < 0.001$	$r_s = 0.452$, $p < 0.002$	$r_s = 0.585$, $p < 0.001$
Language Arts GPA Gain	$r_s = 0.508$ $p < 0.001$	--	$r_s = 0.327$ $p < 0.028$	--	$r_s = 0.339$ $p < 0.023$
Language Arts 4th Grade GPA	$r_s = 0.567$ $p < 0.001$	$r_s = 0.679$ $p < 0.001$	$r_s = 0.587$ $p < 0.001$	$r_s = 0.398$ $p < 0.006$	$r_s = 0.590$ $p < 0.001$
Math GPA Gain	$r_s = 0.326$	--	--	--	--

	Reading SS	Writing SS	Mathematics SS	Science SS	History and Social Science SS
	p < 0.029				
Math 4th Grade GPA	r_s = 0.472 *p* < 0.001	r_s = 0.473 *p* < 0.001	r_s = 0.534 *p* < 0.001	r_s = 0.302 *p* < 0.041	r_s = 0.508 *p* < 0.001
Science GPA Gain	--	--	r_s = 0.371 *p* < 0.012	r_s = 0.396 *p* < 0.006	--
Science 4th Grade GPA	r_s = 0.655 *p* < 0.001	r_s = 0.613 *p* < 0.001	r_s = 0.635 *p* < 0.001	r_s = 0.495, *p* < 0.001	r_s = 0.700, *p* < 0.001
Social Studies 4th Grade GPA	r_s = 0.696, *p* < 0.001	r_s = 0.600 *p* < 0.001	r_s = 0.598, *p* < 0.001	r_s = 0.435, *p* < 0.003	r_s = 0.642, *p* < 0.001
GPA Gain	r_s = 0.446, *p* < 0.002	--	r_s = 0.432, *p* < 0.003	r_s = 0.333, *p* < 0.024	r_s = 0.308, *p* < 0.013
4th Grade GPA	r_s = 0.666, *p* < 0.001	r_s = 0.651 *p* < 0.001	r_s = 0.667, *p* < 0.001	r_s = 0.481, *p* < 0.001	r_s = 0.685, *p* < 0.001
Stanford 9 Reading SS	r_s = 0.739, *p* < 0.001	r_s = 0.646, *p* < 0.001	r_s = 0.721, *p* < 0.001	r_s = 0.590, *p* < 0.001	r_s = 0.617, *p* < 0.001
Stanford 9 Math SS	r_s = 0.727, *p* < 0.001	r_s = 0.605, *p* < 0.001	r_s = 0.766, *p* < 0.001	r_s = 0.576, *p* < 0.001	r_s = 0.663, *p* < 0.001
Stanford 9 Language SS	r_s = 0.667, *p* < 0.001	r_s = 0.577, *p* < 0.001	r_s = 0.632, *p* < 0.001	r_s = 0.499, *p* < 0.001	r_s = 0.568, *p* < 0.001
Stanford 9 Science SS	r_s = 0.651, *p* < 0.001	r_s = 0.581, *p* < 0.001	r_s = 0.794, *p* < 0.001	r_s = 0.696, *p* < 0.001	r_s = 0.633, *p* < 0.001
Stanford 9 Social Studies SS	r_s = 0.675, *p* < 0.001	r_s = 0.623, *p* < 0.001	r_s = 0.671, *p* < 0.001	r_s = 0.527, *p* < 0.001	r_s = 0.618, *p* < 0.001
Stanford 9 NP	r_s = 0.801, *p* < 0.001	r_s = 0.689, *p* < 0.001	r_s = 0.820, *p* < 0.001	r_s = 0.614, *p* < 0.001	r_s = 0.693, *p* < 0.001
Writing Computer Score	--	--	--	--	r_s = 0.348 *p* < 0.018
Daily Computer Use	--	--	--	---	r_s = 0.438 *p* < 0.003
Daily Game Playing	--	--	--	r_s = 0.310 *p* < 0.036	r_s = 0.410 *p* < 0.005
Daily Internet Use	--	r_s = 0.442 *p* < 0.002	--	--	r_s = 0.303 *p* < 0.043

	Reading SS	Writing SS	Mathematics SS	Science SS	History and Social Science SS
Parental Homework Help	--	--	--	$r_s = -0.497$ $p < 0.001$	$r_s = -0.392$ $p < 0.011$

Table E-8. Significant Spearman's rank correlations for student grade gains.

