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ABSTRACT

A study examined the perceptions of participants in a multidisciplinary project regarding the degree to which the integration of technology, mathematics, and science had enabled advanced mental skills in technical thinking and problem solving. A literature review focused on advanced learning and thinking, ill-structured workplace problems, learning transfer, and activating potential knowledge. The research sample consisted of 148 students participating in multidisciplinary projects at 4 high schools in Colorado, Missouri, Nebraska, and Oklahoma. A four-page questionnaire collected data that were analyzed using multivariate analysis of variance (MANOVA) statistical procedures followed by descriptive discriminant analysis (DDA). Results confirmed the significance of grade level, part-time work experience, and enthusiasm to students' ability to benefit from the multidisciplinary approach. Ill-structured problems proved to be a key aspect of the underlying structure and the separation of groups among the dependent variables. (Appendixes include 29 references and 3 data tables.) (YLB)

# Multivariate and Descriptive Discriminant Analysis of Multidisciplinary Approaches to Integrating Mathematics, Science, and Technology Education in the High School

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Abstract

This study was conducted as part of a federally funded demonstration program. The purpose of the program was to develop four demonstration sites in the mid-west where math, science, and technology education curricula were integrated. A priori, the researchers believed that context-based learning, knowledge and skill transfer, ill-structured problems, working in cooperative teams, and thinking skills were elements critical to a successful multidisciplinary project. This aspect of the research was conducted using survey techniques. The data were analyzed using multivariate analysis of variance (MANOVA) statistical procedures followed by descriptive discriminant analysis (DDA). The results confirm the significance of grade level, part-time work experience, and enthusiasm as independent variables. Ill-structured problems proved to be a key aspect of the underlying structure and the separation of groups among the dependent variables.

Multivariate and Descriptive Discriminant Analysis of Multidisciplinary Approaches to Integrating Mathematics, Science, and Technology Education in the High School

> *Employers today complain that they cannot count on schools and colleges to produce young people who can move easily into more complex kinds of work. They seem to be seeking general skills such as the ability to write and speak effectively, the ability to learn easily on the job, the ability to use quantitative skills needed to apply various tools of production and management, the ability to read complex material and the ability to build and evaluate arguments.* (Resnick, 1987, p. 7)

Reforming American vocational education -- a topic that is once again gaining priority on the national agenda. This time, however, it seems we may be doing more than talking. Rapidly, many states and local school districts are adopting Tech-Prep and other forms of instruction designed to integrate vocational and academic topics. All with the expectation of engendering higher order thinkers and problem-solvers -- vocational education that strives to be consistent with the above quote from Resnick's work. This is music to the ears of many reform minded teacher educators. So, *what's the problem*? While we are implementing new and exciting integrated programs, many so called reform movements lack sufficient consideration of the learning theories that could support the desired higher forms of learning (Schell & Rojewski, 1993).

This exploratory study is the first of an investigative series to validate the need for and to identify a solid learning theory that supports these new cooperative initiatives. (For a more detailed discussion of this research agenda see Schell & Rojewski, 1993). With this study we have conducted a preliminary investigation of students, faculty and administrators participating in a federally funded project designed to demonstrate the integration of academic and vocational curricula. The Mid-American Multidisciplinary Project, as it has become known, provided an opportunity to collect qualitative and quantitative data regarding a variety of learning assumptions that we believe support the integration of multidisciplinary education. In this case, demonstration projects that combined aspects of mathematics, science, and technology education were studied.

Caine & Caine (1991) believe, as we do, that to develop learners/workers who possess flexible mental skills required for the modern workplace, an alternative foundation of learning is needed. This assumption is a cornerstone of this study. Here, we explored the perceptions of student participants regarding the degree that alternative learning theories adopted by demonstration programs enabled higher order thinking and problem solving.

A priori, we believed that the use of alternative learning foundations would encourage learners to use, organize, and make sense of learned information (Berryman, 1991; Caine & Caine, 1991; and Resnick, 1987). Further, we believe that information about these assumptions is critical to the meaningful reformation of vocational and technical education. This is especially true when the expected outcomes include student/workers capable of higher order thinking and problem solving skills on the job.

## Purpose and Objectives of the Study

This exploratory phase of our research sought to ascertain the perceptions of project participants regarding the degree to which the integration of technology, mathematics, and science has enabled advanced mental skills in technical thinking and problem solving. Selected variables were examined to determine possible influences on student perceptions. Specific research objectives included:

1. Description of student participants and their perceptions of dimensions of the Mid-American Multidisciplinary Project.
2. Examine the influences of select demographic variables on student perceptions on subscales of context-based learning, learning transfer, ill-structured problem solving, thinking skills, cooperative work teams, and overall project evaluation.
3. Identification and interpretation of underlying structures of subscales consisting of context-based learning, learning transfer, ill-structured problem solving, thinking skills, cooperative work teams, and overall project evaluation.

