

2007

The effect of optional real world application projects on mathematics achievement among undergraduate students

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The Effect of Optional Real World Application Projects on
Mathematics Achievement Among Undergraduate Students

by

David Milligan

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
Department of Adult, Career, and Higher Education
College of Education
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Date of Approval:
March 19, 2007

Keywords: Project learning, Time on task, Course satisfaction,
Curriculum development, Experiential learning;

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Dedication

This work is dedicated to the many unsung educators who humbly serve to perpetuate human values. Instructors across all levels of academia should be heralded for embracing their socially pervasive roles. The greatest dedication goes out to those instructors who are open to new ways of teaching.

Acknowledgments

Special appreciation goes out to my Major Professor, Dr. Jan Ignash; the distinguished members of my committee, Drs. James Eison, James White, and William Young; and to Dr. Helen Gerretson who served as Chairperson of Defense. I thank Dr. Arcadii Grinshpan for the support he provided in conducting the present research, and Dr. Marcus McWaters, Chair of the Department Mathematics and Statistics, for his support of the Project Option.

I have particular fondness for the kind individuals who read the manuscript and offered guidance. Most notably, Dr. Ignash graciously provided many necessary changes to earlier versions of this work in addition to directing the overall dissertation process. My mother, Erika Milligan, and my aunt, Helene Ladenheim, kindly offered editorial direction on the manuscript, as well. The friendly folks with Classroom Support Services who graciously made needed equipment available to me, the helpful group at CORE, and the great staff of the USF Library who went the extra mile to obtain certain journal articles on my behalf are certainly thanked as well.

Many individuals, too many to note separately here, have offered me support in various ways in my dissertation endeavor. You know who you are. Thank you all. I would also like to thank the kind members of our dissertation group who so willingly shared their experiences and resources. You're a great group. Good luck to you all.

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The Effect of Optional Real World Application Projects on Mathematics Achievement Among Undergraduate Students

David Milligan

ABSTRACT

Many undergraduate students enrolled in institutions of higher learning wish to connect their learning to real life experiences. By linking reality to academics, students see first hand the practical value in their studies. The purpose of this study was to critically analyze the practice of application projects in undergraduate mathematics courses to determine if, and if so how, students benefit from optional real world application projects. The study was limited to specific courses within a non-math major's undergraduate mathematics program of study at one large research university.

Until the appearance of "The Mathematics Umbrella: Modeling and Education" (Grinshpan, 2005), no research was available dealing directly with mathematically focused application projects, so this study is purposeful. A review of related literature suggests that projects provide a desirable method of learning. This researcher adopted the educational philosophy of pragmatism established by James, Dewey, Chickering and Gamson, and others. Pragmatism—doing what works—is appropriate to undergraduate mathematics education.

Quantitative and qualitative phases were performed sequentially on two distinct, but related, populations of undergraduate non-mathematics major

students taking calculus courses. The first phase assessed whether completion of optional real world application projects was related to mathematics students' test grades. The second qualitative phase used individual interviews to capture students' opinions as to the value and desirability of the project process.

The overall goal of the research was to gauge the beneficial aspects of application projects. One strong finding concerned the relationship that may exist between application projects and students' levels of time on task. Project students reported greater time on task than non-project students, and increasing time on task may enhance the quality of students' learning experiences.

The numbers of reported incidences of feelings of course satisfaction and of increased positive perception toward mathematics were largely consistent between groups, with somewhat greater numbers within the project group. Pedagogical implications from this study point to the value of both faculty and student effort devoted to application projects in increased student understanding of, and appreciation for, mathematics.

Chapter One

Introduction

Undergraduate students enrolled in institutions of higher learning usually wish to connect their learning experiences with real life activities. Without such opportunities for linking reality with academics the student may find that some theories seem to be arbitrary and poorly founded. When reality and academics are linked, however, students may become personally connected to what they are learning so that the theories are clarified through actual applications. This is especially true with mathematics. Linking learning to the real world provides undergraduate non-math majors with a more valuable learning experience than that available through the more traditional passive learning approach (Grinshpan, 2005). The context of this study focuses on the non-math major undergraduate mathematics curriculum and an alternative teaching approach.

