EDITORIAL

In the process of improving education, educational research when adequately supported, has benefited many dimensions of theory and practice. This is most apparent when discoveries, findings, and conclusions are widely disseminated through writing, analyzed and discussed. That is why I continuously encourage you to write and help me carrying on the Colloquium Journal publication.

Preparing this 8th volume of the Colloquium Journal, I was looking back at the previous issues and noticed that the Journal has a distinctive quality; there is much evidence of intellectual growth and excitement on its pages, as well as I hope, there is a comfortable feel that there exists a save space to try out new ideas and share them with others without fear.

Evidently, some of the GSE students make all efforts to write and submit their papers more than once or twice during their formal course study before they complete their dissertations and even after successful defense. Some prefer to share with their most completed and significant research conducted in the course of the dissertation. I encourage all of you to test, enhance and expand your writing skills at the earlier stages of your degree program. It will help you in the development of your proposal and dissertation.

In this issue several topics are well presented by current and former doctoral students.

Toni Ledger's article provides an informative and comprehensive summary of the research that gives an account to the effect of collaborative concept mapping on the achievement, self-efficacy, and attitude toward science of female eight grade students. It is the second article related to the concept mapping issue (the first was published by Charlie Kaminski in the vol. VI, Formative Use of Select-and-Fill-In Concept Maps in Online Instruction: Implications for Students of Different Learning Styles). The subject of this paper is quite interesting, timely, and significant. The finding of the study shows that when female students are working collaboratively they are able to maintain their positive attitude toward science and demonstrate better performance. The author views the collaborative concept mapping as one of the teaching methods that is worth to implement in the classroom.

Implementation of instructional technology by teachers is considered one of the foremost problems in current education. Mitchell Schuldman in his article, Superintendent Thinking About Teacher Technology Integration, quotes US Department of Education study, which revealed that 33% of teachers surveyed reported that they either feel well (23%) or very well (10%) prepared to teach using technology in their subject area. Sixty-seven percent of teachers do not feel well prepared to utilize technology in their instruction, and 21% reported non-use. While it is accepted that use of instructional technology is important for school improvement, integrating technology into schools and using it in ways that impact student learning is proving more difficult than expected.

The readers who are interested in philosophical, historical and epistemological issues might find the article, Positivism and Post-positivism: A Qualitative Mathematics Perspective, written by Rocco Perla and Danielle Cross quite interesting. The authors discuss the nature of qualitative mathematics and two philosophical trends, logical positivism and post-positivism. They suggest the use of mathematical analysis to establish qualitative mathematical distinctions between the two schools of thought. This is the third article written by Danielle Cross (see also her papers in vol. VI and Vol. VII).

Peggy Labrosse (see also her paper in the vol. VII) presents quite detailed analysis of the self-reported technology competency survey. The preliminary suggestions include that implementation of different school staff group formation such as for example groups with a smaller number of participants, as well as different kinds of school staff training may contribute to better results in training and integrating technology into the classrooms to enhance teaching and learning. For those who are learning how to conduct and report on statistical analysis, the article is a useful material to study.

I thank all authors of this issue and look forward to new submissions and new challenge in helping graduate students in exercising their analytical and writing skills.

Regina M. Panasuk
GUIDELINES FOR SUBMISSION

The papers submitted for the Journal must discuss psychological and pedagogical issues and trends related to mathematics and science education.

WHEN SUBMITTING A PAPER, PLEASE USE THE FOLLOWING GUIDELINES:

1. Submit an electronic version of the paper and one hard copy, an abstract, approximately 150 words, and a biographical sketch, about 30 words. All pictures and diagrams must be submitted in a separate document.

2. Use double spacing with one-inch margins.

3. For references, tables and figures follow the style described in the Publication Manual of the American Psychological Association (APA), Fifth Edition.

4. Paper length should not exceed 30 pages, including pictures, tables, figures, and list of references.

5. Paper must be received by November 15.

6. Authors will be notified about the status of their papers by January 15.

7. The Colloquium is scheduled in April.

SUGGESTIONS TO THE AUTHORS

When preparing a research paper include:

a) a rationale and an identification of the research question(s)

b) a conceptual framework or brief statement of relationship to the literature

c) an identification of research methodology

d) a summary of the analytical technique(s)

e) a summary of preliminary findings

f) conclusions and discussion

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2003-2004 Academic Year
Mathematics and Science Education Program

COMPLETED DISSERTATIONS

Toni Ledger
The Effect of Collaborative Concept Mapping on the Achievement, Self-Efficacy, and Attitude Toward Science of Female Eight Grade Students

Donna Farland
Influencing Elementary Students' Stereotypical Images of scientists: The Case for Including Historical Non-Fiction Trade Books in Elementary Science Instruction

DISSERTATION DEFENSE STAGE

Suellen Robinson
Volition and Its Relationship to Retention in Community College mathematics Classes

Adele Miller
An Investigation of College Students' rational Number Sense in the Developmental Mathematics Classroom

DISSERTATION PROPOSAL STAGE

Rocco Perla
The Development and Validation of a Case Study in Science in the Context of a Non-linear Model of Scientific Change

Scott Stanley
A Study of the Issues Related to the Development of Web-based Science Courses

Kathy Shea
An Examination of the Role of Mentor Teachers Assigned to Alternatively Licensed Science Teachers

Jeff Todd
Middle School Mathematical Teachers' Use of Systematic Lesson Planning and Its Effect on Student Mathematics Achievement

QUALIFYING PAPER STAGE

Danielle Cross
Marsha Pease
Jessica Devonis
ABSTRACT

This twelve-week study sought to examine whether collaborative concept mapping would affect the achievement, science self-efficacy and attitude toward science of female eighth grade science students.

Although many studies have reported on the value of both concept mapping and small group instruction, there are very few studies that combine both techniques in a single study. More specifically, the literature does not fully address the influence of collaborative concept mapping on female science achievement, science self-efficacy and attitude toward science.

This study utilized a pretest-posttest quasi-experimental design supplemented by a survey measuring science self-efficacy and attitude toward science and informal interviews with students and teachers.

The analysis of data indicates that experimental group females showed significantly higher gains in achievement than control group females. An additional analysis of experimental group males data showed significantly greater gains in achievement than experimental group females.

The study indicates that collaborative concept mapping contributes to the improved achievement in science of eighth grade female students. No such claims can be made for the influence of collaborative concept mapping on science self-efficacy and attitude toward science.

The under representation of women in science has been of concern to researchers and educators for many years (AAUW, 1995; Baker & Leary, 1995; Bianchini, Cavazos & Helms, 2000; Brickhouse, 1994, 2001; Campbell, 1986; Harwell, 2000; Kahle & Danzl-Tauer, 1991; Klein & Orman, 1994; Lee & Birkham, 1996; Pollina, 1995; Tobin, 1988). Although women achieve equal or better scores on national and statewide tests (AAUW 1995), their participation in scientific fields and advanced courses is not identical to the participation of males (“The College Board RS-04”, 1998), and consequently is not identical to the participation of males in scientific fields of work (Catsambis, 1995; Marion & Coladarci, 1993; Novack, 1996).

Why such under representation occurs is a matter of current research (AAUW, 1995; Greenfield, 1996; Jegede & Alaiyemola, 1989, Jegede & Okebukola, 1992; Jovanovic, Solano-Flores & Shavelson 1994; Kahle, Parker, Rennie & Riley 1993; Novak, 1990; Okebukola, 1992; Potter & Rosser, 1992). Archer and McDonald (1991), Brickhouse (1994) and Koch (1996) have independently examined the behavior of females in school science courses. They report that females exhibit an unwillingness to attempt complex mathematical and scientific cognitive tasks. This difficulty appears to be related to low self-efficacy when engaged in school science. Self-efficacy is the individual’s belief concerning his/her ability to perform successfully in a given subject area (Bandura, 1977; Sherer, 1983; Smist, 1994). Self-efficacy includes all the perceptions that students have about themselves as learners and has been found to directly correlate to achievement (Bandura, 1977; Mattern & Schau, 2002).

Females appear to have low self-efficacy regarding their ability to attempt and succeed at mathematical and scientific cognitive tasks. Research has demonstrated that the low self-efficacy of females in science can result in what is referred to as a negative attitude toward school science (Bandura, 1977; Shavelson, 1982).

Negative attitudes toward school science originate and are reinforced by lack of parental support for females to enroll in advanced science courses or pursue scientific careers (Tocci & Englehard, 1991), societal norms which govern the appropriateness of career selection to gender, (Kahle & Meece, 1994), teacher attitude (Brickhouse, 1994; Greenfield, 1995; Jovanovic et al. 1994; Kahle, 1990; Plucker, 1996; Sadker & Sadker, 1995; Shepardson & Pizzini, 1992), and peer support (Simpson & Oliver, 1990).

The development of negative attitudes toward school science may be the reason why many females fail to participate in science courses beyond the basic requirements and consequently prevents them from entering scientific fields after school (Kahle, 1990).

This study sought to examine whether the collaborative concept mapping instructional approach may be one of the routes to improving females’ science self efficacy and achievement, which in turn may lead to improvements in females’ attitudes toward school science. Sidlik and Philburn (1993) and Jovanovic and King (1998) have documented that attitudes toward school science can improve when students feel they have more control over and participate more fully in classroom activities.
PURPOSE OF THE STUDY

The focus of this research was to investigate whether the collaborative concept mapping instructional approach would effect the achievement, science self-efficacy and attitude toward science of female students in eighth grade science classes.

CONCEPTUAL FRAMEWORK

The theoretical framework underlying this research originates from four major areas. These areas include (1) “Subsumption theory” proposed by David Ausubel (1963), from which the (2) concept mapping technique is derived and was developed by Novak and Gowin (1984), (3) small group learning studies by Robert E. Slavin (1980) and (4) the work of David Bandura (1977) on self-efficacy.

SELF-EFFICACY AND FEMALES

Self-efficacy is a construct defined by the behavioral psychologist Albert Bandura (1977) as the belief held by people about their ability to successfully perform a certain task, and is also referred to as a perceived power to produce an effect (Lacour & Wilkinson, 1991), or accomplish a particular behavior (Smist & Owen, 1994).

Other researchers documented that self-efficacy affects the motivation of students to succeed (Schunk, 1989; Yamauchi, 1997), student achievement and interest, (Bandura, 1993), career and behavioral choices (Lacour, 1991; Meece et al., 1990).

It has also been reported that generally females exhibit low self-efficacy toward school science and math tasks, (Brickhouse, 1994; Byrne & Shavelson, 1987; Smist & Owen, 1994) and since low self-efficacy is related to both attitudes and achievement, (Marsh, 1990a, 1990b) curriculum changes designed to raise self-efficacy may be a valuable contribution to pedagogical practice (Zimmerman & Martinez-Pons, 1990).

ATTITUDES TOWARD SCIENCE

The primary reason that females self-select out of science courses and careers is the perceived gender-appropriateness of courses and careers. Females do not generally select courses and careers, which are considered male domains, such as math and science, (Andre, 1999; Baker & Leary, 1995; Bandura, 1977, 1993; Brickhouse, 2001; Kahle, 1985, 1992; Mason et al., 1991). Since attitudes can improve when students feel they have control over classroom activities (Jovanovic & King, 1998; Sidlik et al., 1993), collaborative concept mapping may be a technique providing females with control over the project process and outcome, thus altering their attitude that science is a male domain.

Attitude toward science is influenced by parental perceptions of the importance and relevance of math and science to female and male children (Andre, 1999; Bandura, 1993). Although ethnic differences prevail, parents perceive math and science to be more relevant and important to males (Kahle & Meece, 1994; Mason, Kahle & Gardner, 1991).

In addition, schools often portray math and science as male domains through textbooks which enhance gender bias through pictures, text, language and the reporting of male accomplishments (Potter & Rosser, 1992). The research of Potter and Rosser (1992) found that 83%-100% of all depictions including, language, content, career descriptions, and topics of interest appealed more to males than to females.

Plucker (1996) conducted a survey where teachers reported that they were not aware that gender inequity was problematic in schools. He found that teacher behavior caused females to develop negative attitudes toward science. Negative attitudes developed because some teachers found boys to be...more interested, more confident, and to have higher achievement in science and math that girls” (p. 745). Such attitudes could result in the differential treatment of boys over girls. (Shepardson & Pizzini, 1992). This finding was supported by other research studies (AAUW, 1995; Jones, Howe & Rua, 2000; Lee & Birkham, 1996, Meyer, 1998) which indicated that since teachers thought boys to be more adept in handling science equipment, they allowed them to manipulate apparatus while assigning data recording to the females in the class. In addition, males are generally encouraged to be more verbal (Sadker, Sadker & Klein, 1991) and are provided with more feedback from teachers (Jones & Wheatley, 1990).