### The Multidisciplinary Project and It's Purposes

During the spring of 1990 the United States Department of Education requested all interested parties to submit proposals dedicated to developmental curricular research on the integration of the disciplines of mathematics, science, and technology education. Titled the Technology Education Demonstration Program, this research would develop model demonstration school sites at various locations around the United States. Through a variety of different curriculum approaches this project was seeking ways in which the mathematics, science, and technology education departments within public schools could work together in establishing innovative opportunities for students to learn concepts and activities related to these disciplines.

In keeping with the purposes of the Technology Education Demonstration Program, a proposal titled the "Mid-America Region Technology Education Demonstration Project" was funded. This project had three primary objectives. The first objective was to establish a framework for the theory and application of multidisciplinary and/or interdisciplinary education. Representatives from selected high schools learned the concepts associated with learning and teaching that pertaining to the integration of subject matter. Based on these foundations, teams of high school teachers developed a multidisciplinary/interdisciplinary curricular approach. Plans were implemented in their schools during the 1991-92 school year. The second objective was to select four high schools to serve as demonstration sites for this project (see methods section of this article). The third objective was to evaluate and broadly disseminate results of the project. Dissemination has been accomplished through two national teleconferences designed to present the instruction/learning outcomes of each demonstration site.

About the Demonstration Projects. Selection of school sites focused on small or rural school settings because they were more representative of school districts within the Mid-America region of the country. As a result, field testing of the integrative curriculums could be more broadly generalized if these types of schools served as pilot demonstration sites. The Mid-America region consisted of the following states: Arkansas, Colorado, Iowa, Kansas, Minnesota, Missouri, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, and Wyoming. Identification of high schools was supported by a national teleconference aired February, 1991. This teleconference presented the theory and major components of multidisciplinary and interdisciplinary curriculum design along with information that described the qualifications and application procedures for involvement in this project.

## Related Literature

While recent professional literature in vocational education has extolled the virtues of integrating traditional academic material with vocational content (see Gray, 1991; Wirt, 1991), relatively few authors have provided substantive philosophical and psychological reasons *why* integration of subject matter is a good idea when modernizing occupational education. Upon careful examination of the professional literature on the topic, however, one finds that there are many good reasons to implement and then evaluate these educational reforms.

As we have learned from previous research, theories of advanced learning and thinking, situated learning (context), transfer of learned knowledge, the nature of problems to be solved, and working in cooperative teams are germane to this topic. (For a more complete discussion of these issue see Schell & Hartman, 1992 and Schell and Rojewski, 1993). For the purpose of this manuscript, each topic is only briefly summarized.

### Advanced Learning and Thinking

Spiro, Coulson, Feltovich, and Anderson (1988) have defined advanced learning as an intermediate stage between introduction of new material, but before practiced expertise. In this phase, students learn "what to do" with acquired information. Central to advanced learning is the concept of thinking. Resnick (1987) contends that thinking defies definition within the traditional paradigm of public education. She, however, offers nine key elements that are descriptive of higher-order thinking. To her, characteristics of higher order thinking are *nonalgorithmic*, (meaning the path of action is not specified in advance), *complex* and often yield *multiple* rather than simple solutions. Higher order thinkers must demonstrate *nuanced* judgement, application of *multiple criteria*, live well with *uncertainty*, be *self-regulated*, impose *meaning* from apparent disorder, and demonstrate sufficient *effort* when elaboration and judgment is required (p.3).

Ill-structured Workplace Problems

Berryman (1992) describes an emerging workplace that is dependent on accelerated product and process innovation. Companies must respond to fast changing markets by rapid delivery of products and services. These "quick response" capabilities are critical to successful international competition. Competitive workplaces require advanced learning and thinking on the part of employees at lower and lower organizational levels. These mental skills are particularly important in situations where complex problems must be solved under volatile conditions. Indeed, throughout their lives vocational graduates will encounter a diverse array of work and personal problems that are complex, ambiguous and cannot be solved using the same solutions every time (D'Ignazio, 1990). Spiro and Jehng (1990) refer to these "ill-structured" situations or environments. To solve ill-structured problems, workers and learners must be able to adroitly use, or transfer, information often learned in other settings.