Instructors can allow undergraduate students to better connect their learning with the real world by involving them in service to the community, meaningfully integrating this service into their coursework, and providing evaluation for their overall efforts. In a non-math major undergraduate mathematics curriculum, this process largely describes what is referred to as *optional real world application projects*, *application projects*, or when it is clear from the context, simply *projects*. Application projects are similar to educational

methods referred to as “service-learning” or “project learning.” However, it appears that application projects cannot be equated with either service-learning or project learning. Application projects cannot be equated to service-learning because application projects are not restricted to the “extra institutional” community, but rather allow and encourage project work that involves other academic fields as well as direct community service. Application projects cannot be equated with project learning either, since application projects allow for voluntary student participation and these projects are mathematically aligned and generally more extensive than those projects often encountered in project learning scenarios. An important fact with regard to academically linked application projects should be noted immediately, namely, community connections are also formed in the performance of most academically focused project work. An application project supervised by a geology professor, for example, might consider the dynamics of groundwater, and such a project would necessarily be linked to the community by virtue of the importance of maintaining an adequate and healthy supply of water. The inclusion of academically linked application projects along with those that involve the extra-institutional community, appears to deviate from efforts normally placed into the category of service-learning programs. The point is that academically supported application projects surely, but perhaps more subtly, contain elements having “civic value” as do extra-institutionally supported projects that conform more fully to service-learning.

Generally, programs that are deemed “project learning” are often classroom exercises that in some way simulate real world experience. Since application projects require activities strictly outside the classroom environment, it would be confusing to adopt “project learning” as an appropriate descriptor for application projects. Furthermore, application projects are currently performed in undergraduate mathematics courses and the “application” specifically involves mathematics. Service-learning and project learning programs do not distinguish their allowable projects mathematically as the application project program does. The mathematical distinction of the application project program makes it reasonable to devise a unique phrase for describing the program being considered in the current study. Since their inception in 1999, application projects have been called “Mathematics - Business/Science Projects.” This writer feels that the phrase “Mathematics - Business/Science Projects,” while explicit in its reference to mathematics, is less ambiguous than the *optional real world application projects* phrase. For one thing, the latter phrase lends itself easily to the reduced form *application projects*, which contains the important “*application*” aspect. The former phrase lacks this appealing reduced form and fails to suggest what the nature of a student project might be.

The definition Barbara Jacoby and her associates chose to describe service-learning is one amenable to the definition of application projects; namely “. . . experiential education in which students engage in activities that address human and community needs together with structured opportunities intentionally

designed to promote student learning and development” (1996, p.5). This definition includes the “human” element that is important to application projects and seems to transcend the “external community” and more openly, and appropriately, relates projects to the institutions and to the application project participants. Clearly, the “real world” includes the schools and their students.

At this point it may be of interest to delve a bit deeper into the matter of “reality.” While there seems to be valid reasons to accept the philosophical doctrine of post-modernism which asserts that each individual constructs their own reality, there remains a need for individuals to assimilate shared realities that describe our culture and our shared beliefs. This restriction is necessary in order for citizens to effectively participate and contribute to society at large. Since “real” is explicitly included in the phrase “real world application projects,” something should be said about what “real” is meant to imply. It is absurd to merely state the “real” in “real world application projects” is whatever the student wishes it to be and extends to any conceivable state of imagination. Here a compromise is invoked whereby reality has some conceptual malleability, but also conforms to a shared sense of a situation. With real world application projects, a shared sense of reality is expected from the project student and her or his project supervisor. The “reality” must also be able to be sufficiently described so that the project instructor may adequately evaluate the individual project environments. This issue of a shared reality is meant to allow for projects that might appear to be largely intangible and “unreal.” This is in agreement with the

common use of mathematical models to describe the world. To be useful, a model must have some real world authenticity.

Many student projects have historically involved modeling. The “real” example involving transgenic mice, to be more fully discussed later, relies on the ability to model mouse reproduction. It is understood that the model substitutes for physical reality. The expanded sense of reality being adopted here allows students to consider reality simulation in their project work. Students might go as far as to involve the concept of games and gaming and virtual reality. Gredler explains that “. . . [d]eep structure is reflected in the nature of the interactions between the learner and the major tasks in the [student-initiated] exercise . . .” (2004, p. 572). The key is to have students actively learn, and games and simulations can certainly provide requisite student activity.