CONCEPT MAPPING

Concept mapping as a diagnostic tool, developed by Joseph Novak (1984) and his colleagues is based on the Theory of Subsumption proposed by David Ausubel (1963). Subsumption theory is based on the notion that new ideas are subsumed hierarchically under existing ideas as parts of a cognitive structure (Novak & Musonda, 1991). Ausubel (1962) defined a cognitive structure as “a given individual’s organization of knowledge” (p. 213).

Concept maps are graphical representations that include nodes and linking words indicating the relationship between nodes (Ruiz-Primo & Shavelson, 1996). Nodes are concepts whose relationship is
explained by appropriate linking words (Novak, 1977, 1984, 1990). In their book, *Learning How To Learn*, Novak and Gowin (1984) proposed that concept maps are a workable representation of students’ understanding, and are intended to “…tap into a learner’s cognitive structure and to externalize, for both the learner and the teacher to see, what the learner already knows” (p. 40).

Concept mapping has been used extensively at all levels of education and has been found to promote higher order thinking (Okebukola, 1990), aid in communication (Chmielewski & Dansereau, 1998), enhance positive attitudes toward science (Horton, McConney, Gallo, Woods and Senn, 1993), increase knowledge integration (Wallace & Mintzes, 1990), increase achievement and reduce anxiety toward cognitive tasks while promoting meaningful learning (Okebukola &, 1988). Figure 1 represents the attributes of concept mapping in a concept-mapping format.

**GROUP LEARNING**

The practice of group work has been found to increase learning and decrease anxiety associated with cognitive tasks (Gardner, 1993; Meece & Jones, 1996; Okebukola, 1985, 1992). It also has the potential to result in long term retention of information, to promote higher levels of discourse and enhance recall of prior knowledge (Bianchini, 1997; King, Stafieri & Adelgais, 1998, Noddings 1998). For these reasons, students constructed the concept maps in small single sex collaborative dyads or triads rather than alone. Figure 2 represents the attributes of group learning in a concept-mapping format.

**COLLABORATIVE CONCEPT MAPPING**

In the past several decades, numerous research projects have been conducted on concept mapping and collaborative learning separately. Only limited research has combined both techniques in a single study. In the practice of collaborative concept mapping, students work in small groups to construct a representation of their understanding of concepts. Through the use of collaborative concept mapping, students have shown increases in self-efficacy (Okebukola, 1990, 1992; Roth & Roychoudhury, 1992), knowledge integration (Sizmur et al., 1997; Roth, 1994) meaningful learning (Roth, 1994; Okebukola & Jegede, 1988) and long term retention of information (Roth & Roychoudhury, 1992; Seaman, 1990). The practice has also raised achievement scores (Okebukola & Jegede, 1989; Ogunsola-Bandele, 2000; Czerniak & Haney, 1998) and generally
enhanced communication among participants (Campbell & Salem 1999; Sizmur, 1997). Figure 3 represents the attributes of collaborative concept mapping in a concept-mapping format.

Clearly, collaborative concept mapping, a combination of group work and concept mapping, has lead to multiple educational gains in whole class settings. For this reason, the researcher chose to use the combined techniques to determine if the practice would also increase the self-efficacy, achievement and positive attitudes specifically of females studying science. Prior to this study, only whole class values were reported.

STUDY POPULATION

Only the scores of those students who took both the pre and post tests in all three categories were analyzed. The number of tests analyzed for females in the experimental group was 274 (Nf achievement = 98; Nf self-efficacy = 88; Nf attitude = 88). The number of tests analyzed for males in the experimental group was 212 (Nm achievement = 84; Nm self-efficacy = 64; Nm attitude = 64). The number of tests analyzed for females in the control group was 131 (Nf achievement = 55; Nf self-efficacy = 38; Nf attitude = 38) The number of tests analyzed for males in the control group was 111 (Nm achievement = 39; Nm self-efficacy = 36; Nm attitude = 36). All students received instruction in astronomy using the same eighth grade science text published by Prentice-Hall. The students were members of 14 intact classes from three different middle schools. Ten classes were designated as experimental, and four as control groups. All classes were heterogeneously grouped, containing between five and ten percent special needs students.

DESIGN

All students, female and male were given pre and posttests consisting of an achievement test and a survey consisting of questions relating to science self-efficacy and attitude toward science. The achievement test was teacher-researcher constructed and consisted of items taken from the local state test and TIMSS (1999) released eighth grade science examination. The Student Opinion Survey (McMillan, 1992) developed by Virginia Commonwealth University was used to measure student science self-efficacy and attitude toward science. The survey consisted of 29 items and was specifically designed for middle school students. The achievement test and survey was given as a pre-test to establish equivalency and as a posttest to determine if gains had been achieved.
During the course of the 12-week study, the 10 experimental groups performed collaborative concept mapping using pre-determined vocabulary terms. The 4 control classes performed no collaborative concept mapping.

During the 12-week study students were asked to complete collaboratively constructed concept maps in single sex dyads or triads using pre-determined vocabulary terms. The vocabulary terms were written on self-stick movable cards. Physically moving the cards was a sign that changing one's mind in the light of additional information was acceptable and expected. The maps were not analyzed pre to post or corrected for accuracy, rather they were included so that the researcher could gain insight into the perceptions of students participating in the study.

During the course of the study, the researcher visited the classes in which students were engaged in collaborative concept mapping and informally obtained perceptions of students relative to their experience of collaborative concept mapping. The researcher also visited a control class in which students did not participate in collaborative concept mapping in order to obtain their perceptions of the unit on astronomy. The three teachers involved in the study were also interviewed to obtain testimonial evidence on their perceptions.

**SUMMARY OF EQUIVALENCY DATA**

All students, females and males, in both the control and experimental groups were found to have no statistically significant differences among them with respect to achievement and science self-efficacy and could therefore be considered to belong to the same population. Females in the experimental group however, showed significantly higher scores in attitude toward science scores than males in the experimental group and therefore are considered to belong to a different population.

In all tests where the researcher predicted the outcome, one tailed t test was used. In all tests where the researcher did not predict the outcome, two tailed t test was used. The researcher predicted that female student scores in achievement, science self-efficacy and attitude toward science would increase from pre to posttest influenced by their participation in collaborative concept mapping experiences.

**RESULTS OF THE DATA ANALYSIS**

**THE ACHIEVEMENT TEST**

Since the researcher predicted that the females in the experimental group would have higher scores than the
females in the control group, a one-tail t test was used to analyze the results. When pre to post change scores of the two groups were analyzed, using a one tail t test, the results were quite different. As seen in Table 1, the females in the experimental group achieved a 4.8 point gain over the females in the control group and a comparison of the change score was found to be significant.

Table 1: Pre to Post Achievement Mean Change Scores of Females in the Experimental and Control Groups

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean of change score</td>
<td>+9.3</td>
<td>+14.1</td>
</tr>
</tbody>
</table>

Note: *p<0.05

Although the researcher's interest was in the performance of female students, she decided to compare the posttest achievement scores of males in the control and experimental groups. A two-tail t test was performed because the researcher did not predict that the males would have higher scores after the collaborative concept mapping experience. As Table 2 shows, the males in the experimental group achieved higher scores than the males in the control group and reached statistical significance at the p<0.05 level.

Table 2: Posttest Achievement Scores of Males in the Experimental and Control Groups

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>39</td>
<td>67.2</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Note: *p<0.05

The researcher performed a two-tail t test on the means of the change scores of the males in the control and experimental groups. As seen in Table 3, the males in the experimental group show higher gains than the males in the control group and achieved statistical significance. Clearly, collaborative concept mapping influenced the achievement of the males as well as the females in the study.

Table 3: Pre to Post Achievement Mean Change Scores of Males in the Experimental and Control Groups

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean of gain score</td>
<td>+11.8</td>
<td>+17.6</td>
</tr>
</tbody>
</table>

Note: *p<0.05

As seen in Table 4, the posttest achievement scores of females and males in the experimental group were compared and results of a two-tailed t test indicated that the score of the males was significantly higher than the score of the females.

Table 4: Posttest Achievement Scores of Female and Males Students in the Experimental Group

<table>
<thead>
<tr>
<th></th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>98</td>
<td>67.8</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Note: *p<0.05

As both female and male students in the experimental groups showed significant gains in achievement over their control group counterparts, the researcher performed a two-tailed t test on the pre to post mean change scores. As Table 5 indicates, the mean change score of the males in the experimental group was statistically different to the mean change score of the females in the experimental group, with males showing greater gains in achievement.

Table 5: Pre to Post Achievement Mean Change Scores of Females and Males in the Experimental Group

<table>
<thead>
<tr>
<th></th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean of change score</td>
<td>+9.3</td>
<td>+14.1</td>
</tr>
</tbody>
</table>

Note: *p<0.05

Science Self-Efficacy Survey

Although the experimental females had significantly higher posttest self-efficacy scores than control group females, both showed a decrease in their self-efficacy scores pre to post. The decrease in self-efficacy for the control group was greater than that of the experimental group [Experimental 40.6 to 39.8; Control 38.9 to 37.9], but neither decrease reached statistical significance.

Upon completion of the study, no statistically significant differences were found in the posttest scores for self-efficacy among males in the experimental and control groups [Experimental 39.6; Control 40.2]. Although males in both the experimental and control groups decreased pre to posttest, neither decrease was significant. When the scores of females and males in the experimental group were compared, although females showed a posttest score of 39.8 while males showed a posttest score of 39.6, the slightly higher score of the females was not significant.

Additionally, when comparing the means of the pre to post change scores for females and males in the experimental group, no significant differences were
found. However, scores for males decreased slightly more than scores for females but the difference was not significant.

**Attitude Toward Science Survey**

The results of a one-tail t test revealed that there was a statistically significant difference between the posttest attitude scores of the females in the experimental group and the females in the control group.

Analysis of the mean change scores of females in the experimental and control groups revealed that the experimental group stayed exactly the same, while the control group decreased by -2.9 points. The score range was as follows: [Experimental 36.9 to 36.9; Control 36.7 to 33.8]. While the score of the females in the experimental group remained the same pre to posttest, the decrease in the mean score of the control group was significant. Females in the experimental group did not improve their attitude toward science, but maintained the exact same score.

**Discussion**

Clearly, experimental group females who participated in collaborative concept mapping, made significant gains in achievement scores when compared to control group females who did not experience collaborative concept mapping. Researchers (Bandura, 1977, 1982, 1993; Slavin, 1980) agree that carefully constructed instructional strategies such as collaborative concept mapping may have the power to influence achievement scores because they “provide the context for sustained discourse” (Roth & Roychoudhury, 1992, p. 552). This study supported the findings in the literature.

While Novak and Gowin (1984) reported that achievement gains were raised in whole classes as a result of participating in concept mapping, this study extended their work by confirming that female scores in particular could be raised by the use of collaborative concept mapping. The process of collaboration may be an example of what Campbell and Salem (1999) referred to as “collective wisdom” meaning that information that may elude a single student was brought out to the group through the sharing of ideas and the negotiation of meaning, thus enabling individuals to learn from the group process. The process of collaboration enabled the females to learn the content information in a way that its absence did not do for the control group females who experienced no collaborative concept mapping.

Experimental group males also made significant gains in achievement when compared to control group males. The gains of the experimental group males were also significantly higher than those of the experimental group females as is consistent with the literature (AAUW, 1995; Campbell et al., 1999).

In the view of the researcher, although males did benefit from concept mapping regarding their achievement scores, they did not appear to find the collaborative process to be of great benefit, nor did they appear to find the process as socially rewarding as the females. Other researcher (Campbell & Salem, 1999; Osisioma, 1997; Riger, 1999; Tobin, 1988) claimed that females enjoy and are more productive in collaborative work.

During the informal interviews, the researcher gathered evidence, which suggested that female students found the process of learning through collaborative concept mapping a successful strategy. It was successful because the single sex dyads provided for horizontal (student to student) rather than vertical (teacher to student) conversation, which was less threatening than traditional expository instruction. Since males often take a lead in science group experiences (Kahle, 1985) single sex dyads provided an opportunity for females to take charge of conversations, negotiations and interpreting their own work and ideas. Rather than feeling compelled to project canonical views of science, the female students were encouraged and expected to share their own ideas and findings. Collaboration encouraged in-depth conversation and the free un-edited expression of ideas that is more appealing to females in general.

The female and male students in this study did not show gains in self-efficacy scores perhaps because “…self-efficacy is built over many years and is less likely to show instability due to recent experiences” (McMillan, 1992, p.28). Although experimental and control group females scores both declined pre to posttest, the decline was not significant and experimental group females showed significantly higher scores than control group females at posttest.