	Overall Grade Point Gain	Language Arts GPA Gain	Mathematics GPA Gain	Science GPA Gain	Social Studies GPA Gain
Language Arts GPA Gain	$r_s = 0.665$ $p < 0.001$				
Mathematics GPA Gain	$r_s = 0.809$ $p < 0.001$	$r_s = 0.350$ $p < 0.016$			
Science GPA Gain	$r_s = 0.541$ $p < 0.001$	--	--		
Social Studies GPA Gain	$r_s = 0.750$ $p < 0.001$	$r_s = 0.470$ $p < 0.001$	$r_s = 0.509$ $p < 0.001$	$r_s = 0.311$ $p < 0.033$	
Both Classes					
Math 4th Grade GPA	--	--	$r_s = -0.360$ $p < 0.013$	$r_s = 0.295$ $p < 0.044$	--
SOL Reading SS	$r_s = 0.446$ $p < 0.002$	$r_s = 0.508$ $p < 0.001$	$r_s = 0.326$ $p < 0.029$	--	--
SOL Math SS	$r_s = 0.432$ $p < 0.003$	$r_s = 0.327$ $p < 0.028$	--	$r_s = 0.371$ $p < 0.012$	--
SOL History and Social Science SS	$r_s = 0.368$, $p < 0.013$	$r_s = 0.339$ $p < 0.023$	--	--	--
SOL Science SS	$r_s = 0.333$, $p < 0.024$	--	--	$r_s = 0.396$ $p < 0.006$	--
SOL Technology SS	$r_s = 0.519$, $p < 0.001$	$r_s = 0.356$ $p < 0.016$	$r_s = 0.463$ $p < 0.001$	--	$r_s = 0.320$, $p < 0.032$
Entry Writing Computer Score	--	--	--	$r_s = 0.348$ $p < 0.018$	--
Entry SAM NP	$r_s = 0.342$ $p < 0.019$	$r_s = 0.302$ $p < 0.039$	--	--	$r_s = 0.322$ $p < 0.027$

	Overall Grade Point Gain	Language Arts GPA Gain	Mathematics GPA Gain	Science GPA Gain	Social Studies GPA Gain
Home Internet Use	--	--	$r_s = 0.300$ $p < 0.045$	--	--
Percentage Homework Completed	--	--	---	--	$r_s = 0.309$, $p < 0.035$
Parental Homework Help	$r_s = -0.415$ $p < 0.007$	--	$r_s = -0.325$ $p < 0.038$	--	--
PCF Class					
Email Received	--	$r_s = 0.509$ $p < 0.011$	--	--	--
Family WWW Pages	$r_s = 0.481$ $p < 0.017$	---	--	$r_s = 0.434$ $p < 0.034$	--
Chat Lines	--	--	--	$r_s = 0.569$ $p < 0.004$	--

E.1.1 Homework Process

Table E-9. Significant Spearman's rank correlations for the SOL homework process measures.