Learning Transfer

For years, educators have assumed that schooling directly enabled transfer to occupational or life settings. Yet, Berryman (1991) aggressively reports otherwise. She maintains that individuals *do not* predictably use knowledge learned in school in everyday practice, nor do they use everyday knowledge in school settings. Perhaps most importantly, learners do not predictably transfer learning across school subjects. Berryman (1991) writes that context "turns out to be critical for understanding and thus for learning. We are back to Caine and Caine's (1991) issue of meaning-making and sense-making. . .*[T]he importance of context lies in the meaning that it gives to learning*" (Berryman, 1991, p. 11). This gives us a sense that context and transfer are highly interrelated topics. Assuming this is true, how can teachers in integrated programs best "activate" knowledge for occupational use?

Wittgenstein (1953) postulated that the meaning of information is determined by its intended use. Bransford and Vye (1989) further believe that "students must have the opportunity to actively use this information themselves and to experience its effects on their own performance" (p. 188). If knowledge has no apparent application, it may not be perceived as meaningful; therefore, not readily transferred to other learning opportunities (Bransford et al., 1990).

Brown, Collins, and Duguid (1989) believe that advanced concepts are learned and progressively developed when thought of as "mental tools" to be used in meaningful activities of a "particular culture." However, these tools can only be fully understood through their use in a particular culture which involves changing the user's "view of the world and adopting the belief systems of the culture in which they [tools] are used" (p. 33). This approach rests on the assumption that there is more to using a tool (*i.e.,* developing an advanced cognitive skill) than mastering of a list of explicit knowledge and rules.

Activating Potential Knowledge. To the extent that schooling is isolated from the community, too many concepts are learned in abstract ways. Theorists such as Berryman (1990), Resnick (1987), and Spiro, et al. (1988) believe that transfer of knowledge is inhibitied by this condition which does little to activate knowledge for later use. Brown et al. (1989) approach this problem by advancing the concept of "authentic activity" which they define as ordinary practices of a given culture. Rather than using the educational syntax of the classroom, they propose using everyday activities as a means of providing contextualized or situated learning. This places learners in a freer and more relevant classroom shaped by a community of practitioners. Perkins and Salomon (1989) concluded that "to the extent that transfer does take place, it is highly specific and must be cued, primed, and guided; it seldom occurs spontaneously" (p. 19).

In summary, the research suggests several specific areas that must be considered by educators who wish to implement multidisciplinary teaching and learning. This is particularly important when the expectation of higher order thinking and problem solving is adopted as it has been in many suggestions for reform of vocational education. We have used these concepts as foundations for our research.

## Methods

This research study consisted of a survey of student perceptions based upon involvement in a multidisciplinary project. In the next few paragraphs we will detail the methods and procedures used to accomplish the research.

### Sample

Four schools were purposively selected from 40 applications received from high schools in the Mid-America Region. Applications were evaluated by three independent reviewers. Criteria for selection included (a) interest and capability of high school faculty and staff, (b) interest and capability of a cooperating teacher educator from the region, and (c) the school's overall capability to complete the project. Ultimately, four projects located in Colorado, Missouri, Nebraska, and Oklahoma were selected.

The research sample for this study consisted of 148 students participating in multidisciplinary projects at the four sites. While a nonprobability, purposive selection method does restrict the generalizability of research findings, this is an appropriate selection alternative where research is designed to generate theory (Babbie, 1986; Frankfort-Nachmias, 1992; Glaser & Strauss, 1967).

At each demonstration site, special multidisciplinary classes combining aspects of mathematics, science and technology education were established. Student were enrolled in these classes based on scheduling availability. Instructional programs at each of the sites were developed integrating different aspects of mathematics, science, and technology education. One project integrated biological sciences with mathematics and technology while another integrated aspects of technology with basic mathematics. Another project developed an integrated course entitled "Introduction to Engineering," while the last project developed consolidated course work around algebra and selected principles of technology. The unifying theme for all of these classes was "hands & minds-on" or learning applied to real world applications.

Because we were not interested in comparing the four schools, the sample for this research included 148 students from four schools. Demographics of the final research sample included 79 (53.4%) males, and 69 (46.6%) females. Seven percent ($\underline{n}=10$) of the sample were in the eighth grade, 17.6% ($\underline{n}=26$) the ninth grade, 12.8% ($\underline{n}=19$) the tenth grade, 35.8% ($\underline{n}=53$) the eleventh grade, and 27.0% ($\underline{n}=40$) had achieved the twelfth grade.

When asked how many years of part time work experience they had 43.2% ($\underline{n}=64$) reported 0 to 1 year, 29.1% ($\underline{n}=43$) had experienced one to two years, 18.9% ($\underline{n}=28$) two to three years, and 8.8% ($\underline{n}=13$) three or more years.