The female and male students in this study did not show gains in attitude toward science scores. While control group females’ scores decreased significantly pre to posttest, experimental group females maintained the exact same score pre to posttest. Since at the pretest, experimental group females’ scores were significantly higher than experimental group males’ scores, their scores cannot be compared. Although Jovanovic and King (1998) reported that collaborative concept mapping has the potential to raise attitude toward science scores, in whole classes, this study cannot support their findings.

Although this study sought to examine gain scores, valuable information was also obtained when examining...
the mean scores of experimental and control groups. To determine if science self-efficacy and attitude toward science can be raised, a study of longer duration is warranted.

References


Roth, W., & Roychoudhury, A. (1992). The social construction of scientific concepts or the concept map as conscription device and tool for social thinking in high school science. Science Education, 76 (5), 531-557.


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INTRODUCTION

The implementation of computer and telecommunications technologies in schools has long been a national, state, and local educational goal (Glennan & Melmed, 1996; National Task Force on Educational Technology, 1984 cited in Reiber & Welliver, 1989). American public education has invested dearly in these technologies both wiring buildings and classrooms, and accumulating an impressive computer inventory (Becker, 2000c; U.S. Congress, Office of Technology Assessment, 1995). This substantial public investment underscores society's expectation that education will successfully integrate technology into the classroom. However, integrating technology into schools and using it in ways that impact student learning is proving more difficult than expected (Scheffler & Logan 1999, citing Houghton, 1997).

A snapshot survey by the US Department of Education (National Center for Educational Statistics, Fast Response Survey System, January 1999) revealed that 33% of surveyed teachers self-reported feeling either well (23%) or very well (10%) prepared to teach using technology in their subject area. In addition recent self-assessment by New Hampshire teachers on Moersch's (1995) Level of Technology Implementation (LoTi) scale reveals that 31% assess their technology use skills at Level 3 (Infusion) or higher (LoTi, 2002) (see Figure 1). LoTi registers teachers' self-assessed level of technology integration on a scale of 0 – 6. Zero being nonuse. Level 3 indicates technology use that complements selected instructional activities.

When viewed within the context of diffusion theory (Rogers, 1995), these numbers indicate that teachers are making good progress. Given that the Innovators and Early Adopters, people who have been using technology and thinking about technology for some time, constitute only 16% of a potential adopting population, these two statistics suggest diffusion has moved into the next large category of potential adopters—the Early Majority (see Figure 2).

It is important to keep in mind that while many teachers do feel prepared to use technology, many others do not – or not yet. Sixty-seven percent of teachers do not feel well prepared to utilize technology in their instruction, and 69% of New Hampshire teachers are strewn across LoTi Levels 0-2. Twenty-one percent report non-use. Thirty-two percent reside at LoTi Level 2 – poised to adapt. Rogers’ theory on innovativeness suggests further than these latter groups of potential adopters, who by definition come to innovations late in the game, tend to be more skeptical about innovations, deliberate and traditional in their thinking. In the end, Rogers (1995) reminds us adoption is never a given. There are always opportunities to reject an innovation.

There is a growing consensus that administrative support and leadership are crucial to successful implementation of instructional technologies, and that the importance of this administrative support is often understated (Gibson, 2001; MacNeil & Delafield, 1998; Mims, 1998; Murphy & Gunter, 1998; U.S. Congress, OTA, 1995). Thomas (1999) suggested that administrators “do not appear prepared for their emerging role in technology, and their lack of understanding and resources sometimes creates barriers to change and improvement” (p.3). Radlick (1998) observed in some districts that, “superintendents have remained withdrawn from the technology discussions, leaving to staff the leadership roles of planning and implementing technology” (p. 239). This remoteness can have consequences of its own, especially if technology decisions are left to those with a greater interest and focus on the technology itself. Wasser (1996) wrote that “the results of such disregard” are often costly, and could result in the loss of “control of technology decisions to those parts of the system that do not hold a curricular outlook” (p. xlix).
The superintendent's role and requisite skill set in systemic technology integration is just emerging (Reitz, 2000; TSSA, 2001). It has been suggested “the people who make decisions about policies and finances in schools have little or no training in educational technology and few resources to make informed decisions. School administrators do not appear to be prepared for their emerging role in technology, and their lack of understanding and resources sometimes creates barriers to change and improvement” (Thomas, 1999, p. 3). Regardless of whether or not school administrators are prepared, as Thomas suggests, they are nevertheless “still faced with the increased responsibilities of infusing technology into the schools under their charge” (Schoeny, Heaton, & Washington, 1999, p. 2).

While an occasional study focuses on superintendent thinking, behavior and leadership (see for example, Petersen, 1999), there is, in the overall, little research on the superintendency (Grogan, 2000; Mullen & Keedy, 1998) and even less on superintendency and technology.

With an underlying interest in seeing the continued growth and development of teachers’ technology skills and understanding, this study inquired into the thinking of three New Hampshire superintendents asking the question What are superintendents’ conceptions of the institutional conditions that facilitate or impede the process of teacher technology integration?

**Conceptual Frameworks**

Whole bodies of literature have developed within the context of diffusion theory in response to the difficulty public education is having integrating technology. One strand of literature (Hall & Hord, 1987; Hooper & Reiber, 1995; Marcinkiewicz & Welliver, 1993; Reiber & Welliver, 1989; Rogers, 1995; Sandholtz, Ringstaff & Dwyer, 1997; Sherry, 1998) suggests several multi-stage models of technology integration that broadly describe the process as a developmental continuum of knowledge, skills, and use, ranging from the naive to the sophisticated. These models also identify teachers’ needs and concerns as they move through various suggested stages. A second strand of research has identified institutional conditions that may facilitate this very integration process by helping to resolve barriers from teachers’ experiences (Becker, 1994, 2000a; Ely, 1990a, 1999a, 1999b). When taken together these strands provide a comprehensive picture of the process teachers go through as they adopt and integrate technology, of the barriers and concerns that impact their integration, and the conditions that may facilitate that process. The picture that emerges speaks to the importance of superintendents themselves having robust conceptions with regards to technology and education. It is ultimately their decisions and policies that determine the success or failure of technology integration district-wide and at the teacher level, where research and common sense suggest it will have the most impact on student learning.

**Teacher Technology Integration**

A great deal of accumulated evidence has identified obstacles that impede teachers’ ability to adopt and integrate technology into their teaching. These include the lack of time, expertise, access, resources, and support (Leggett & Persichitte, 1998, cited in Wilson; Sherry, Dobrovolny, Batty, & Ryder, 2000). However, other recent evidence indicating classroom teachers’ lack of integration understanding (Jerald & Orloffsky, 1999, citing Chambers; Lieberman, Parrish, Kaleba, Campen, & Stullich, 1999) is particularly troubling because integration literature suggests that technology’s greatest impact on student learning becomes evident only after teachers have sufficient skills coupled with a sophisticated understanding of how technologies can be used as cognitive tools and then woven into their daily practice. It is further suggested that this robust level of understanding comes over time, as teachers have opportunities to practice with the technology and reflect on how these new tools fit in with their current instructional practices and their notions and beliefs about the nature of learning.

When teachers actually begin using technology in their instruction they enter the implementation phase suggested in Rogers’ (1995) innovation-decision process. Everything up to this point is characterized strictly as a mental exercise (p. 172), one in which each individual adopter weighs the costs and benefits of various attributes of the innovation in relation to one’s existing instructional practice and/or beliefs about the nature of how people learn.

When painted with a broad brush these models suggest a continuum of knowledge and skills that range from naive to sophisticated. Early or naive technology use tends to mirror traditional practice, that is, it adheres very closely to, and is compatible with, a teacher’s established style of teaching (Reiber & Welliver, 1989; Salomon & Almog, 1998; Sandholtz, et al., 1997). Diffusion theory (Rogers, 1995) views compatibility as a positive attribute of an innovation and as a lure for the use of technology. However, achieving a level of compatible use does not equal integrative success. It has been suggested that compatible use by itself may not be transformative enough of the educational
experience to result in positive student learning (Salomon & Almog, 1998; Reiber & Welliver, 1989). The later stages of integration describe a teacher with a more comprehensive definition and understanding of technology, i.e., someone who is flexible and capable of designing daily curricula using various combinations of technologies in combination with a variety of teaching strategies and activities. The power of technology in this vision, “is not its potential to replicate existing educational practice, but in its ability to combine idea and product technologies [i.e., instructional concepts and strategies, and hardware and software] to encourage students to engage in deeper cognitive activity” (Hooper & Reiber, 1995, p. 9).

**Institutional Conditions**

The importance of institutional conditions in facilitating the process of technology integration is just emerging. Traditionally, researchers have identified barriers that impede teachers’ adoption of technology (Evans-Andris, 1995). Ely (1999a) argues that there are certain obstacles that “thwart diffusion and implementation efforts” and “if we knew what types of resistance exist, perhaps we could design strategies to combat them” (p. 24). Ely’s research looked at sites where technology implementation had already been successful and identified emerging themes in the environment that appeared to facilitate the implementation process and were common to all. Ely (1990a, 1999a, 1999b) identified eight conditions that were present across multiple sites. They are dissatisfaction with the status quo, existence of knowledge and skills, availability of resources, availability of time, rewards or incentives, participation, commitment, and leadership.

These eight conditions have been used as a framework in numerous studies on the implementation of various innovations in varying educational contexts (See: Bauder, 1993; Ellsworth, 1998; Haryono, 1990; Jeffrey, 1993; Marovitz, 1994; Ravitz, 1999; Read, 1996; Riley, 1997; Stein, 1996). Ely (1999a, 1999b) himself reports considerable corroborative qualitative evidence across a broad range of educational cultures that support these conditions as well. Wilson, et al (2000) suggested that these conditions may serve as a potential roadmap to facilitate integration by providing useful guidance to those responsible for technology adoption in schools. Becker (1994, 2000a, 2000b, 2000c) has also examined institutional conditions. His question was related to how the teaching environment of exemplary technology-using teachers differs from the teaching environment of other technology-using teachers in the same subject.

Becker (1994) found that exemplary technology-using teachers teach in schools that have both technology and pedagogic support, a full-time technology coordinator, teachers with an above average level of technology expertise, as well as formal staff development, access to technology resources, time, and authentic or consequential use of technology. Exemplary technology-using teachers tend to work in schools that invest heavily in building teachers’ knowledge and skill level.

**Methodology**

Superintendents have a key role to play in facilitating technology integration since it is the policies that flow from their decisions that creates the community’s culture. The implications their conceptions have on the policies that create the institutional conditions and structures in which teachers adopt are substantial. For these reasons superintendents were chosen as the unit of study. A multiple case study was developed to understand three superintendents thinking with regards to the conditions they believe teachers need in order to be effective users of technology.

**Sample selection and description**

Merriam (1991) suggests that if one is interested in understanding or gaining insight into a particular issue, “one needs to select a sample from which one can learn the most” (p. 48). For precisely this reason, this study chose a purposeful sample of superintendents recommended by an informant from the New Hampshire State Department of Education for their grasp of technology integration issues and their potential to offer insight into understanding systemic technology integration, and not because their district’s exhibited exemplary practices. Fifteen superintendents divided into two tiers were recommended. The first tier of five was singled out because of their grasp of technology issues. The second tier of ten served as a backup. The three cases in this study all came from the first tier of the five recommended.

The sample consisted of two females, Roberta and Natalie and one male; Matthew. All were Caucasian. Natalie has a doctoral degree in special education. Roberta and Natalie both hold Certificates of Advanced Graduate Study (C.A.G.S), which is the minimum state educational requirement to be a superintendent in New Hampshire. All but one attended public schools through high school. While all have been working in their current district for at least fifteen years, and in two cases (Roberta and Matthew) for over twenty years, they were new to the superintendency within eighteen months at...
the time of this study (2002), and were educated before computer-based technologies were a concern to education. They have all worked their way up through various administrative positions from principal to assistant superintendent to superintendent. They have all witnessed the growth of computers and telecommunications technologies in education, and have been instrumental, if not pivotal, in shaping the technology organization and delivery in their respective districts.

Roberta believes that technology is a core value in the future of the enterprise, admitting that, “frankly we’d be lost without it.” She sees technology as a possible way to reinvigorate education and to more deeply engage students with their teachers in the content. She views technology as a tool that facilitates the “independence” piece of helping students to become independent life-long learners. Above all else, she believes that technology must bring something to the teaching and learning process, “otherwise it is a waste of time.”

Natalie admits to having a clear conception of the culture a successful learning environment requires in a traditional setting using traditional tools. She believes that many of the conditions that are important for good schooling without technology are equally important for good schooling with technology. She believes that teachers must have certain amount of knowledge and level of skill and comfort in order to be effective users of technology, and realizes that not all have such knowledge and skills, yet. Natalie has her reservations about the value technology brings to a traditional education.