	Time Spent on Homework	Homework Assignments Delivered On-time	Homework Assignments Completed	Parental Homework Help
Homework Assignments Completed	--	$r_s = 0.744$, $p < 0.001$		
Parental Homework Help	$r_s = 0.484$, $p < 0.001$			
Both Classes				
Absent (5th) - Absent (4th)	--	--	$r_s = -0.335$, $p < 0.021$	--
Thinking - Feeling MMPI score	--	$r_s = 0.342$, $p < 0.025$	--	--
Typing Speed	--	$r_s = 0.336$, $p < 0.026$	--	$r_s = 0.323$, $p < 0.042$
Language Arts 4th Grade GPA	--	--	--	$r_s = -0.317$, $p < 0.041$
Science 4th Grade GPA	--	--	--	$r_s = -0.417$, $p < 0.006$
Social Studies GPA Gain	--	--	$r_s = 0.309$, $p < 0.035$	$r_s = -0.308$, $p < 0.047$
SOL Reading SS	--	--	--	$r_s = -0.415$, $p < 0.007$
SOL Math SS	--	--	--	$r_s = -0.325$, $p < 0.038$
SOL History and Social Science	--	--	--	$r_s = -0.392$, $p < 0.011$
SOL Science	--	--	--	$r_s = -0.497$, $p < 0.001$
SOL Technology	$r_s = -0.319$, $p < 0.042$	--	--	$r_s = -0.563$, $p < 0.001$
PCF Class				
Family WWW Pages	--	$r_s = -0.433$, $p < 0.029$	$r_s = -0.438$, $p < 0.032$	--

APPENDIX F: WORKSTATION DESIGNS FROM THE PARTICIPATORY SESSIONS

Appendix Table of Contents

F.1 ISSUES LIST 318
F.2 POST-SESSION STRUCTURED INTERVIEW PROTOCOL 318
F.3 DESIGN SUMMARIES 319
F.3.1 CHILD1 320
F.3.2 CHILD2 320
F.3.3 CHILD3 321
F.3.4 CHILD4 322
F.3.5 CHILD5 322
F.3.6 PARENT1 323
F.3.7 PARENT2 323
F.3.8 PARENT3 323
F.3.9 PARENT4 323
F.3.10 TEACHER1....................324
F.3.11 TEACHER2....................324

F.1 Issues List

<u>Only Constraints</u> :

1. Must support both computer and non-computer classroom activities.
2. Must be buildable .. but doesn't need to look anything like typical school or office furniture!
3. Whenever possible, add labels to design materials (*e.g.*, 32" monitor, storage, etc.).

<u>Issues to address</u> (feel free to look at other issues ..)

1. How many students should work together?

2. How will students work together (*e.g.* shared control of computer, one student physically interacts, etc.)? Where will students be seated? Where will computer technology be located? Do students have a clear view of the teacher, chalkboards, and projector screen? Can all students easily view the monitor?

3. How does the design facilitate student collaboration? Is there sufficient space for students to work on non-computer activities?

4. What type of computer equipment should the workstation have and how will it be shared among students (*e.g.* how mice, how many keyboards, how many monitors)?

5. Do individual students have their own space (*e.g.* a storage area just their own)?

6. What furniture will be found in the work area? What will it look like? Where will students store their belongings?

7. How can different sized students make use of the same furniture?

8. How would multiple workstations be arranged in a classroom?

F.2 Post-session Structured Interview Protocol

Each facilitator should fill out this form with his/her group's help after their design is complete. Whenever possible, try to include information about why a particular decision was made. Facilitators, after completing this form, please take this form and your design representation to Faith. Please make sure the facilitator name is on the design representation. If additional space is needed for a question, please use the back of this sheet.

1. Check any areas that team members perceived as a problem with the existing student workstation going into the design process? (Check any that apply)
    ___ Insufficient storage space
    ___ Insufficient personal space
    ___ Too crowded, not enough space for non-computer work, insufficient personal

space
___ Unaesthetic, unappealing
___ Not appropriately sized for student
___ Insufficient equipment, *e.g.* needs larger monitor, another mouse, additional equipment
___ Difficult to collaborate
___ Other (please list)

2. What activities will take place at the workstation?

3. How many students should work together? Why?

4. What computer equipment will be available? (Please be specific and include the number of each item that is needed.) At the very minimum, need to know the types of equipment, number of keyboards, number of mice, number of monitors?

5. What is the layout of the workstation? What is the shape of the work surface? Where will students sit? Where will computer equipment be located? Why was this particular layout chosen?