Instrumentation

The instrument used for data collection was a four page questionnaire. The first inside page contained an introduction, definitions of key terms, and six questions about respondent characteristics. Nineteen survey items were placed on the third page in four contiguous columns. For each item the statement "The integrated program has .." preceded individual statements. In the second column, respondents were asked to place a check mark next to one of the following Likert-like stations "highly," "moderately," "somewhat, "marginally" or "not." Each variable statement was completed in the third column. The last page of the instrument was devoted to ascertaining the participant's perceptions of the project's success in causing them to think critically and creatively and making estimates of the overall success of the project.

For the purposes of research and data analysis, survey items where collapsed into subscales of related items. These subscales consisted of items related to: (a) learning context, (b) ill-structured problem situations, (c) transfer of learning, (d) cooperative work teams, (e) thinking skills, and (f) overall project evaluation.

A review of the instrument for face validity was conducted by a panel of experts consisting of professors and graduate students in the Technology Studies program at The University of Georgia (Borg & Gall, 1989; Zikmund, 1986). This review assured that each item and its associated scale logically appears to accurately reflect what it claims to measure (Zikmund, 1986). Questionnaire reliability was obtained through a test-retest procedure. Our equivalent groups consisted of students at a Georgia high school where a similar integrated activity was occurring. The test-retest procedure resulted in a Person Product Moment correlation of .88. In addition, internal scale reliability was determined with a Cronbach alpha reliability coefficient of .85 (Borg & Gall, 1989).

Procedure and Data Analysis

All participants were required to review and sign an informed consent form that is required under the human subjects policies of The University of Georgia. All surveys where administered in class, during the Spring 1992 semester. Upon completion, each survey form was sealed in an envelope and returned to the teacher or administrator responsible for the survey at each demonstration site. Envelopes were not opened until responses were coded for computer analysis.

A combination of descriptive and inferential statistics were used to address research objectives. Multivariate analysis of variance (MANOVA) was used to examine differences among student perceptions as they relate to the second research objective. The results of this research were obtained using SPSSPC™.

## Results

Overall Description of Student's Perceptions.

Table 1 displays the means and standard deviations for each item statement included on the survey questionnaire.

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Insert Table 1 about here.

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Student perceptions of multidisciplinary projects. Overall means for the 19 perception items range from a high of 4.05 for item 3 to 2.83 for item 12 ( 5 = highly enabled; 1 = not enabled). Students held a strong perception that the multidisciplinary demonstration project enabled them to better understand the integrative relationship among mathematics, science, and technology subjects. The item with the lowest mean suggests that teachers in the multi-disciplinary projects are not maximizing their opportunities to have deep class discussions about how mathematics, science, and technology are linked.

Student enthusiasum. While 52% ($n = 77$) indicated "yes" they would take and/or recommend this course, 16.2% ($n = 24$) denoted that they would not take or recommend, and

30.4% (n=45) suggested that they "don't know." When asked if students would recommend an integrated course to their friends 56.8% (n=84) responded "yes",18.2% (n=27) said "no", and 23.6% (n=35) indicated "I don't know."

Table 2 presents the grouped means and standard deviations of the subscales describing major factors evaluated in this study.

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Insert Table 2 about here.

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Examination of response patterns to the individual scale items revealed several interesting differences. On dimensions of number of years part-time work experience, students with highest levels of work experience were consistently more positive about the program than those with less. In a related finding, student respondents in the eleventh and twelfth grades were more likely to view the program more positively than did those learners in grades nine and ten. Lastly, those students more enthusiastic about the multidisciplinary project (those who would take the course again and/or those who would recommend the program to their friends) consistently valued the program more than those who were less enthusiastic.

Influences of Selected Demographic Variables on Student Perceptions.

Multivariate analysis of variance (MANOVA) was used to investigate the influences of selected demographic variables. MANOVA is an inferential statistical procedure used to test simultaneously differences among groups on multiple dependent variables while controlling for Type I error (Haase & Ellis, 1987; Pedhauzer, 1982). An a priori alpha level of .05 was set.

A post hoc descriptive discriminant analysis (DDA) was used as a follow-up on significant MANOVA results (Huberty & Wisenbaker, 1991). When used as a follow-up, DDA affords three procedural advantages. First, to examine the nature of the significant differences. Second, to control for experimentwise error common to analysis where multiple dependent variables are used. And three, to consider high interscale correlations (Bray & Maxwell, 1982; Chartrand & Camp, 1991; Haase & Ellis, 1987).