Matthew views technology as a vehicle that enables “other things to happen.” He believes teachers are paid to use their judgment as to how teach best. If they are to use their judgment with regards to integrating technology, he suggests, they must have a clear understanding of technology on many levels. He believes teachers must be informed and competent, and the district has the responsibility to ensure the technology allows the teachers to do what the administration expects of them. He has concerns about the district integration effort, and sees that where students have a tendency to embrace technology, teachers are uneasy and hesitant.

The student population sizes of these three districts ranged between fifteen hundred and five thousand students. Each district has one middle and one high school. The number of elementary schools in the districts ranged from two to nine. Total annual school budgets ranged from twelve to forty-six million dollars.

**DATA COLLECTION AND ANALYSIS**

This study was designed around a four-phase protocol that was applied to each case. The two early phases concentrated on data collection for the purpose of constructing a sufficient understanding of how the district organized its technology resources in order to engage in an informed conversation with the superintendent. Using a combination of interview, observation, and document data, this study began by gathering information about how these three districts organized, managed, and delivered their technology resources and services. The non-superintendent interview data consisted of three to four hours of both face-to-face and telephone conversations with a wide variety of personnel.

From these interviews, coupled with two half-day observations conducted mostly in computer labs, a detailed descriptive technology profile emerged for each district constructed around three questions that school districts confront as they integrate technology:

1. How does the district address the many issues of infrastructure, technology management, maintenance, and support?  
2. How has the district organized its resources to address teaching technology skills to students?  
3. How has the district organized its resources to facilitate the acquisition and integration of technology knowledge and skills by their teachers? As more data were gathered each technology profile grew richer.

Document data, which included the district’s technology plan, technology grant applications, online materials from the district’s own web site, and demographic information from the New Hampshire Department of Education website, were primarily used in the construction of the technology profiles. These early data helped triangulate and substantiate later superintendent interview data. Field notes were descriptive and reflective, and contained information gathered through informal conversations with technology personnel, librarians, and classroom teachers during observations.

Superintendent interviews followed a semi-structured protocol, consisting of two sessions lasting between sixty and ninety minutes each. Questions for the superintendent interviews were informed by the literature on institutional conditions and the individual context reflected in the technology profile. All interviews (superintendents and others) were audio taped and transcribed. Transcripts of superintendent interviews were sent to each subject to allow them to check for accuracy and/or clarification. No changes or clarifications were suggested.

Data collection and data analysis were overlapping simultaneous processes (Merriam, 1991). In the early phases of the study data collection and data analysis resulted in each district’s individual technology profile. In the later phases, superintendent interviews were
descriptively summarized and coded by broad topics such as professional development, resources, infrastructure, and time, for example. Much of the superintendent thinking seemed to naturally cluster around Ely’s (1990a, 1990b, 1999a, 1999b) conditional headings. The findings were later grouped and are discussed under these conditional headings. Doing so created less terminology clutter, which aided the broader integration discussion. Wilson, et al (2000) suggested that many conditional research studies can be made to fit Ely’s framework quite comfortably. Some of the detailed descriptive findings in this study also lend operational clarity to Ely’s conditional categories, some of which Ely himself has suggested may be a bit ambiguous.

**FINDINGS**

Common thinking was found in this purposive sample of three “technology-informed” New Hampshire superintendents. Topping conceptions were leadership, teacher technology knowledge and skills, and time. In addition, they all see lack of time and the public’s hesitation to spend public monies on building teacher capacity as obstacles.

**Multiple Levels of Leadership**

These superintendents believe that three levels of leadership are essential to successful technology integration including their own involvement, principal and administrative leadership, and effective technology leadership. They believe that a clearly defined and articulated technology message, understood by their administrative team, and used to build broad community and school board support, is necessary to secure funding, good will and buy-in. However, they have not all crafted such a message because they are not all convinced of the value technology adds to a traditional education. Natalie commented, “We don’t know yet what value it adds to a traditional education. To Reading, Writing, the traditional skills. We are making assumptions that it can enhance them.” Notwithstanding her reservations however, she remains open to technology’s transformational potential, and has exhibited a commitment and a willingness to try new technology initiatives when they make sense to her.

The type and level of superintendent involvement across the three cases varied. Examples included active participation on the district’s technology committee – often as Chair (Roberta); engagement in active discussions with technology personnel to smooth out and clarify lines of responsibility, authority, and overlapping interests (Natalie); the creation of site-based technology committees to ensure active engagement by principals (Matthew); redefinition of technology teacher positions and the creation of technology curriculum coordinator positions (Roberta); the use of the persuasive power of the superintendency to help a technology coordinator involve middle school reading specialists into full-time technology integrators and to infuse the district Tech Ed faculty with technology skills (Natalie); assisting in the establishment of free evening technology classes for adults (Roberta) – an initiative Roberta admits was “probably the best thing that we have done to get technology support in our district;” facilitating a project that has middle school students teaching e-mail technology to senior citizens (Roberta); and actively engaging other locally-elected civic boards into the district technology discussion to build broader community support (Matthew).

All three superintendents have demonstrated the depth of their commitment to seeing successful implementation as judged by their willingness to use the power of office of the superintendency to make substantive changes in both organizational and teaching structures that would better accommodate the integration of technology. For example, Natalie exerted pressure on her middle school reading specialists to implement her technology coordinator’s initiative of infusing technology into their skill set and expanding their instructional role to include teaching the technology curriculum as an integral member of the grade-level team. In another case, Roberta persuaded her school board to configure the district’s new elementary technology teacher position and program in a way that she believed was more likely to enhance teachers’ understanding of technology.

These superintendents believe there can be no effective system-wide integration without the direct involvement and leadership of the building principal. While they believe it is their responsibility to ensure that their principals understand and implement the district’s technology vision, they expect the principals to take the lead in ensuring that all teachers in their building work towards adopting technology. This included encouraging principals to ensure that teachers included technology goals in their annual professional development plans. In one district, when the superintendent (Matthew) realized that the district technology committee recommendations did not match principals’ plans, he created site-based principal-led technology committees to ensure their participation, buy-in and ownership. This in turn led to greater principal participation in technology discussions at the district level.
Lastly, all three superintendents believe there must be some form of oversight and management of the district’s technology resources and efforts, both technological and instructional. There is surprising wide variance in how these three districts have organized their technology resources. There is no emerging pattern of preferred oversight or organization. No two districts define the position of technology coordinator in the same way. In fact, not every district had a person or position responsible for technology management and oversight. In Natalie’s district, for example, the technology coordinator is in charge of all aspects of both the district’s technology infrastructure and instruction, where decisions are the result of one-on-one superintendent-to-technology coordinator conversations. In Roberta’s district the responsibilities are split. There is a technology coordinator who oversees technology management, maintenance, and support, and chairs the district technology committee. The district’s elementary technology teacher oversees and coordinates curriculum integration of technology for grades K-8. Technology decisions in this district are the result of active engagement in the district’s technology committee across all levels of the district’s educational community. Matthew’s district had no technology management piece in place at the time of the study. He acknowledged this as an issue and was leaning towards hiring both a network administrator and a director of technology in the future. In this district, each building-level technology teacher was responsible for all the technology in their building, in addition to a full schedule of teaching responsibilities.

Knowledge and Skills

These superintendents also agree that teachers need to enhance their technology skill and understanding. They believe that training is important, and that it requires their attention and personal involvement.

They all believe that professional development is an important, if not critical, component of their district’s integration strategy. Access to technology professional development in each district is varied and employs a broad range of traditional strategies to accommodate the diversity of adult learning styles. These include both after-school workshops and hands-on summer institutes. However, they all agree that professional development, by itself, at least in its current form, is not sufficient to ensure success. They believe that in concert with professional development, classroom teachers need more opportunities that offer regular contact with the technology itself and with someone who has greater knowledge, experience, and expertise in teaching with technology. While they are not all sure exactly how to accomplish that, the superintendents are willing to address knowledge deficit; approaches that involve both grade-level, and in some cases, district-wide organizational and teaching structural changes.

For example, Natalie, the same superintendent who was the most unconvinced of technology’s impact on a traditional education, believes the best hope for technology may lie in its use as an online communication tool that allows teachers to engage and collaborate with one another within a building and across the district. Encouraging online discussion amongst teachers in study groups is a core feature of her district’s professional development strategy. One poignant incident had convinced her in the potential of online discussion. On a bulletin board, which the technology coordinator set up without her permission and which teachers primarily used as vehicle for swapping or selling personal items, one teacher posted a request for information concerning her mother’s degenerative progression of Alzheimer’s disease. This posting opened a flood of support from teachers and administrators across the district who had been through similar ordeals. Natalie realized that online communication had real potential for adding value to the educational enterprise. The question she now asks is “How do we get that kind of communication around reading?” Her technology coordinator has characterized the level of online discussion as slowly evolving from one of information exchange to a bona fide platform for discussion, conversation and dialogue.

Time

In searching for ways to create various opportunities for classroom teachers to have regular contact with technology and technology expertise, superintendents run up against the constraints of time. Professional development and other opportunities both require time, and they are often in conflict with other, equally worthwhile, uses for that same time. How the precious commodity of time is used may be more important.

All three superintendents distinguish between a teachers’ own time and contractual time. Ely (1999b) speaks of the need for contractual time, and so do they. The notion of needing more contractual days for teachers without students was mentioned more than once by these superintendents. Matthew views professional development as a part of the district’s responsibility suggesting that one cannot expect teachers to learn technology by themselves on their own time. His district, which has three full days of professional development time set aside, recently approved an extra four
The schools got new computer labs, the students

In contrast, Roberta's district has eight contractual
days throughout the school year for professional develop-
ment, some of which are taken up by what she refers
to as “administrivia.” In the ideal, she would like to see
twenty extra contractual days without students as a way
to ensure that all teachers engage in the process.
However, short of actually having twenty days, Roberta
offers a solution that uses teacher contractual time in a
way that directly links teachers to the technology
knowledge, skills and expertise they need. When
Roberta had the opportunity to establish an elementary
technology program and hire an elementary technology
teacher, she believed it would be important to have ele-
mentary classroom teachers remain with their students
in the computer lab as a way to expose them to the
technology on a regular basis and to increase their indi-
vidual skills and understanding. In what were both a
political as well as an instructional victory, Roberta
established a co-teaching dynamic in the computer lab
between the elementary classroom teacher and the ele-
mentary technology teacher. She said,

If we really want to bring about using tech-
ology as a seamless tool we had to have
the classroom teacher in there with the stu-
dents, otherwise they would be dropping [them] off as they do for gym, PE and art,
saying, ‘This is my time off. You do your
technology magic with them and I’ll pick
them up in 45 minutes.’ In that model
we’re missing the teacher. We’re missing
the team-teaching that the classroom
teacher and the technology teacher can be
doing. That’s not fair to the technology
teacher number one. And it’s not fair to the
students. And the classroom teacher does-
n’t gain by it other than the time. They
don’t gain knowledge.

It was customary practice for teachers in the other
two districts to drop their students off at the computer
lab, much like many do for music, art, or physical edu-
cation. In exchange the teachers received a contractual-
ly negotiated professional planning period. It is easy to
see how the establishment of a technology curriculum,
creation of computer labs and the creation and hiring of
a technology teacher position in exchange for teacher
professional time was viewed as an all around win by the
superintendent, principals, school board, and teachers.
The Roberta's district created a technology curriculum,
the schools got new computer labs, the students

received the technology skills society and their parents
expect they will need to have in order to succeed, and
teachers got their time. However, the opportunity to use
time in ways that encourage this co-teaching dynamic to
further teacher technology understanding is lost.
Finding more time to create other avenues or
workarounds for these needed opportunities is difficult
and challenging even under the best of circumstances.

Matthew's district is a good potential example of this
workaround problem. In his district, there is an overlap
in the technology knowledge base and skill set between
the district's librarians and technology teachers, which
has resulted in a history of tension between the two
camps. Library research skills inevitably overlap with
technology instruction since basic information technol-
yogy skills are a prerequisite to engaging in modern
library research. However, the real contention has to do
with how the library/media positions have been defined.
For example, librarians do not have a fixed schedule of
classes. Their time, unlike the technology teachers, is
their own. If a teacher wants a class to engage in library
research, they contact the librarian and set up a time.
The librarian leads the instruction with the classroom
teacher as a partner. The superintendent and members
of the technology staff, all consider such model to be the
ideal for technology instruction and have contemplated
reconfiguring the technology teacher's position to more
closely resemble this model. However, in this scenario,
only those students whose teachers are interested in
using technology would actually receive computer
instruction. As a workaround, this causes more prob-
lems than it solves, one of which would be inequity of
technology instruction for all students.