6. What furniture will be found at the workstation? How will different sized students use the equipment?

7. What postures can the students assume when using the workstation?

8. How will different sized students use the same workstation?

9. If workstation furniture is adjustable, who will do the adjusting? Students? Teachers?

10. What aspects of the workstation were included to increase student comfort? To improve visual look of workstation (*e.g.* decoration or color)?

11. How will students work together on student activities?

12. How will students work on individual activities in this space?

13. How will students work on non-computer activities in this space?

14. Where do students store their belongings?

15. How would multiple workstations be arranged in a classroom?

F.3 Design Summaries

In order to preserve participant anonymity, individual designs were given labels. This label is used as the title for each design in the following sections. In all 5 student designs

(CHILD1 - CHILD 5), 4 parent designs (PARENT1-PARENT4), and 2 teacher designs[27] (TEACHER1, TEACHER2).

CHILD1

This design team was comprised of 2 fifth grade girls, 1 third grade boy (sibling), and 1 human factors graduate student. Key elements of this design included the pairing of students at a much larger workstation, two sets of input devices including a touchpad for drawing, larger work surface, wireless technology and wheeled workstations to increase the flexibility of the classroom, increased storage space, and a monitor which could be dropped and hidden away during non-computer activities. Groups larger than two were considered unsuitable as it would make decision-making harder and provide a better social dynamic as no one could be ganged up on. Also, the workstation wheels were to be lockable by the teacher so students wouldn't play with them. The classroom teacher would be at the center of the classroom workstation grouping.

Adjustability and comfort of the workstation was of great concern to the team in the belief that increasing these two aspects of the workstation would make work faster and decrease errors. As shown in Figure 8, the work surface was broken into 3 sections, all of which could be adjusted separately: the monitor support, and two student work spaces. The keyboard trays and chairs were fully adjustable and featured five inch cushions for added comfort. Common elements of the workstation, *e.g.* monitor height, can only be adjusted by the teacher as children may play with it, while individual elements should be adjustable by the student as teachers always make chairs the wrong height. Personalization was also important. Students would have different color furniture and personalized mouse pads. The workstation could be further personalized by sliding pictures and drawings under its see-through top.

CHILD2

This design team was comprised of 4 fifth grade boys and the PCF technologist. Key elements of this design included the pairing of students at a larger workstation, a divided work surface, more individualized space, 2 keyboards, multiple earphones with extra long cords as wireless earphones are too heavy, more individualized storage space, smaller speakers that did not take up space on the desktop, mouse drawer that slides under desk, and rocket-shaped controls. Individual activities occur only when one partner is gone. Reasons behind student pairing included cost, insufficient computer time if more than two students, and as one boy put it "..you know skills" in reference the collaboration skills gained from group work. Workstations were to be grouped in a U-shaped configuration around the teacher, so that everyone will be able to see the teacher and the blackboards.

Adjustability and comfort of the workstation were of great concern to the team. Chairs were to have more padding and armrests, plus gel pads to support wrists. The shared worktop was to be height-adjustable by teacher, while individual elements, *e.g.* chair

[27] To preserve their anonymity, technologist and teacher are grouped together under teachers.

height, were to be adjustable by the students, plus foot stools for the shorter students. A photograph of the CHILD2 prototype is shown in Figure F-1.