Three separate MANOVA tests were performed to ascertain potential differences based on the independent variables of gender, grade level achieved, part-time work experience, and enthusiasm for the multidisciplinary project. The dependent variables were composed of subscales with themes of context-based learning, ill-structured problems, knowledge transfer, work teams, thinking skills and overall project evaluation (see Table 2).

MANOVA results revealed the existence of several group differences. However, there were no significant differences between males and females on any of the multidisciplinary subscales,

$H^2(1,101) = .092$, *n.s.* Because no significance was found, no DDA follow-up analysis was conducted.

Further analysis revealed that students with more part-time work experience perceived involvement in the multidisciplinary project significantly differently than did those with less part-time experience, $\Lambda(3,99) = .744$, $p < .05$. Mean scores for those with two or more years part-time work experiences were consistently higher than those with zero to one year part-time experience. Other significant differences were observed among students who had achieved higher grade levels, $\Lambda(3,96) = .732$, $p < .05$. Means for students enthusiastic about multidisciplinary programs were significantly different than those less enthusiastic colleagues, $\Lambda(2,98) = .589$, $p < .05$. As stated earlier, enthusiastic students were defined as those who would take this multidisciplinary course again and would recommend it to their friends.

Identification and interpretation of Underlying Constructs

Separate DDAs were conducted for each significant MANOVA (high grade attained, part-time work experience, and enthusiasm). This procedure afforded an examination of the outcome variables that make up an underlying structure of each subscale. Additionally, when overall group differences are considered, the relative contribution of outcome variables to group separation can be observed (Huberty & Wisenbaker, 1991).

In DDA, all multidisciplinary subscales are considered simultaneously, thus allowing the full range of variable relationships to be considered. This results in a better accounting of the complexity of the multidisciplinary learning environment and the richness of the research data (Huberty & Wisenbaker, 1991). Table 3 presents the statistical results of these analyses.

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Insert Table 3 about here.

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When grade level is considered, a plot of the canonical discriminant functions suggest that 9th grade participants are differentiated from 10th, 11th, 12th grade participants. Examining the within-groups structure coefficients, the underlying structure for this function is ill-structuredness (see Table 3). This means that 9th grade participants perceived themselves to be more enabled by the integrated program to solve problems with more than one possible answer. For the purpose of identifying overall group differences, an examination of the F-to-remove values (see Table 3) shows that ill-structuredness followed by context-based learning, and working in cooperative teams are most likely to account for the separation of the 9th grade level from the higher grade groups.

When part-time work experience is considered, a plot of the canonical discriminant functions suggest that on the first function (which we will call situated learning), students with 1 to 2 years part-time work experience is differentiated from those with none to 1 year, 2 to 3 years, and 3 or more years. In general, workers with one to two years work experience has *lower* means than those with less and those with more part-time experience. Examining the within-groups structure coefficients, the underlying structure for this function is a combination of ill-structuredness, context, and transfer (see Table 3). This means that student/workers with 1 to 2 years part time work experiences perceived themselves to be *less enabled* to solve problems with more than one possible correct answer, to see the connection between learned information and realistic work situations, and then use that information in other situations when solving problems. For the purpose of identifying overall group separation, an examination of the F-to-remove values (see Table 3) shows that ill-structuredness followed by working in cooperative teams, overall project evaluation, and transfer are most likely to account for the separation of the groups.

When enthusiasm for the project is considered, a plot of the main canonical discriminant function (that we will call "participant ambiguity"), suggests that the "I don't know" group is differentiated from the "would take/recommend this class" group, and the "would not take/recommend this class" group. Examining the within-groups structure coefficients, for the ambiguity function, the underlying structure is a combination of thinking skills, working in cooperative teams, transfer learning, and overall project evaluation. (see Table 3). This means that student participants who are ambiguous in their support for the integrated project were *less enabled* on dimensions of thinking, team work, and learning transfer than were those who would and would not participate again. For the purpose of identifying overall group differences, an examination of the F-to-remove values (see Table 3) shows that ill-structuredness followed by thinking skills, learning transfer, and working in cooperative teams are most likely to account for the separation of the groups.

Although further analysis using DDA is possible, we believe that because our study is exploring relatively new ground, we should be content with an analysis of group separation. In subsequent studies, where more grounded theory can be applied, an analysis of group contrasts would be more appropriate while providing interesting insights into the nature of students participating in multidisciplinary vocational programs.