Projects can also involve the concept of systems inquiry. In a larger sense everything is part of a human system and consequently involves human problems. Education is itself a part of a human system, so the educational function of application projects is naturally subsumed under the human systems banner. Banathy and Jenlink emphasize the importance of “. . . reflection on the sources of knowledge, social practice, community, and interest in and commitment to ideas, especially the moral idea, affectivity, and faith” (2004, p. 45). Our concept of reality thus includes some rather subjective, “ideological” notions. This expanded reality is precisely what makes learning vital. If it can effectively be integrated into mathematics education, then the discipline is

energized by the infusion of societal issues. One might consider this a kind of “humanizing” of mathematics that appears to benefit all parties involved with the project learning experience.

Intimately connected to application projects is the promotion of students’ time on task (Chapman, 2003). There is no assertion that the duration of time on task is as important as the “quality” of the task. Also, a meta-analysis compiled by Susan Paik reveals that “[a]mong developed countries, the United States has the fewest school days . . . [and] U.S. students also spend less time, on average, doing homework” (2003, p. 83). The key, almost obvious, insight from time on task is that when students spend more time in their studies, they are generally more successful in achieving their course objectives. As Paik concludes, “[s]tudents who are focused and actively engaged make more progress toward their goals” (2003, p. 83). Since project students construct their own learning environments, their engagement is guaranteed.

There are several extensive studies (e.g., NCES, 1997) that confirm the importance of time on task. At the collegiate level this concept often remains unspoken. It should be clear to undergraduate students that they must devote a good deal of their time outside the classroom to relevant course study in order to get more from any particular course. This is especially true in mathematics courses where a “rule-of-thumb” for the amount of time a student might expect to spend doing homework is two hours for every one in-class hour. This might mean spending two hours per day on homework, and this is a pace that most students

would find difficult to maintain. Because students may find their project work to be personally meaningful, they may be willing to spend more time doing “homework” than they might have had they had not elected the project option. Given that application projects increase students’ time on task, it is reasonable to assert that, if application projects are in no way harmful to either project or non-project students, then the potential benefits from increased time on task in itself justifies the application project approach.

Also of importance to the application projects program is the interdisciplinary value of the general education components that application projects often include. Application projects conform to the experiences appropriate for a liberal education; namely, these experiences include manipulating numbers, literacy, and critical thinking (Stark & Lattuca, 2002, p. 93). These authors also describe the continuing debates being waged over the value of liberal education as compared to the value of vocational or specialized education. Through a broader, more liberal presentation of material, application projects often address both the general notion of “. . . understanding and improving society” and the more utilitarian mission to “. . . train citizens to participate in the nation’s economic and commercial life” (p. 70). Most application projects also have some service value. This reconciliation of liberal and vocational (or practical) education, made possible with an application project approach, is demonstrated whenever learners make connections between basic course content and the real world. The direct student application of a pertinent

mathematical concept explicitly to a real world situation appears to be a very powerful learning device. Connected with this “personal” student involvement is the notion that students will undoubtedly attach greater value to the concepts they are learning when they can use these concepts in their own externally valued efforts. If indeed the appreciation of his or her work by others leads to increased time on task, a student’s likelihood of success with the associated course objectives is also expected to increase.

In the extensive longitudinal study of fourth-, eighth-, and twelfth-grade students across the United States conducted by the National Center for Education Statistics (NCES, 2000), certain results suggest that educators can be optimistic that improvements are being made in pre-collegiate mathematics education. However, there are other data that seem to indicate that our strengthening of mathematics education in some areas is sadly negated by a weakening in other areas. In particular, the study finds that “. . . while the percentage of fourth-grade students who agreed that math was useful for solving everyday problems increased from 63 percent in 1990 to 71 percent in 2000, the percentage of twelfth-grade students . . . decreased from 73 percent in 1990 to 61 percent in 2000” (NCES, 2000, p. 178). These percentages seem to suggest that, in this case, over the course of eight or ten years, some of our seniors in high school have concluded that math is *not* “useful for solving everyday problems,” contrary to how they felt in elementary school. This implication of “maturing disillusionment” for the usefulness of math is rather unsettling, and

perhaps part of the reason why this could happen is that students begin working with mathematical concepts that become increasingly abstract as they move into higher levels of secondary education. Perhaps students aren't being provided with the opportunity to make the "math to real world" connections in high school that they were able to make when they were younger (and presumably not wiser).