In the end, it took Roberta two years of advocating
her vision to the district's administrative council and
school board before her notion of pairing the classroom
teacher and technology teacher was finally established.
At one point, she went so far as to remove the discus-
sion from the bargaining table for fear the school board
was headed in a different direction. In this case,
through negotiations between the middle school and
elementary principals, the contractual teacher planning
time was found another way, and all elementary class-
room teachers were required to remain with their stu-
dents in the lab.

Using time in such a way satisfies a variety of con-
ditions. For one, it solves the time dilemma. It places
teachers in the position of having more regular contact
with the technology itself, observing another teacher
modeling technology use in practice, and having
opportunities to learn the technology right alongside
their students, if there is a need. In addition, teachers
are available to assist their students, offering them another opportunity to interact directly with the content while emphasizing and strengthening the academic purpose of the technology use. It also offers teachers opportunities to improve their own understanding by engaging in professional discussions and planning activities with the technology teacher.

**EXTERNAL CONDITIONS THAT IMPEDE INTEGRATION**

These superintendents view the public's hesitation to spend public money on building teachers' technology capacity, i.e., building teachers knowledge and skills, as an obstacle. It was evident from the technology profiles that the lion's share of the technology resources in these districts has gone towards creating and managing infrastructure (technical and instructional) in the service of offering access and a coherent technology curriculum to students. In fact, each superintendent had a lesson learned and a story to tell and about how the tax-paying public expects public to spend money. Based on their early administrative experiences and observations, it became clear that using public money that would place technology directly into the hands of teachers, especially if they are able also to use this technology for personal use, i.e., home use, before placing it into the hands of students was, and remains, a touchy political proposition. The public seems more comfortable placing technology into the hands of students before and perhaps at the expense of teachers learning how to use it (Rhodes, 1998). It has proven easier, to obtain funding to build computer labs and hire technology teachers for students than for building teacher technology capacity. Addressing teacher technology skills and understanding still remains a crucial issue to be confronted.

**DISCUSSION**

When painted with a broad brush the literature suggests that technology will have little impact on student learning unless and until teachers evolve a clear and comprehensive understanding of technology and its role in instruction. This is nothing less than one would expect of any teacher using any other instructional tool. In order to learn how to effectively think about and use technology, teachers go through a process that is essentially progressive in nature, where progress is dependent upon skill and understanding, and that each level of progress poses unique challenges to the individual as well as to the district. The implications of recognizing that different groups of adopters are at varying levels of use and understanding implies a systemic response that is comprehensive, multi-leveled, and able to support beginning and exemplary technology-using teachers alike. This calls district leadership to the task of creating conditions that help facilitate the process that leads teachers to a more robust technology conception.

The technology profiles constructed for this study suggest that, in the overall, the technology resources of these three districts are not organized to facilitate technology integration for teachers. They seem better organized to create, implement, and support a coherent curriculum of technology skills for students. If the goal of technology in education is to positively impact student learning and achievement, then teachers must achieve a clear and comprehensive understanding of and facility with the many faces of technology. If effective use is a function of a sophisticated understanding, then addressing the conditions that facilitates the process that fosters the sophisticated understanding becomes important. Superintendents decisions and the policies that flow from those decisions create the institutional conditions within which teachers adopt technological innovations at the district level. At the same time, these superintendents have learned over time that the public doesn't always have much interest, or patience, in spending public money to build teacher capacity, whether it is purchasing computers to put directly into teachers' hands or trying to build more contractual professional time into the school year.

These three superintendents all exhibit leadership behaviors that attempt to resolve the constraints and complexities of the local context, and work to address the issue of a technology knowledge deficit. Driven by their dissatisfaction with teachers' current level of technology implementation and the shared conception that having a separate technology curriculum in the upper grades is a waste of valuable resources, these superintendents have all reexamined the use and purpose of existing technology structural elements (instructional and technical) in their districts and decided it was important to institute changes that better accommodate the innovation. They clearly realized that such action would demand their personal involvement. In all cases, superintendent intervention was required to institute structural changes. In one case the superintendent recognized the need to revisit earlier contractual agreements with regards to the use of computer time in exchange for a professional planning period.

Many of the behaviors and thoughts reflected by these New Hampshire superintendents are similar to Petersen's (1999) research of five California superintendents identified as instructional leaders. Petersen identified professional development, opportunities for
shared decision making, expecting the leadership and involvement of building principals, building school board support, the hiring, transfer and/or replacement of personnel (structural and position changes), and personal responsibility and involvement in the form of crafting a vision, risk taking, and high visibility articulating the vision around the district as behaviors of instructional leaders. The superintendents in this study also recognized the necessity of their personal involvement, the risk taking in using the power of the superintendent to restructure the organization. They acknowledged the need in reconfiguring old positions, defining new positions and programs in order to shape a new vision. They saw the articulation of that vision and commitment to it via shared decision making opportunities, building community and school board support, and by expecting the engagement and active leadership of their building principals who help implement the innovation.

Superintendents’ conceptions should include technology as a tool to enhance the curriculum and to allocate resources that help teachers in areas that are directly connected to student learning. Strategic application or misplacement of limited resources could make or break a facilitative environment. If education is to have meaningful proof of a wise and effective investment in technology, district leaders must develop robust conceptions of technology in education. This becomes paramount as chief school officers “struggle with being behind rather than at the leading edge of school reform across the country” (Petersen, 1999). Ely’s (1999b) conditions may play a central role, serving as a broad roadmap that helps focus superintendent attention on the needs and concerns of teachers in ways that create conditions that facilitate the implementation process.

References


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ABSTRACT
This paper describes the qualitative mathematical distinctions between two antagonistic philosophical traditions in science known as logical positivism and post-positivism. After a brief overview of each philosophical tradition, specific qualitative mathematics terms and concepts are defined and discussed. Next, mathematical models are developed for each school of thought and subsequently contrasted to one another. The instructional implications of the use of mathematical models to describe the nature of scientific thinking and scientific change over time are discussed.

AN OVERVIEW OF POSITIVISM AND POST-POSITIVISM

Logical positivism is a philosophical movement that developed in Austria and Germany during the 1920's under the influence and guidance of the Vienna Circle, a group of scholars that included philosophers, scientists, and mathematicians. The aim of the early positivist movement was strikingly lucid and extremely ambitious: to develop a foundationist account of scientific knowledge that would logically justify the scientific enterprise (Giere, 1988). As the name implies, foundationism is the view that all knowledge is based on a set of basic beliefs or “first principles” that are “self-evident.” Anything that is self-evident can be directly observed and perceived by the senses (e.g., the movement of celestial bodies). For positivists, experience and observation provided the foundation for all scientific knowledge, because the validity of observation claims could be determined empirically. Accordingly, positivists completely rejected all metaphysical claims or claims that were not empirically testable assertions of reality (Feigl, 1969). For example, assertions like, “God created the universe,” and “All knowledge is infinite” cannot be directly determined by logical or empirical analysis and are therefore meaningless.

In developing their own philosophy of science, positivists described scientific theories as axiomatic systems. These systems acquire an empirical interpretation through rules of correspondence. Rules of correspondence are analytic statements that link the abstract concepts of theories to experience and observation. In physics, for example, a correspondence rule might say that the symbol E in a formal axiomatic system is represented by the amount of energy released or absorbed by an atom. Here the symbol E, which is an abstract concept, is mapped to something that is empirically verifiable (i.e. the energy level of the atom).

Inasmuch as these analytical statements or “observational terms” were believed to be objective and theory independent, positivists argued that such terms were capable of determining the “true” meaning of a theory. In other words, theories do not influence the meaning of observations; rather observations influence the meaning of theories (Shapere, 1969). To the extent that observation terms were considered objective, knowledge claims...
took on an accreting or cumulative function. Indeed, logical positivism was a movement that from its earliest charter looked to construct a new philosophy of science, one that would provide the corpus of science with “epistemological guarantees” vis-à-vis formal axiomatic systems (Toulmin, 1969).

Although some of the concepts developed by the positivists still play an important role in science studies today (e.g., the importance of a precise scientific language), much of their program has been abandoned in favor of a less deterministic or dynamic interpretation of scientific knowledge. In part, this less deterministic approach argues that scientific theories are fallible (and therefore tentative) and that observations are influenced by existing theories. In arguing the latter point, Hanson (as cited in Eldredge & Gould, 1972) contends that “[m]uch recent philosophy of science has been dedicated to disclosing that a ‘given’ or a ‘pure’ observation language is a myth-eaten fabric of philosophical fiction…In any observation statement the cloven hoof print of theory can readily be detected” (p. 85). This view of scientific knowledge is often associated with the ideas and theories advanced in Thomas Kuhn’s (1962/1996) classic book *The Structure of Scientific Revolutions*.

Based on a historical analysis of the physical sciences, Kuhn argued that scientists (a) see the world (and hence make observations) based on their guiding commitments, (b) compete vigorously for acceptance against competing and incommensurable views, (c) may experience a sudden or gestalt-like “switch” in theoretical commitment, and (d) may over time revert to a previously “rejected” idea or commitment based on “newer” findings, or new ways of looking at previously discarded ideas. These ideas are part of a dynamic view of the development of scientific knowledge, which sharply contrast the early positivist thesis. It is important to note that the ideas and theories explicated by Kuhn do not represent a de novo synthesis. Rather they represent a point of imbrications among a number of post-positivist philosophers of science and science educators that predate Kuhn’s *Structure* (e.g., Fleck, 1935/1979; Hanson, 1958; Schwab, 1962; Toulmin, 1953). Kuhn’s work also has influenced and is consistent with more contemporary views in the philosophy of science (Lakatos, 1970; Laudan, 1977). It is this dynamic view of the development of knowledge, which we refer to as post-positivism. Using the precise concepts and language of qualitative mathematics, some of the similarities and differences between these two philosophical perspectives about the nature of scientific knowledge can be described in detail.

**WHAT IS QUALITATIVE MATHEMATICS?**

As Isnard & Zeeman (1977) point out, mathematics has three levels or types of structure: order, topological, and algebraic. *Order structure* involves ordinal-level measurements, which satisfy the transitivity postulate: If x is greater than y, and y is greater than z, then x is greater than z. Comparisons like “greater than” and “less than” are order concepts. *Topological structure* is measured using a continuous scale. The assumption of continuity allows for the moderated and careful use of some calculus concepts, such as smoothness. *Smooth* means that a function or relation is *differentiable* to all orders. Differentiable means that a function or relation is *continuous* (it can be drawn without picking up your pencil) and does not have any hard corners, cusps or vertical tangents.

*Algebraic structure* involves operations such as addition and multiplication, which have little value in measuring sociological phenomena. As Isnard and Zeeman (1977) point out in their sociological model of the causes and tolls of war, “one cannot ‘add’ two senses of threat to get a third, and even twice the cost can become meaningless if one tries to include in the cost of a war the measure of human suffering” (p. 321). Hence properties involving order structure and topological structure are defined as *qualitative*, while properties that rely on algebraic structure are defined as *quantitative*. This distinction is critically important because it implies that as long as changes between different scales are “smooth and order-preserving” (Isnard and Zeeman, 1977, p. 321) they are considered qualitatively similar, even if the algebraic structure is not preserved. This qualitative perspective allows for non-linear variations of scale, which are the type of variations that are recoverable from the theses of post-positivist philosophers of science such as Kuhn, Laudan, and Lakatos, among others.

**RECOVERING MATHEMATICAL MODELS FOR POSITIVISM AND POST-POSITIVISM**

**A RECOVERY OF POSSIBLE MODELS FOR POSITIVISM**

Based on the brief overview of the early positivist thesis described above we can, in hindsight, characterize this view of the nature of science as essentially accreting with respect to the development of scientific knowledge over time. This is in fact what Toulmin (1969) is implying when he refers to “epistemological guarantees” in science or the idea that scientific knowledge is incorrigible. Therefore, from this description of positivism, we can glean some basic mathematical...
assumptions that will help us to construct a qualitative model of positivism. These assumptions are:

a) The acceptance of a fundamental scientific theory or group of theories is always monotonically increasing over time (the derivative with respect to time \( t \) is positive for all \( t \)).

b) The development of scientific theories is continuous over time.

Based on these assumptions, it is possible to construct many working models for positivism, four of which (linear, quadratic, exponential, and quartic development) are shown in Figure 1.