## Discussion

We begin this section by reminding the reader of the inherent limitations of this research that must be considered when interpreting these findings. Specifically, the use of self-reporting measures and the absence of random selection restrict the degree to which these results can be generalized to all students participating in integrated vocational and academic courses. Further, Huberty and Wisenbaker (1991), caution against over-generalizing beyond the data when ordering overall group differences using DDA.

When thought of as an exploratory research activity, however, these results do provide interesting insight into the perceptions of students participating in real integrated academic and technical programs. Further, this study does establish a base of information while providing a direction for further research. Also, this study provides practical information when planning a multidisciplinary program where advanced thinking and problem solving is an expected outcome. Those inferences are detailed in the following paragraphs.

Grade Level

At first, we found it confusing that ninth graders were more enabled by the multidisciplinary project than students in grades 10, 11, and 12. Upon further analysis, it was discovered that almost all ninth graders considered in the DDA ($n=14$) were from the Colorado project's Introduction to Engineering class. The underlying structure for this finding was ill-structuredness and the groups were separated on the context-based learning, and working in cooperative team constructs.

The Introduction to Engineering class, required 9th grade students (and other participating students) to routinely solve problems where more than one correct answer is possible. Curriculum objectives for this class included: (a) Interpretation of mathematics and science principles, (b) application of technology to solve for natural and man-made problems, (c) synthesize mathematics, science, and technological techniques to aid in problem resolution, and (d) evaluation of engineering solutions for appropriateness. All of these objectives are targeted on the solution of context-based ill-structured problems. We believe that these results provide additional support to the flexible cognition work of Spiro et al. (1988) which is based on the resolution of ill-structured and complex problems.

On a wider scale, this finding suggests that younger students can appreciate the more relative side of the world of science, mathematics and technology. From this more analogous position, learners may be capable of more flexible thinking and problem-solving abilities (Spiro & Jehng, 1990). We concur with their belief that the learner's ability to solve ill-structured problems is a critically important element in a successful multidisciplinary curriculum.

Part-time Work Experience

Part-time work experience when directly associated with learning expectations may contribute to student learning in a multidisciplinary project where the expectation is higher order thinking and problem solving. Generally, in our study, the more part-time work experience, the higher the mean score was on the subscales. (Some exceptions exist, see Table 2). It was not surprising that the underlying structure for the primary differences on part-time work experience was once again ill-structuredness, combined with learning context and transfer of learning. Many researchers believe that work experiences allow student/learners to place learned information into an occupational context thus extending its meaningfulness and usefulness. To the extent that work experience is coordinated with classroom activities, learner/workers are afforded an opportunity to associate their learning with their real world work experiences. This finding is consistent with the research that suggests context and transfer are tightly interrelated and is quite important to activating acquired knowledge (Berryman, 1990; 1992; Bransford, Sherwood, Hasselbring, Kinzer, & Williams, 1990; and Resnick, 1987 and many others). The finding that students with 1 to 2 years part-time experience reported lower means may suggest a window of opportunity for schools to address this problem. Is it possible that students with 0 to 1 year of work experience do not have a complete picture of the work world? Can the lower means of those within their first year of experience be explained by a on-the-job learning curve? Are the higher means of those with greater than two years work experience explained by learner/workers who are seeing the real world application of school information?

If so, then these years of part-time work experience should be more carefully matched with a formalized multidisciplinary curriculum. Actually, we would prefer that all educational experiences be matched with a real world experience (Resnick, 1990). Here, we are _not_ talking about work that is performed simply to support the entertainment habits (*i.e.* cars, cd's, dates, etc). of high school aged part-time workers. Rather, a formal program of education that associates learning with school supervised work programs (Lynch, Price, & Burrow, in press). One way of accomplishing this objective is through the use of apprenticeships as suggested by Bottoms, Presson, and Johnson (1992). Another, yet related approach is the use of cognitive apprenticeships. In this approach, the classroom teaching expert provides "authentic activities" where instruction relies on and interacts more directly with the context and culture of the workplace (Brown, et al., 1989; Resnick, 1990).

The important point of this finding is that from the learner's perspective work experience seems to have a positive influence on participants in multidisiplinary programs. We might further hypothesize that part-time work experience allows learners the opportunity to solve real, but ill-structured problems, adding relevance through real applications (context), and meaningful opportunities to use acquired knowledge (transfer).

<u>Enthusiasm for the Project</u>

It appears that there are some common characteristics unique to those more excited participants. Those students who "would" take and/or recommend their project and those who "would not" take and/or recommend their project are differentiated by those who "don't know."