The previous supposition concerning a misconception that mathematics is useless is clearly harmful to the undergraduate. In order to learn about the pervasiveness of the "useless math" misconception, some of the interview questions in the present study explores whether undergraduates feel that mathematics is useful to them. There may be relatively large numbers of students who merely accept that math is included in their curricula as a kind of "discipline" measure and that the connections do not exist.

As mentioned, application projects offer students an opportunity to study a real world condition or problem in greater depth and to apply the concepts of mathematics to their work. Since there are no restrictions on project topics, except that they be "mathematically" connected to the real world, students can venture deeper and more intimately into their chosen topics. The result of intimate pursuits stimulated by academically rooted project work is that students can participate in ". . . the production of new knowledge" (Stark & Lattuca, 2002, p. 70). This link to undergraduate research is very important, especially for a research university such as the one involved in the application projects program

featured in this study. As mentioned earlier, academically rooted project work usually branches out beyond the academy, but beside this “civic bridge” is the liberal concept that research has benefits for its own sake. Certainly new knowledge may itself be valuable and lend prestige to the student, supervisor, and instructor involved in the research, but the new knowledge can lend prestige to the institution as well. Moreover, observing potential research development rounds out the basic institutional missions that have crystallized over the generations of higher education in the United States (Stark & Lattuca, 2002). In summary, project work supports number use, literacy, and critical thinking that are important to a liberal education, but might also stimulate undergraduate research. Furthermore, the constructivists’ idea of “personalized understanding” appears to be another issue coincident with project work.

Application projects rely on the constructivist perspective of learning. The concept of constructivism is that “. . . we each construct our own understanding of the large bodies of organized public knowledge that the disciplines represent” (Donald, 2002, p. 4). It is understood that undergraduate students are largely responsible for much of their own educational experiences. As adult learners, the academic success of undergraduate students hinges on their motivation to learn and their reasons for seeking higher learning. Donald (2002) describes how students are motivated to learn both intrinsically (“to learn for the sake of learning”) and extrinsically (“to attain an external goal”) (p. 5). Most students taking mathematics courses are fulfilling a liberal arts requirement while majoring

in a non-mathematics discipline such as business, biology, geology, engineering, or chemistry. Through constructivism it is natural to assert that each student views his or her educational experiences a bit differently. Application projects may allow students to learn in a constructivist manner befitting a liberal education.

Another issue is that throughout academia students are becoming more “career savvy.” Astin’s (1998) study, which considered the trend in American higher education over the last third of the twentieth century, revealed a move toward learning motivated by career goals. If Astin is correct in the implications of his study, extrinsic motivation largely drives student populations (including the population for this study) to learn. Application projects have the further advantage of allowing for vocationally targeted projects should this be what the student desires. An even greater advantage is that there is a choice for the student. Not only can a student choose what direction to take in their projects, they also have the more fundamental choice of whether they should undertake a project at all. The project instructor in this study reports several comments from both his project and non-project students stating that they liked having the project option available (A. Grinshpan, personal communication, February 17, 2006).

Statement of the Problem

It may be that the very abstractness of mathematics limits some students’ abilities to see the potential applications of mathematics to real world problem solving. Researchers, such as Janet Donald (2002), have determined that

learning processes vary between disciplines and that the instructor must consider these differences so that students are provided with effective learning experiences. Grinshpan explains that, at the collegiate level, mathematics is often quite abstract and this makes it necessary to consider using specific project scenarios as possible instructional aids (2005). This alternative consideration is especially applicable to undergraduate mathematics courses in which students are often dissatisfied with the “pure lecture” teaching practices that many undergraduate students and instructors believe to be the only valid approach in mathematics education.