**A RECOVERY OF POSSIBLE MODELS FOR POST-POSITIVISM**

Because early positivists embraced a foundationist epistemology, they believed that established scientific knowledge was in many ways indubitable. Conversely, in examining the history of science, a number of scholars recognized that many of the important scientific achievements that provided the foundational edifice to a particular discipline have been rejected over time in favor of completely incompatible views. Indeed, this point is a central and recurrent theme among a number of post-positivist philosophers of science and science educators. For example, in describing the transition in scientific thinking of infectious diseases from the mystical and fanciful to the etiological, Fleck (1935/1979) comments that “many theories pass through two periods: a classical one during which everything is in striking agreement, followed by a second period during which the exceptions begin to come to the fore” (p. 9). Eventually, as Fleck documents, these exceptions may lead to the rejection of previously venerated scientific commitments in favor of incompatible commitments and views. Similarly, Toulmin (1953) argues:

Now and then there may have to be second thoughts about matters which had been thought to be settled, but when this happens and the lower courses have to be altered, the superstructure has to be knocked down, too, and a batch of concepts in terms of which the scientist's working problems used to be stated—‘phlogiston’ and the like—will be swept into the pages of the history books. (p. 81)

On the educational front, Schwab’s (1962) distinction between “stable enquiry” and “fluid enquiry” in science was intended to ameliorate the stagnant and immutable image of scientific knowledge proffered by most textbooks and science teachers at the time. The aim of stable enquiry is to contribute to and support an existing body of knowledge within a particular discipline. When extreme difficulties arise during periods of stable enquiry, fluid enquiry allows for the “development of new principles which will redefine that subject matter and guide a new course of effective, stable enquiries” (Schwab 1962, p. 17). And Kuhn’s (1996) “normal” and “revolutionary” science highlights periods of theoretical stability punctuated by relatively rare periods of instability and subsequent change in the physical sciences.

Of course these brief recapitulations do not do justice to the positions developed by each scholar, but simply serve to provide a flavor for the generally nonaccretive or dynamic view of science that is the hallmark of post-positivism. Accordingly, we can recover two important mathematical assumptions from the ideas and theories explicated by the post-positivist philosophers of science.

a) The acceptance of a fundamental scientific theory or group of theories (i.e., a paradigm) is not always monotonically increasing over time \( t \) (the derivative with respect to time is negative for some time interval \( t_1 \leq t \leq t_2 \)).

b) The development of scientific theories is continuous over time.

Figure 1. Various models of theoretical development in science under our assumptions of logical positivism.
Based on these assumptions, it is possible to construct several models for post-positivism, three of which are shown in Figure 2.

EQUIVALENCE GRAPHS AND QUALITATIVELY EQUIVALENT MODELS

The aim of this section of the paper is to describe and compare the positivist and post-positivist models developed earlier using the concepts and language of qualitative mathematics. Because this language may involve a number of unfamiliar terms such as mapping, diffeomorphism, and qualitative equivalence, we provide a brief introduction and explanation of these terms and concepts.

MAPPING

One may map a graph to a new graph using a transform, which is a rule that assigns each point on a graph to a point on a new graph. For example, the points that form the R shape in Figure 3a could be mapped to form the shape shown in Figure 3b using the transform \(X_{\text{new}} = 4X_{\text{old}} - 3\) and \(Y_{\text{new}} = Y_{\text{old}}\). Using this transform, the point (2,3) in graph 3a is transformed to the point (5,3) in graph 3b. Repeating this transform for each point in Figure 3a gives rise to the graph in Figure 3b. Similarly, the graph in Figure 3a is mapped to the graph in Figures 3c, d, and e using the transforms \(X_{\text{new}} = 2X_{\text{old}} - 1\) and \(Y_{\text{new}} = 3Y_{\text{old}} - 2\), \(X_{\text{new}} = X_{\text{old}} + Y_{\text{old}} - 1\) and \(Y_{\text{new}} = Y_{\text{old}}\), \(X_{\text{new}} = X_{\text{old}} + Y_{\text{old}} - 1\) and \(Y_{\text{new}} = |Y_{\text{old}} - 2| + 1\), respectively.

Although each of the graphs in Figure 3 is a transform of the letter R shown in Figure 3a, we need to establish specific mathematical criteria to determine the degree to which each of these graphs is equivalent to one another. It will be recalled that a change in scale between different graphs means that the graphs cannot be quantitatively equivalent. And in each of these graphs (Figures 3a-3e) there is a change in scale, so these graphs are not quantitatively equivalent. However, based on Isnard & Zeeman’s (1977) definition of qualitative equivalence, multiple graphs can sometimes have different scales, but still be considered qualitatively equivalent. The criteria for qualitative equivalence is described in the next section.

DIFFEOMORPHISMS AND QUALITATIVE EQUIVALENCE

The definition Isnard & Zeeman provide for qualitatively equivalent states that as long as a first graph can be mapped to a second graph using a diffeomorphism, then the graphs are considered qualitatively equivalent. A diffeomorphism is simply a smooth mathematical transformation of one graph to another that maps vertical lines to vertical lines. Indeed, both smoothness and the ability to transform vertical lines to vertical lines are necessary to ensure that the transform is a diffeomorphism. The graphs in Figure 3b and 3c have been transformed from graph 3a using a mapping where order has been preserved by mapping vertical lines to vertical lines smoothly. In other words, a diffeomorphism exists that qualitatively maps these graphs to one another. Conversely, the transform used to map graph 3a to graph 3d is not a diffeomorphism, because it is not order-preserving (it does not map vertical lines to vertical lines). Also, the transform used to map graph 3a to 3e is not a diffeomorphism because it is neither smooth (the transform \(|Y_{\text{old}} - 2| + 1\) is not differentiable at \(Y_{\text{old}} = 2\)) nor order-preserving. Thus, graphs a, b, and c are said to be qualitatively equivalent, whereas graphs d and e are not qualitatively equivalent to graphs a, b, and c.
MATHEMATICAL CONSIDERATIONS OF THE WORKING MODELS OF POSITIVISM AND POST-POSITIVISM

Using the concepts and terms in the mapping example above, we can describe all of the positivist models shown in Figure 1 as qualitatively similar. That is, there exists a diffeomorphism that maps these graphs to one another. For example, using the diffeomorphism $X_{new} = X_{old}$ and $Y_{new} = Y_{old}^2$, the linear graph in Figure 1a is transformed to the quadratic graph in Figure 1b. Likewise, a diffeomorphism exists that can transform the linear graph in Figure 1a to the exponential and quartic graphs in Figure 1c and d, respectively. Again, since each of these transformations is a smooth mapping that takes vertical lines to vertical lines, each of the graphs is qualitatively equivalent.

We can also describe the post-positivist models as qualitatively equivalent using the qualitative mathematical criterion established above. For instance, the graph in Figure 2a is mapped to the graph in Figure 2b via the diffeomorphism $X_{new} = X_{old} + 4(Y_{old} - 5)$ and $Y_{new} = Y_{old}$. Although the scales of each of these graphs are different, the fact that a diffeomorphism exists between each pair of graphs allows us to describe these graphs as qualitatively equivalent. Indeed, any two S-shaped curves that can be transformed using a diffeomorphism are qualitatively equivalent.

The criteria above also can be used to show that the positivist and post-positivist models shown in Figures 1a-d and 2a-c are not qualitatively equivalent. That is, no diffeomorphism exists that can map any of the graphs in Figure 1 to any of the graphs in Figure 2. This is evident in the fact that the points that lie in a vertical line in the post-positivist model (from Figure 2a), which...
are highlighted in Figure 4a, would have to be mapped to a vertical line and hence they would all have to be mapped to the same point in the positivist model (from Figure 1a) highlighted in Figure 4b. In order for this to happen, the transform function would not be smooth (it would not be differentiable at at least two points). It will be recalled that smoothness is a necessary condition for a transform to be a diffeomorphism and therefore, when the transform is not smooth there is no chance the two graphs are qualitatively equivalent. Therefore, as long as our criteria for qualitative equivalence involves a smooth mapping that takes vertical lines to vertical lines thereby preserving order, we are forced to conclude that the mathematical models developed here for positivism and post-positivism are not qualitatively equivalent.

**DISCUSSION**

Today science educators are committed to helping students move away from an absolutist and rigidly cumulative view of the nature of science consistent with the early positivist movement toward an understanding of the tentative and revisionary character of scientific knowledge represented by post-positivist philosophers of science (American Association for the Advancement of Science, 1993; National Research Council, 1996; National Science Teacher's Association, 1998). Implicit in this concern is an appreciation and understanding of basic mathematical concepts such as linearity, nonlinearity, and rate of change. Although the field of mathematics can provide a number of graphic models that could be useful in describing the nature of scientific thinking and change over time, such models have not been developed for use in the classroom. In this paper, we provide one example of how formal mathematical models can be used to conceptualize specific epistemological commitments in science. The models developed in this paper could easily be transformed into activities that might be useful in helping mathematics and science educators develop a more sophisticated, formal and explicit view or schema of the nature of scientific knowledge and scientific change.

Briefly, an instructional activity for science educators might begin with a class discussion focused on the ways mathematicians deal with the rate of change over time (i.e., the concept of the derivative) in describing observations of the natural world. During these discussions, the different mathematical models described in this paper (e.g., linear, quadratic, quartic, s-shaped and exponential functions) could be introduced, compared and contrasted. During the next class period or periods, students (i.e., the science educators) are introduced to and discuss the philosophical positions referred to as positivism and post-positivism, perhaps through a series of vignettes. At some point, the students are asked to read selected excerpts from positivist and post-positivist scholars as homework and to characterize the development of scientific knowledge suggested by each philosophical orientation implied in the excerpts. These homework excerpts or readings should be chosen carefully and highlight how a positivist or post-positivist would characterize the concept of change as it relates to scientific knowledge or theoretical commitments over time. The homework assignment could be guided by the following questions:

- Are the views of positivists and post-positivists similar or different as they relate to how knowledge develops over time in science? Explain your reasoning.

![Figure 4](image)
• Can the views of theoretical progress and development in science advanced by positivists be characterized using any or all of the mathematical models discussed in class? Explain which model(s) would or would not, in your opinion, be consistent with positivism.

• Can the views of theoretical progress and development in science advanced by post-positivists be characterized using any or all of the mathematical models discussed in class? Explain which model(s) would or would not, in your opinion, be consistent with post-positivism.

• Can the views of theoretical progress and development in science as described by positivists and post-positivists be distinguished using the mathematical models discussed in class? Explain your reasoning.

• Is there any value in attempting to characterize the views of theory development and progress in science advanced by positivists and post-positivists using the formal mathematical models discussed in class? Explain your reasoning.

This type of activity and its associated concepts could be made more or less sophisticated based on the type of students in the class. For example, students with little background and interest in mathematics may be better served by an activity that emphasizes the general relationship between positivism and a linear or accretive view of theoretical development in science (shown in Figure 1a) and post-positivism and a dynamic or nonaccretive view of scientific development (shown in Figure 2a). Conversely, students with a strong mathematics background may be interested in discussing qualitative mathematics and the idea of mathematical equivalence and trying to demonstrate how positivism and post-positivism are either equivalent or non-equivalent using the more technical mathematical concepts elucidated in this paper. It should be emphasized that this brief discussion is not intended to represent a complete or comprehensive instructional activity, but only suggests a crude example of the instructional possibilities that can be linked to the ideas raised in this paper.

Some may readily object to using this level of mathematical formalism to describe the nature of scientific change and progress over time on the grounds that these ideas are fairly straightforward enough to discuss in plain English, thereby eliminating the need for abstract models. However, many adolescent (as well as adult) learners have difficulty with multi-modal thinking or the ability to consider and conceptualize antagonistic or opposing perspectives (Perry, 1970)—such as positivism and post-positivism. Further, epistemological and philosophical concepts often pose conceptual difficulties for students at all levels, making the development of explicit and formal models in these areas quite desirable. Indeed, the instructional virtue of formal models is suggested by Thom (1975), the progenitor of catastrophe theory, when he states that “[a]s soon as a formal model is intelligible, it admits a semantic realization, that is, the mind can attach a meaning to each of the symbols of the system…” (p. 20, emphasis in original). In other words, formal models have the potential to serve as compensatory instructional devices for students by allowing students to operationalize and examine their views and arguments in graphic form, which may encourage a higher level of reflection, abstraction and meaning-making. Although mathematical modeling is common practice in the sciences, the use of mathematical models to describe the nature of scientific knowledge is a largely unexploited area—an area that may yield practical instructional fruit, as this paper has suggested.

References


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A Comparison of Self-Reported Technology Competency in Staff Groups

Peggy LaBrosse
Hollis/Brookline High School in Hollis, NH

INTRODUCTION

In July 2002, a public high school in southern New Hampshire was awarded a technology grant. I will refer to the high school as South High School (a fictitious name to be used for this paper). The grant provided financial support for hardware, software, and training with four overarching goals:

- Create a Curriculum Innovation Team (CIT) to collaboratively implement technology.
- Integrate technology into the classroom to enhance teaching and learning. Purchase hardware and software to be implemented in each learning area and integrated into the curriculum.
- Improve training programs for students, staff, and community.
- Use a “Staff Communicator” to improve communications between partnering schools and staff.