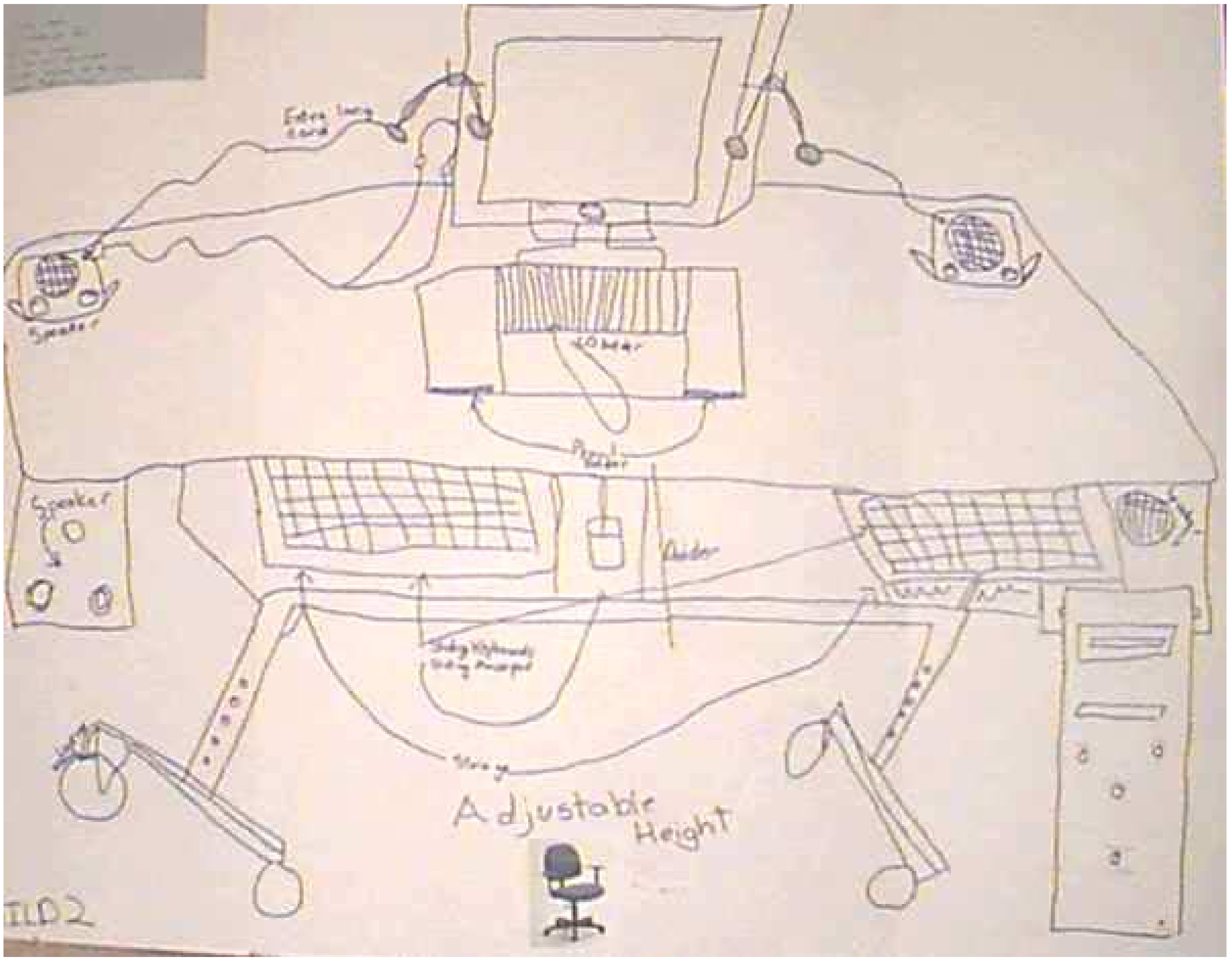


Figure F-9-1. Workstation design produced by the CHILD2 team.

CHILD3

This design team was comprised of 2 fifth grade girls, the extension specialist, and 1 human factors graduate student. Again, students were paired at the workstation due to ease of work, difficulty of sharing the space when more than two, and the expectation that work would be done more slowly if more than two students shared the workstation. Each student was to have an individual computer as the configuration didn't allow one student to dominate during collaboration. The girls also expressed the opinion that not much partner work got done in school anyway so two machines were better. Workstations were to be arranged in three rows, with seating determined by height ---- short students in front and tall ones in back.

Other key elements of this design included a doll-shaped CPU, donut-shaped ear phones, a whimsical keyboard with the keys in reverse alphabetical order so better typists wouldn't be at an advantage for computer work, a 32" height-adjustable monitor which hanged from the ceiling and would rotate 360 degrees, see-through plastic covers for the equipment, and increased storage. Also, an extra long table was needed to allow more space for non-computer work, with students scooting to the middle to work together. Personalization was achieved by allowing students to have different colored workstations.