Application projects have not previously been the subject of systematic research, and such systematic research is desirable. Furthermore, if systematic research on application projects demonstrates that students benefit from them, then application projects could be a valuable tool in teaching general education mathematics. Additionally, educators may wish to expand their teaching repertoires by including application projects, thus allowing them to more fully and effectively serve diverse undergraduate populations. Furthermore, application projects and similar types of programs may provide a very satisfying portion of an undergraduate’s education. All of the items just mentioned are summarized beautifully by the views of Dewey as expressed by Ehrlich. In particular, Dewey held high regard for the value of a “traditional,” liberal education, but felt that there should also be contemporary applications for what is taught. Dewey believed “[t]he interaction of knowledge and skills with experience, focused on a

problem, is key to learning” (Ehrlich, 2002, p. 125). But the first step should be to verify the hypothesis that projects deliver observable benefits to students; only then might one try Dewey’s key.

Significance of the Problem

As stated above, application projects may be desirable from a number of standpoints and this study explored two of these in particular: potential improvement of students’ learning outcomes, and levels of time on task connected to project work. This study addresses these ideas in two phases. The first phase directly consider learning outcomes as demonstrated by students’ grades on their common third test. The second phase in this application projects study involves students’ self-reported assessments of application projects and the extent time on task may have been increased by application projects. These self-reports were obtained from personal interviews with a subset of the students enrolled during the spring of Year 3.

It appears that application projects require the instructor to have significant dedication to her or his profession, since application projects demand a great deal of contact with students outside the classroom. Also, administrators within the hierarchy overseeing an application projects program may likewise need to spend greater portions of their already scarce professional resources, and time, in order to support the program. Administrators should try to positively reinforce those instructors involved with application projects programs, provided that application projects are deemed to be good practice and “good business.” It

is reasonable, then, to want to assess the educational value of application projects. Since no studies have been conducted concerning the potential benefits of application projects in relation to student learning gains in undergraduate mathematics, obtaining results in this area serves to inform and provide fuller meaning to project work. Results, as described in Chapter Four, provide support for project teaching.

Purpose of the Study

The purpose of this study is to critically analyze the practice of application projects in certain mathematics courses to determine if, and if so how, students benefit from application projects. The study is limited to certain specific courses within a non-math major's undergraduate mathematics program of study. The determination of possible overall student benefit of application projects compared to the traditional non-project approach should be informative to administrators, faculty, and students. While it is somewhat speculative to assert that application projects may work well in other academic areas outside of mathematics, it seems reasonable that this would be the case, thus extending the potential implications of this study.

Application project instructors and the immediate administrative officers of various mathematics departments, as well as potential project students, may find the results of the study to be useful. It is desirable to provide undergraduate mathematics educators with some measure of "return," in terms of increased student success, for the added time and energy they may invest in facilitation of

application project courses. Providing reliable information on the academic value of application projects is one objective (being explored in phase one) of this research project.

The second purpose of this study is to explore relationships that may exist between application projects and levels of time on task. It is understood that heightened time on task can have powerful educational value that relates directly to overall student satisfaction. Interviewing project and non-project students alike have facilitated this exploration into student satisfaction (in phase two). Again, this information is expected to be valuable to administrators, faculty, and students who might consider application projects in the future.

Significance of the Study

The significance of the present study is illustrated with a brief look at the perspectives and theoretical framework for this study. This section presents the underlying theory, developed by James, Dewey, Chickering and Gamson, and others, that serves to demonstrate why this study of application projects should be of interest to educators; to be followed by some observations on contemporary thinking pertaining to application projects.

Pajeres (2003) describes the influential thinking of William James during the latter half of the nineteenth century that defined the philosophy of pragmatism. John Dewey (1929) followed James as one of many pioneering educators who saw advantages in making education more meaningful to students by involving them in real world applications. Dewey's progressivist

approach, together with the constructivist approach mentioned earlier, form the theoretical framework for this study. Hall describes the benchmarks of progressivism by observing that Dewey

. . . believed that changes that had occurred in the culture necessitated changes in the classroom. Classrooms should prepare students to be good citizens in the modern world . . . [where it is best to] learn by doing. Any type of drill and lecture was frowned on” (2003, p. 15).

The progressivist desire to uphold and enhance social structures and employ the good undergraduate teaching practices Chickering and Gamson speak of (1987), together with the constructivist view that knowing is unique to the knower, form the basis of application projects.