Continued funding from The Plan for Social Excellence (PFSE) depends upon regular progress reports. In response to the request for information regarding progress made, this paper describes self-reported staff competency in technology use as determined by a survey (see Appendix A), completed in January 2003, by 100% of the staff. For the purposes of the survey, the staff was divided into nine groups: science teachers, math teachers, English teachers, social studies teachers, wellness teachers, administrators, art and music teachers, special education teachers, and support staff (paraprofessionals). This paper presents an analysis of the survey data. The purpose of the data analysis is to provide a baseline for determining professional development needs of the staff and to establish whether different groups have significantly different technology competency. Based on the analysis of the results, CIT made certain recommendations to the school’s professional development committee. The survey will be repeated and the resulting data will be analyzed to describe gains, if any, made by the staff after one year of professional development provided by the CIT and use of the technology purchased with the grant money.

In this study the following question was investigated: Is there a significant difference in the technology competency of the nine staff groups—science teachers, math teachers, English teachers, special studies teachers, wellness teachers, administrators, art and music teachers, special education teachers, and support staff (paraprofessionals)—as reported in a self-evaluation survey conducted by individual staff members of South High School?

This analysis should be useful to the staff development committee at South High School in preparing professional development for the staff and, since these groups were the natural intact groups most often used at South High School, the choice is most practical for future applications.

METHODOLOGY

SAMPLE SIZE AND DEMOGRAPHICS

The research was conducted at a southern New Hampshire high school. The school serves approximately 830 students in grades 9 through 12. The 80 staff members employed by South High School as of January 2003 comprised the sample. The staff members included 33 males and 47 females. Dividing the staff into the nine groups yielded the breakdown by gender listed in Table 1. The uneven sample size, the uneven breakdown by gender, and the small numbers of individuals in each group will be discussed in the Limitations section of the paper.

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of Males</th>
<th>No. of Females</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science teachers</td>
<td>6</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Math teachers</td>
<td>2</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>English teachers</td>
<td>4</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Social studies teachers</td>
<td>6</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Wellness teachers</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Administrators</td>
<td>8</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Art and music teachers</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Special education teachers</td>
<td>3</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Support staff (paraprofessionals)</td>
<td>0</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>33</strong></td>
<td><strong>47</strong></td>
<td><strong>80</strong></td>
</tr>
</tbody>
</table>

Table 1. Breakdown of the Nine Staff Groups by Gender

A determination of competency was conducted using a self-evaluation survey. The data is self-reported and the surveys include the name of the staff member and the department the staff member is affiliated with. The survey is included in Appendix A in its original form.

Professional development was generally provided in two forms, for the entire staff or in small groups at the...
### Table 2. Weighting of Survey Responses

<table>
<thead>
<tr>
<th>Survey Response</th>
<th>Scaled Value for Data Entry</th>
<th>Weighted Value for Analysis</th>
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<tr>
<td>Non-User</td>
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</tr>
<tr>
<td>Everyday User</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Skilled User</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Power User</td>
<td>4</td>
<td>7</td>
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</table>

Test of Normality

<table>
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<th></th>
<th>Kolmogorov-Smirnov$^b$</th>
<th>Shapiro-Wilk</th>
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<tr>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td>8.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.00</td>
</tr>
</tbody>
</table>

|        | WAVERAGE   | 1.00 | .220 | 9 | .200* | .856 | 9 | .086 |
|         |           | 2.00 | .170 | 9 | .200* | .926 | 9 | .441 |
|         |           | 3.00 | .287 | 8 | .051 | .848 | 8 | .090 |
|         |           | 4.00 | .355 | 12 | .000 | .761 | 12 | .004 |
|         |           | 5.00 | .267 | 6 | .200* | .809 | 6 | .070 |
|         |           | 6.00 | .183 | 11 | .200* | .873 | 11 | .086 |
|         |           | 7.00 | .329 | 4 |  | .895 | 4 | .406 |
|         |           | 8.00 | .279 | 11 | .026 | .868 | 10 | .094 |
|         |           | 9.00 | .251 | 11 | .052 | .837 | 11 | .029 |

* This is a lower bound of the true significance.

$^b$ Lilliefors Significance Correction

Table 3. Shapiro-Wilk Statistic, the test for normality of the weighted total and the weighted average scores for each staff grouping

Test of Homogeneity of Variances

<table>
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<th>df2</th>
<th>Sig.</th>
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<td>8</td>
<td>71</td>
<td>.000</td>
</tr>
<tr>
<td>WAVERAGE</td>
<td>4.322</td>
<td>8</td>
<td>71</td>
<td>.000</td>
</tr>
</tbody>
</table>

Table 4. Levene’s Statistic, the test for homogeneity of variance of the weighted total and the weighted average scores for each staff grouping.

### ANOVA

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<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>WTOTAL</td>
<td>Between Groups</td>
<td>2259.143</td>
<td>8</td>
<td>282.393</td>
<td>3.535</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>5672.057</td>
<td>71</td>
<td>79.888</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>7931.200</td>
<td>79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAVERAGE</td>
<td>Between Groups</td>
<td>62.754</td>
<td>8</td>
<td>7.844</td>
<td>3.535</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>157.557</td>
<td>71</td>
<td>2.219</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>220.311</td>
<td>79</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5. The results of ANOVA as run on SPSS
same time. To determine which form was most appropriate for delivering professional development, the self-evaluation surveys were completed by individual staff members and analyzed. The nine groups—science teachers, math teachers, English teachers, social studies teachers, wellness teachers, administrators, art and music teachers, special education teachers, and support staff (paraprofessionals)—were chosen because such grouping was used most often for providing professional development at South High School, especially when the staff required subject- or curriculum-specific training. To brainstorm needs analysis, the staff was broken up into subject-based groups. The decision to categorize the staff according to these nine groups also reflects attendance at professional development in technology over the past three years. Further justification for this decision includes: the computer laboratory logs showed that science and English teachers booked and used the computer labs more often than other staff; professional development courses at the beginner level were most often attended by social studies and foreign language teachers; and advanced courses were most often attended by science teachers and administrators. Most importantly, the staff at South High School requested department-specific professional development. In responding to this request, the staff was divided according to department so that any recommendations made could be followed through and would be met with acceptance by the staff. Dividing the staff into these nine groupings was also based on the following two assumptions: First, that there was a meaningful relationship between the departments to which staff belong and their perceived competency in technology as measured by the survey from January 2003. Second, the staff members whom most often used the computer laboratories with their classes, or who took advanced technology professional development courses, were more likely to rate themselves higher in technology competency. The converse was also assumed, that teachers who used the computer labs less often or who took beginner courses in technology in professional development were more likely to rate themselves lower in technology competency.

Since the major question of the study was to find out whether there was a difference in the technology competence between nine staff groups, an analysis of variance was the most appropriate method to test the hypotheses, using the sample means for technology competency.

**HYPOTHESES**

The null hypothesis: \( H_0: \mu_1 = \mu_2 = \ldots = \mu_9 \) for all \( i \), where if all group means are equal in the population, each group mean will equal the grand mean \( \mu_G \).

The null hypothesis may also be written \( H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 = \mu_7 = \mu_8 = \mu_9 \). The subscripts 1-9 refer to each of the nine staff groups. In all cases, the null hypothesis is that there is no significant difference in the means of self-evaluated technology competency between the nine groups—science teachers, math teachers, English teachers, social studies teachers, wellness teachers, administrators, art and music teachers, special education teachers, and support staff (paraprofessionals)—at South High School. The null hypothesis says that the scores from each group will have the same mean; there will be no significant difference.

The alternative hypothesis:

\[ H_1: \mu_i - \mu_G \neq 0 \text{ for some } i = 1, 2, \ldots, 9. \]

There is at least one group of the nine at South High School—science teachers, math teachers, English teachers, social studies teachers, wellness teachers, administrators, art and music teachers, special education teachers, and support staff (paraprofessionals)—with a mean significantly different from the means of the other eight groups as it relates to self-evaluated technology competency. The observed differences between the nine means are not likely to have arisen by chance.

**DATA COLLECTION**

The survey (see Appendix A) was presented to the staff in January 2003. It consists of six categories for self-evaluation: Web Browsing, PowerPoint, Digital Camera, Scanner, Projector-LCD Panel, and Digital Video Camera. The staff were asked to rate themselves in each category using a Likert-type scale where 1 = Non-User, 2 = Everyday User, 3 = Skilled User, and 4 = Power User. The survey directions describe a Power User as “knowing the technology so well you could teach it to others,” and a Non-User as “you cannot operate the device independently.” The survey also includes skills checklists for each technology area, to provide the staff with appropriate criteria for self-evaluation.

Every member of the staff (total 80) returned a completed survey (100% return). Return of the survey was a part of the requirement for participation in professional development through the CIT initiative. Since continuation of the grant is contingent upon statistics measuring staff competency and integration of technology into the classroom, each staff member had agreed to participate in the survey even though it was not anonymous. It has been made clear to the staff that the survey results in no way would be a part of any evaluation by administrators and were kept only for use by the CIT. The participants returned the survey by email.
in person, en masse after a faculty meeting, and in staff mailboxes. The data were entered into a table in Statistical Package for the Social Sciences (SPSS). The survey includes the name and department of each staff member. The departments were numbered 1-9 and the scaled response data (1-4) was entered for each staff member in each category as reported in the survey. At the suggestion of Dr. Carriño, I weighted the data as shown in Table 2. The rationale behind the weighting is that it gives a truer representation of the distance between Non-User and Power-User. The weighted scores were averaged and totaled for each staff member. These scores—“Weighted Average” and “Weighted Total”—are the scores used in the data analysis.

To check for a normal distribution of weighted total and weighted average for each department, I created histograms in SPSS. It was difficult to discern normality accurately, so I ran a Shapiro-Wilk Test of Normality using SPSS. The results are listed in the right-most three columns of Table 3. The Shapiro-Wilk statistic is calculated when the weighted sample size lies between 3 and 50. The data from the survey meet this requirement.

The null hypothesis, $H_0$: The data set is normally distributed.

The alternative hypothesis, $H_1$: The data set is not normally distributed.

For this test, $\alpha$ is set at .01, so if the significance (or $p$-value) is lower than .01, the null hypothesis will be rejected, meaning that the data is not normally distributed. For the social studies group, using both the weighted total and weighted average, the null hypothesis is rejected at the .01 level. The data in group four is not normally distributed. For all of the other groups, the null hypothesis is retained at the .01 level; the data in these groups is (approximately) normally distributed.

The other concern is whether the data display homogeneity of variance. This test was done before the analysis of variance (ANOVA) to check if the variances in each group are equal. This test uses a pooled or averaged sample variance to estimate the population variance. It is important to note that using Levene’s Test, as shown in Table 4, is only valid when the variances are equal. Levene’s statistic tests the significance of the difference between the variances by looking at their ratio and testing the assumption that $\sigma_1^2 = \sigma_2^2$. For $F = \sigma_1^2 / \sigma_2^2$, if the variances are equal, then $F$ will be close to 1. If $F$ is non-significant—retain the null hypothesis and proceed under the assumption of equal variances. If $F$ is significant—reject the null hypothesis and interpret—in this case using the ANOVA results, in light of having violated this assumption. The Levene statistic for the Weighted Total and the Weighted Average is .000. Since $p$ is significant, we reject the null hypothesis and interpret in light of having violated the assumption of homogeneity of variances. This violation will be further discussed in the Limitations of the Design Section.

**DATA ANALYSIS**

To determine whether significant differences exist between groups, data analysis was performed. Given that there are nine groups, a one-way analysis of variance (ANOVA) was used. The subjects were grouped only one way, by department. The departments were predetermined by job description at South High School.

**ANOVA**

The purpose of the one-way ANOVA is to compare the means of two or more groups to decide whether the observed differences between them represent a chance occurrence or a systematic effect. In this case, the nine groups were: science teachers, math teachers, English teachers, social studies teachers, wellness teachers, administrators, art and music teachers, special education teachers, and support staff (paraprofessionals). The ANOVA procedure compares the between groups variance to the within group variance. Significantly greater variability between groups than within groups suggests that the null hypothesis of no treatment effect should be rejected. In such a case, we could conclude that there are significant differences between the nine groups. With ANOVA we know that at least two groups differ significantly, but we do not know specifically which two groups they are. It is important to keep in mind that the data for the social studies group is not normally distributed. To detect which groups differ significantly, post hoc testing was used. The two post hoc tests, Tukey’s and Scheffe’s, are described later.