Adjustability and comfort of the workstation was also of great concern to the team. Chairs were to be height-adjustable by students as work would be easier and more comfortable if the table wasn't so high. Also, arm and head rests were added to chairs, and chair seats were given 5" of padding.

CHILD4

This design team was comprised of 2 fifth grade girls, the extension specialist, and 1 human factors graduate student. Again students were paired at the workstation as the teacher would have a more difficult time finding more than two people that got along all the time. The workstation was comprised of two side-by-side individual workstations, so that they could be pushed apart if students wanted more individual space. Other features included equipment covers to increase durability, beanie babies for every workstation, and more storage. Personalization was achieved by students selecting a pattern for their mousepad and a color for their chair. Workstations were to be arranged in staggered rows with lots of space between workstations.

Again, adjustability and comfort of the workstation was of great concern to the team. A footrest was added for short students to keep legs from falling asleep. Chairs were to be height-adjustable by the students, with extra padding. Keyboards and mice were to be on a pull-out shelf so students wouldn't have to stretch to reach the mouse. The CPU monitor was to be in a cabinet at the side of the desk. This made the floppy and CD-ROM drive higher, which eliminated bending over all the time.

CHILD5

This design team was comprised of 2 fifth grade boys, and 1 human factors graduate student. Again, students were paired at the workstation as working with more students would be too difficult. Individual space was ensured by having an extra large monitor which could be split for individual work, individual drawer space, two mice so students wouldn't have to either reach across keyboard or use non-preferred when working with mouse, 2 keyboards, and a line drawn down middle workspace and monitor to make clear each student's space. Pairs of controls were thought to mean easier sharing, less switching, and faster completion of work. Equipment can be covered by a sliding panel for non-computer activities. Personalization was achieved with rocket-shaped computer controls, individual workstation controls, student-selected color scheme, and collection display areas. Adjustability and comfort were increased by having student adjustable chairs with lots of padding. Common areas, *e.g.* desk height, were not changeable. Workstations were grouped in circular rows around teacher.

PARENT1

This design team was comprised of 3 parents (2 male and 1 female) and the PCF technologist. Key elements of this design included the pairing of students at a larger workstation, more individualized space, increased storage, wireless mice and headphones, and individual display area for student artwork. Each student was provided with an individual computer in order to increase personal ownership of work, allow students to work at own pace, and facilitate both individual and paired work. Workstations were arranged in standard rows facing the teacher.

Adjustability and comfort were major concerns, with the work surface split in two so it could be adjusted to individual students. Chairs were height-adjustable by student and well-padded. Armrests were added and an adjustable platform around the bottom served as a footrest for smaller students. Height adjustable monitors hung from the ceiling.

PARENT2

This design team was comprised of 3 parents (all female). Workstations were designed for 2-4 students and placed in rows sandwiched between two rows of project tables with students sitting in swivel chairs between the workstations and tables. The number of students working together was limited to 4 in order to control chaos and increase work efficiency. Students had individual computers to prevent one student from monopolizing the equipment. Colorful chairs and storage units were included to decrease the dreariness of the classroom. Workstations also had pullout writing desks for non-computer tasks. Student comfort was increased by providing height-adjustable chairs for the students. Tight teacher control of classroom activities was facilitated by placing rotating video cameras throughout the room.

PARENT3

This design team was comprised of 2 parents (both female). Two students shared a workstation, with workstations arranged in rows in the classroom. Again, students had individual workstations to prevent an individual student from taking over the work. CPUs were set side-by-side on the table top to provide individual space. Storage was increased and pull-out tables provided for non-computer work. Student comfort was increased by padding chairs and making them height-adjustable by students.