Fifty-three percent of the student participants stated that they would take and/or recommend this course, while 16.3% would not, and 30.4% did not know. Group separation appears to be best identified by thinking skills, working as a cooperative team, learning transfer, and overall project evaluation. Generally, the means on all subscales for those who "would take or recommend" the approach are much higher than those who "would not" and those who "don't know."

Student enthusiasm is important. It may be the link that provides the connection between meaning and the eventual use of knowledge. Caine and Caine (1991) state that teaching and learning that engages the brain's limbic system is more likely to be associated with emotions and thus more likely to be valued. It is valued information that gets used or transferred (Bransford, et al., 1990).

There are many possible issues that might influence student enthusiasm for multidisciplinary projects. These range from the sociology of the learning place (Brown et al., 1989) to issues of personal or career maturity (Crites, 1978). From this research, little inference can be drawn that sheds new light on this complex subject. However, we might verify other research that suggests that student enthusiasm is important to successful multidisiciplinary programs (Caine & Caine, 1991). Further, this and other evidence strongly suggests that enthusiasm is also important to the ultimate use of acquired information.

## Summary

This study coincides with previous findings regarding the importance of context and knowledge transfer in the development of programs of integrated content. Further, this research illustrates the importance of integrating ill-structured learning expectations and activities into these programs.

As an exploratory study, these findings shape the direction of our future research. Obviously, the solution of ill-structured problems formulated substantative parts of the underlying structure of many of the dependent variables of this study. In the future, we will be conducting more directed research on the role of ill-structured problem situations in multidisiplinary projects. Much of this research will center on the theoretical underpinnings of flexible cognition theories as posited by Spiro, et al. (1988). (For a more complete discussion of an application of flexible cognition theory in technology-based vocational settings see Schell & Hartman, 1992).

A second issue that plays at the edge of this research is that of human development. An underlying concern are questions like "How are student's ability to solve complex problems governed by developmental processes?" For example, how and why do those with more work experience benefit from multidisiciplinary projects? Is it because of their additional career maturity? If so, how should programs be shaped to maximize these differences? These are the types of questions that will guide future research.

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Table 1.

Students' Perceptions Toward Multidisciplinary Projects

| Rank Order | Item No | Item Statement | M | SD |
|---|---|---|---|---|
| | | The integrated program has... | | |
| 1 | 3 | ... enabled me to better understand that math, science, and technology are highly related. | 4.05 | .92 |
| 2 | 8 | ... enabled me to value the worth of continuing to learn after high school graduation. | 3.99 | 1.11 |
| 3 | 4 | ... enabled me to take more responsibility for my own leaning. | 3.99 | 1.10 |
| 4 | 19 | Overall, how successful is your integrated program? | 3.78 | .96 |
| 5 | 4 | ... enabled me to value the worth of math, science, and technology in today's society. | 3.74 | 1.08 |
| 6 | 15 | ... enabled my math, science, and technology teachers to work well together as a team. | 3.72 | 1.21 |
| 7 | 18 | As a result of the integrated program how likely are you to use principles of math, science and technology to solve everyday problems? | 3.59 | 1.02 |
| 8 | 2 | ... enabled me to better understand science because it was applied to the world outside of school. | 3.52 | 1.57 |
| 9 | 5 | ... enabled me to use math, science, and technology to solve problems where more than one answer is likely. | 3.51 | 1.09 |
| 10 | 16 | ... causing you to think critically about math, science, and technology? | 3.48 | .98 |
| 11 | 17 | ... causing you to think creatively about match, science, and technology? | 3.48 | 1.07 |
| 12 | 6 | ... enabled me to learn in a setting similar to the world outside of school. | 3.44 | 1.18 |
| 13 | 10 | ... enabled me to analyze a difficult technical problem using math and science facts. | 3.36 | 1.25 |
| 14 | 7 | ... enabled me to work as a member of a technical team. | 3.35 | 1.39 |
| 15 | 9 | ... enabled me to use my creativity combined with math and science facts to solve technical problems. | 3.35 | 1.21 |
| 16 | 11 | ... enabled me to consider technical occupations as a future option. | 3.28 | 1.37 |
| 17 | 1 | ...enabled me to better understand math because it was applied to the world outside of school. | 3.17 | 1.16 |
| 18 | 13 | ... enabled me to feel relaxed enough to ask questions that challenge present knowledge of math, science, and technology. | 3.12 | 1.30 |
| 19 | 12 | ... enabled deep class discussions about the links among math, science and technology. | 2.83 | 1.26 |

Scoring Scale: 5 = highly; 4 = moderately; 3 = somewhat; 2 = marginally; 1 = not

Table 2.