There are two sources of variation in the dependent variable—the variation between groups and the variation within groups. To calculate $F_{observed}$, the mean squares between groups are compared to the mean squares within groups $F_{observed} = MS_{between}/MS_{within}$. Finally, the $F_{observed}$ is compared to the $F_{critical}$ to decide whether to reject the null hypothesis of no significant differences due to grouping. The $F_{critical}$ value depends on the degrees of freedom for each source of variation on the level of significance ($\alpha$). If $F_{observed}$ exceeds $F_{critical}$, we conclude that the difference between $MS_{between}$ and $MS_{within}$ did not arise from chance.
Rather, the population means differ due to significant differences between the groups. The SPSS output for a one-way ANOVA shown in Table 5 produced an F = 3.535, which means the MS between is 3.535 times the MS within, indicating a significant difference of at least two or more means at the .05 alpha level. In fact, the significance (p) level is less than .05—it is .002. The null hypothesis is rejected; at least two of the population means differ due to significant differences between the groups. The observed differences between at least two of the nine means are not likely due to chance.

**DESIGN REQUIREMENTS AND ASSUMPTIONS**

The one-way analysis of variance has three design requirements:

- There is one independent variable with two or more levels.
- The levels of independent variables may differ quantitatively or qualitatively.
- A subject may appear in only one group.

The data used in this paper has an independent variable with nine levels. The levels represent science teachers, math teachers, English teachers, social studies teachers, wellness teachers, administrators, art and music teachers, special education teachers, and support staff (paraprofessionals). The levels differ qualitatively; the specific job description the individuals have at South High School determines which group individuals were placed in. Each subject belongs to only one group. The data used for this study meet the design requirements of a one-way ANOVA.

The assumptions of ANOVA are:

- Independence – that the scores for any subject are independent of the scores of all other subjects.
- Normality – that the scores within each population are normally distributed.
- Homogeneity of variances – that the means of the scores are affected by the independent variable, not the variance; the variances in each treatment populations are equal, $\sigma_1^2 = ... = \sigma_k^2$; however, when the sample sizes (n’s) are equal, ANOVA is robust to this assumption.

The data used in this paper violate the third assumption, homogeneity of variance as determined by the Levene Test of Homogeneity of Variance. The n’s are not equal, so ANOVA is not robust to the violation of this assumption. This means that, for this paper, Type I error levels are not guaranteed. A Type I error is failing to reject a true null hypothesis. This will be discussed in the Limitations of the Design section.

**POST HOC, SCHEFFE AND TUKEY**

Having used ANOVA to determine that F is significant, it is now clear that there are significant differences between at least two of the nine groups. It is not known between which groups the differences may be found.

Scheffe’s Test is most widely used. It permits comparisons of pairs of means and complex combinations of means. It can be applied when the n’s are unequal—which is the case in this study. Scheffe’s Test is also less sensitive to departures from normality and homogeneity of variance assumptions. This data set violates the homogeneity of variance assumption. The test is more conservative than others because the value of a is reduced, so the critical value for determining significance is increased. In Scheffe’s Test the hypotheses tested are:

$H_0: C=0$, where C is the contrast, the assumption is that the contrast is 0

$H_1: C\neq 0$, where C is the contrast, the assumption is that the contrast is not 0

The question is:

- Is the difference between two group means significant?

The results of Scheffe’s Test call for us to retain the null hypothesis.

Because the value of a is reduced in this more conservative test, the critical value for determining significance is increased. Following up with Tukey’s Test produces a different result.

Tukey’s Test works by testing the largest pair-wise difference in the set of J means. The means are ordered by size and the difference compared is the difference between the largest and smallest mean at the .01 alpha level. After a significant range has been encountered with the largest mean, the next largest mean is tested against the smallest mean until there is a point of no significant difference. The q statistic is computed, which represents the minimum difference between means necessary to reject the null hypothesis. The minimum difference is known as the Honest Significant Difference (HSD). This technique is most often preferred and is less conservative than Scheffe’s test. Tukey’s Test is more powerful for comparing pairs of means. Tukey’s should not be used for comparing more than two means.

In Tukey’s Test the hypotheses tested are:

$H_0: C=0$, where C is the contrast, the assumption is that the contrast is 0

$H_1: C\neq 0$, where C is the contrast, the assumption is that the contrast is not 0
The question is:

- Is the difference between two group means significant?

The results of the Tukey's Test show significant differences, in both the Weighted Total and the Weighted Average at the .05 alpha level, between the following pairs of groups: science teachers and English teachers, science teachers and social studies teachers, science teachers and support staff (paraprofessionals) (i.e., groups 1 and 3, 1 and 4, and 1 and 9). Significant differences in the Weighted Average and the Weighted Total were also found between administrators and English teachers, administrators and social studies teachers, and administrators and support staff (i.e., groups 6 and 3, 6 and 4, and 6 and 9).

**LIMITATIONS OF THE DESIGN**

This research design is limited by several factors, including the design of the survey, the conditions under which it was administered, the lack of accountability for objectivity, and other factors that the researcher did not control for by virtue of the number of variables that exist in behavioral research.

This research is based on results from a survey that was created before the data analysis was considered. The researcher did not validate the survey, test the survey for reliability, or test pilot the survey in any systematic way.

The staff members completed the surveys under a variety of conditions. Some may have been rushed, others thoughtful; there is no way to tell. Each staff member was required to fill out a survey before being permitted to use the LCD projectors purchased with the grant money, which ensured 100% return of surveys. The effect of the mandate, however, cannot be measured. Some staff members asked for clarification of some survey items, others did not. There is no way to determine whether staff members perceived the levels of competency in the same or similar ways.

It was brought to my attention by Dr. Carifio that males tend to rate themselves higher than females on self-assessment instruments. If this is true, then the fact that groups are not consistent by gender ratio is a variable that could account for differences not considered in this design. The differences shown to be significant by ANOVA may be due to a reason other than grouping, in this case, gender.

The groups were not randomly assigned and the samples were not randomly drawn from a larger population. The pre-existing groups were of unequal size and all of the groups had n<30.

The Levene’s Test showed the variances in the groups are not equal. This could lead to an increase of Type I error, rejecting a true null hypothesis.

Group 4 was found not to have a normal distribution using the Shapiro-Wilk Test. The results using group 4 data may not be reliable.

Care must be taken when drawing inferences from this data analysis, given the numerous limitations of the design.

**IMPLICATIONS**

The analysis shows that there are significant differences between the Weighted Average and the Weighted Total scores, reported as a result of self-evaluation of technology competency, between some groups within the staff at South High School. This analysis suggests several recommendations, keeping in mind that the goal of the grant was to improve training programs for students, staff, and community:

1. Further analysis of the differences between the groups. It is possible that these differences may be used to group staff members pair-wise, so that group members may assist each other in advancing in particular areas of technology. The differences may also be used to devise new groupings, to streamline professional development into a smaller number of groups during technology training.

2. Study the surveys further to discover trends in particular areas that need to be addressed. There may be a need for training on PowerPoint, LCD projectors, or other areas that can be ascertained by an item analysis.

3. Conduct the survey again and compare the results with the data to determine gain scores.

There are other recommendations waiting to be made after more detailed study of staff competencies at South High School. It is important to note that this paper represents data analysis from only one source of information. It is important to triangulate—or collect data in at least three different ways, such as dialogue, observation, and interviews—to make more meaningful recommendations. This paper offers some preliminary recommendations based on this initial analysis; better recommendations may follow from more stringent data collection and analysis.

**Bibliography**

APPENDIX A

Name _________________________ Date _______________

Position at SHS_____________

CIT Technology Self-Assessment Tool

The Curriculum Innovation Team (CIT) has been charged with collecting some data to track our progress as a staff now that we will be getting training and equipment through the Plan for Social Excellence (PFSE) Grant.

Please check off each skill you are competent in. When you are finished, choose the category that best describes your competence in that particular area of technology based on the checks you have entered and your self-knowledge. Please circle the most appropriate category. You will choose from “Non-User”, “Everyday-User”, “Skilled-User”, and “Power-User”, as listed at the bottom of each page. Please consider yourself a “Non-User” if you really cannot use the equipment independently and “Power-User” if you can help others on the particular equipment any time. If you do not know what a term means you probably do not know how to do it. We (the CIT) will be offering training in the next three years based on staff needs and requests.

We will repeat this exact process at the end of the year for comparison. This information is only for use by the CIT and the results will be included in our report to Mario Pena, director of the Plan for Social Excellence (PFSE, the grant name).

Thank you in advance for your time.

WEB BROWSING

Please check the skills that you have then circle the category that best summarizes your skills.

**Everyday User**

**Phase 1**

- Searching
  - Search Engines
  - Searching Strategies
- Researching via the Internet
  - Evaluating Websites
  - Citing Websites
  - Understanding Copyright Laws
  - Using search engines to identify plagiarized materials
  - Understanding URLs .gov, .edu, .com (Universal Resource Locator)
- Navigation Forward – Back
- Printing
  - Print
  - Print Preview

**Skilled User**

- Book Marks/Favorites
- Setting your Start and Search Pages
- Use the Toolbar Effectively
- Opening Multiple Windows
- Maintenance and Management
  - Deleting cache files
  - Deleting History
  - Deleting Cookies

**Power User**

- Downloading Information
  - Graphics
  - Websites
  - Plug-ins
- Default Settings

Web Browsing—Please circle the category that best describes you

Non-User   Everyday User   Skilled User   Power User
POWER POINT

Please check the skills that you have then circle the category that best summarizes your skills.

Skilled User
- Understanding Toolbars
- Using Templates
- Choosing Page/slide lay out
- Printing Options
  - Slides
  - Notes
- Using Common Tasks
  - New Slide
  - Apply Design
  - Auto Layout
- Inserting
  - Pictures
  - Graphics
  - Text box
  - Sound
  - Movies
  - Charts
  - Tables
- Animating Slides
- Transitioning from slide to slide
- Views
  - Slide
  - Outline
  - Notes
  - Slide Sorter
  - Slide Show
  - Normal
- Running a Slide Show
  - Slide Timing

Power User
- Save to Web
- Inserting a Hyperlink
- Creating a Master Slide
- Creating Speaker Notes
- Note Page

Power Point- Please circle the category that best describes you, since there is no “Everyday User” category listed above, if you have checked some skills you may consider yourself “Everyday User,” you be the judge.

Non-User  Everyday User  Skilled User  Power User

MULTI MEDIA DEVICES

Please check the skills you have for each device. Rate yourself “Non User” to “Power User” dependent on the number of checks you have. Remember “Non User” means you cannot operate the device independently and “Power User” means you could teach others. You be the judge.

Digital Camera

Disc/Basic Camera
- Load
- Zoom
- Click
- Delete
- Save
- Print, Insert to…..

Camera Specific
- Down loading to computer

Non-User  Everyday User  Skilled User  Power User

Scanner
- Acquire Image
- File size DPI 72 (dots per inch)
- Save
- Export to file type
- OCR--optical character recognition

Non-User  Everyday User  Skilled User  Power User

Projector/LCD Panel
- Proper Connection Procedure
- Bulb Care/Shut Down
- Inputs
- On-screen menus

Non-User  Everyday User  Skilled User  Power User

Digital Video Camera
- Batteries/Electrical Connection
- Loading
- Recording/Zoom
- Editing--Toggle
- Viewing
- Connection/Interfacing

Non-User  Everyday User  Skilled User  Power User
General Description of the Educational Doctorate in Mathematics and Science Education at UMass Lowell

Foundations ................... 6 credits
Research Courses ............ 9 credits (minimum)
Core Program Courses ....... 15 credits
Electives ......................... 6 credits (minimum)
Dissertation Research ........ 12 credits (minimum)

Students must pass a comprehensive and a qualifying exam prior to dissertation research.

Who Should Apply?

• K–12 teachers or Higher Education faculty who hold the equivalent of an undergraduate degree in mathematics, science, or engineering, together with a masters in any field.
• Teachers without an undergraduate degree in mathematics, science, or engineering, but who are PALMS specialists or National Board Certified in Science or Mathematics and hold a masters degree in any field.
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Educators, researchers and graduate students are invited to submit papers that will be presented at the Tenth Annual Colloquium on Research in Mathematics and Science Education and published in the Colloquium Journal, vol. IX. The papers must discuss issues and trends in Mathematics and Science Education.

WHEN SUBMITTING A PAPER, PLEASE USE THE FOLLOWING GUIDELINES.

1. Submit an electronic version of the paper and one hard copy, an abstract, approximately 150 words, and a biographical sketch, about 30 words. All pictures and diagrams must be submitted in a separate document.

2. Use double spacing with one-inch margins.

3. For references, diagrams, etc. follow the style described in the Publication Manual of the American Psychological Association (APA), Fourth Edition.

4. Paper length must not exceed 30 pages, including pictures, tables, figures, and list of references.

5. Paper must be received by November 15, 2004.

6. Authors will be notified about the status of their paper by January 15, 2005.

7. A Colloquium will be scheduled for April 2005.

SUBMIT PAPERS AND CORRESPONDENCE TO:

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