PARENT4

This design team was comprised of 4 parents (2 male and 2 female). Again, students were paired at the workstations, which were arranged in rows facing the teacher. Each student was given a laptop so as to prevent one student from dominating the partnership and to increase the fit between student hands and keyboards. As shown in Figure F-2, laptops were placed in pull-out drawers to increase workspace for non-computer activities and decrease the distractibility of students on both computer and non-computer tasks. Storage was also increased and individual spaces clearly delimited.

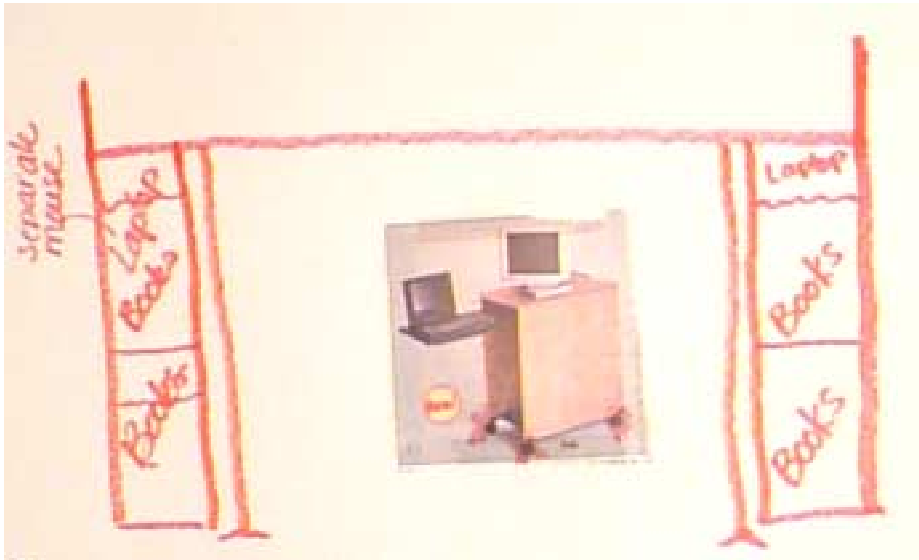


Figure F-9-2. Workstation revised by parents for students. Note that design facilitates individual computer work but discourages collaboration on computer tasks as students will sit back-to-back when working at the computer.

TEACHER1

In an individual effort, the teacher put four students at a large, kidney-shaped workstation to facilitate cooperative learning. Workstations were designed to also allow paired work and were arranged in a circle around the teacher. Workstations were equipped with two computers, whose monitors were on height-adjustable arms. Storage was also increased, with height-adjustable chairs provided to increase student comfort.

TEACHER2

In an individual effort, the teacher paired two students at workstations. More than two children at a workstation was believed to increase social problems and decrease productivity. Workstations were placed in a line in the back of the room with each classroom containing one workstation for every two students. A separate area with traditional student desks was available for non-computer work. This arrangement was chosen as 1) it made individual and non-computer work easier to do, and 2) student pairing in computer area could be done on a task by task basis.

Individual workstations were equipped with two computers. Individual computers were selected as the configuration allows both individual and paired work. Computer monitors were placed under the glass work top so students could have an unobstructed view of the teacher. Height-adjustable seating was provided to increase student comfort

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SELECTED PUBLICATIONS AND PRESENTATIONS

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Ehrich, R., McCreary, F., and Lisanti, M. (1999). *Immersive Educational Technology: Changing Families and Learning*. Paper presented at the 1999 Annual Meeting of the American Educational Research Association. Montreal, Canada.

Edited Books

Ehrich, R., Lisanti, M., and McCreary, F. (1999). Networking Families into the Schools. In A. Cohill and A. Kavanaugh (editors, second edition). *Community Networks: Lessons from Blacksburg, Virginia*. Norwood, MA: Artech House.

Invited Presentations

McCreary, F. (2001). Educational Ergonomics panel. Panel to occur during the *45th Annual Human Factors and Ergonomics Society Meeting*.

Ehrich, R., and McCreary, F. (1998). *PCs for Families - Can Student and Family Access Promote Student Achievement?* Presentation at the American Association for the Advancement of Science Annual Meeting, Philadelphia, February 1998.