Means and Standard Deviations on Multidisciplinary Subscales by Select Student Characteristics

| | | Multidisciplinary Subscales and Associated Survey Items | | | | | |
|---|---|---|---|---|---|---|---|
| Factors | | Context 1, 2, 3, 4, 6 | Ill-Structure 5 | Transfer 8, 9, 10, 18 | Work Teams 7, 15 | Thinking Skills 12, 13, 14, 16, 17 | Overall Project Evaluation 11, 19 |
| Gender | | | | | | | |
| Males | *M* | 8.90 | 3.75 | 15.04 | 7.30 | 18.00 | 7.79 |
| | SD | (3.41) | (.99) | (2.98) | (1.88) | (3.40) | (1.50) |
| Females | *M* | 18.44 | 3.65 | 14.65 | 7.52 | 17.71 | 7.02 |
| | SD | (3.03) | (.90) | (3.37) | (1.61) | (4.24) | (1.89) |
| Part-time Work Experience | | | | | | | |
| 0 to 1 yr | *M* | 18.42 | 3.67 | 14.87 | 7.07 | 17.10 | 7.05 |
| | SD | (2.88) | (.89) | (3.29) | (1.56) | (3.89) | (1.69) |
| 1 to 2 yrs | *M* | 17.78 | 3.36 | 13.90 | 7.51 | 18.09 | 7.36 |
| | SD | (3.98) | (1.08) | (3.40) | (1.86) | (3.99) | (1.88) |
| 2 to 3 yrs | *M* | 20.11 | 4.00 | 15.89 | 7.28 | 18.61 | 8.22 |
| | SD | (2.65) | (.69) | (2.25) | (2.05) | (3.48) | (1.44) |
| 3 or more | *M* | 19.91 | 4.33 | 15.92 | 8.33 | 18.75 | 7.83 |
| yrs | SD | (1.78) | (.65) | (2.47) | (1.50) | (3.17) | (1.40) |
| Grade Level | | | | | | | |
| 9th | *M* | 18.71 | 4.28 | 15.64 | 7.64 | 17.71 | 7.79 |
| | SD | (3.89) | (.61) | (3.34) | (1.44) | (3.93) | (1.58) |
| 10th | *M* | 18.07 | 3.21 | 14.35 | 7.00 | 17.64 | 7.21 |
| | SD | (2.59) | (.89) | (3.52) | (1.92) | (3.37) | (1.67) |
| 11th | *M* | 19.28 | 3.89 | 15.38 | 7.20 | 17.84 | 7.28 |
| | SD | (3.28) | (.82) | (2.50) | (1.85) | (3.78) | (1.82) |
| 12th | *M* | 18.54 | 3.54 | 14.48 | 7.81 | 18.69 | 7.67 |
| | SD | (3.57) | (1.00) | (3.43) | (1.76) | (3.41) | (1.73) |
| Enthusiasm. | | | | | | | |
| Yes | *M* | 19.51 | 3.77 | 15.84 | 8.05 | 19.63 | 7.96 |
| | SD | (2.97) | (.89) | (2.75) | (1.49) | (2.98) | (1.55) |
| No | *M* | 17.71 | 3.84 | 13.45 | 6.84 | 16.03 | 6.90 |
| | SD | (3.62) | (.90) | (3.00) | (1.90) | (3.63) | (1.60) |
| I Don't | *M* | 17.86 | 3.29 | 14.21 | 6.21 | 15.00 | 6.71 |
| know | SD | (2.74) | (1.20) | (3.40) | (1.42) | (3.82) | (2.05) |

Table 3.

Results of Descriptive Discriminant Analysis for Selected Student Characteristics and Multidisciplinary Subscales

| | High Grade Achieved | | Part-Time Work Experience | | Program Enthusiasm | |
|---|---|---|---|---|---|---|
| Multi-disciplinary Subscales | Within-Group Structure Coefficients | F-to-Remove Values | Within-Group Structure Coefficients | F-to-Remove Values | Within-Group Structure Coefficients | F-to-Remove Values |
| Context | .188 | 1.3899 | .634 | .46089 | .399 | .13449 |
| Ill-structuredness | .765 | 4.5429 | .766 | 1.7769 | .069 | 6.9435 |
| Transfer | .349 | .88842 | .602 | 1.0418 | .529 | 3.4278 |
| Work Teams | -.063 | 1.2502 | .006 | 1.7410 | .616 | 2.3626 |
| Thinking Skills | -.156 | .70154 | .062 | .72359 | .842 | 5.5957 |
| Overall Project Evaluation | .015 | .96971 | .307 | 1.0628 | .486 | .47290E-01 |