In addition to Donald’s observation that disciplines themselves necessitate certain basic teaching techniques (2002), it is also necessary to recognize that students learn in different ways (Denig, 2004). By employing application projects, instructors heighten students’ time on task and acknowledge their cognitive and learning style differences. Furthermore, several researchers, such as Perkins (1999) and Bonwell and Eison (1991), have endorsed active forms of learning as being more authentic and meaningful to students and projects promote active learning.

Also of interest with regard to the significance of the study are the civically functioning liberal arts curricula established at various institutions. These tend to endow application projects with the virtue of service to the community at large. A

particularly powerful case in point is the curriculum designed by Franklin Pierce College where the entire faculty is cognizant of the positive effects that active learning and civic engagement can have on students (due in part to increases in time on task). Their curriculum is promoted as the “Individual and Community Integrated Curriculum (IC).” Here, all of a student’s coursework incorporates the concept of civic engagement. It is within precisely this kind of academic environment that application projects and similar programs can thrive. The Franklin Pierce College Catalog explains that

[t]he purpose of the Individual and Community program is not to instill in students a prescribed set of answers, but to foster a common understanding of the questions and issues that lie at the heart of contemporary American life (2004, p. 104).

Franklin Pierce College exhibits application projects applied at an institutional level. Both application projects and Franklin Pierce’s Individual and Community program are founded on a civic arts approach to education. There is commonality in the desire to promote “. . . higher education’s potential to provide those skills, dispositions, and habits of mind that are essential for constructive participation in the democratic process [and to provide] . . . personal connectedness [and the ability to make] . . . public judgments” (Pratt, 2002, p. 160). These programs instill and nurture in students an awareness of their potential societal value as responsible, active citizens. The Individual and Community and application project programs both offer students the opportunity

to serve the community and, in the process, learn how they can personally play an active role in society.

The specific significance of phase one of the study is that it tries to explore whether distinct benefits can be obtained from application project learning in terms of achieving course objectives. In particular, it is important to know if a student's learning, as reflected by the student's third test results, is impacted by her or his application project activities.

This study is also significant because it examines whether or not any relationship exists between application projects and students' self-reported levels of course satisfaction and time on task. Application project students reported higher course satisfaction and greater levels of time on task than did non-project students as revealed through interviews performed on each group.

No research has been found that deals directly with mathematically focused application projects. By conducting the study into the specific area of mathematics application projects many important facts may be revealed. It is enough to begin and end this study using the two basic concepts mentioned above, namely, common third test grades (phase one) and measures of time on task (phase two). The obvious categorization of the population into a project learner group and a non-project learner group are maintained in both phases of the study. Any findings have the potential to be of importance to educational practices involving undergraduate mathematics students and optional real world application projects. The approach to be employed in this study is mixed.

The Mixed-Methods Rationale

“Mixed-methods” refers to the use of both quantitative and qualitative data in research. If the courses of interest were merely the “lecture and test” variety, then the approach would likely have been purely quantitative. Fortunately, the courses are made more interesting by the inclusion of the optional project element. It seems natural, and perhaps necessary, to use qualitative data in the analysis of the project program. As Merriam (2002) aptly explains “[w]e are closer to reality than if an instrument with predefined items had been interjected between the researcher and the phenomenon being studied” (p. 25).

For example, “course satisfaction” is perhaps the most noteworthy element of real world application projects and it is one of the elements that were of interest in this current research. “Course satisfaction” is a qualitative variable that is best approached through student interviews. It was not necessary to provide students with a definition of “course satisfaction,” since they are free to use their own understanding of what course satisfaction means to them. The open-ended nature of the interview process in phase two of this study, has the exciting prospect of possibly revealing new elements concerning application projects and thus may promote further fruitful research in this area. This second phase of the study reveals deep, rich insights into the production of projects and the motivations of project and non-project students. It was important to interview non-project students who shared the same classroom environment as those students electing the project option. At the same time data was also gathered

concerning students' time on task, in this case, students' time spent in preparation for course evaluation (either toward assignments, tests, and eventual projects or standard tests throughout the course). Students in the project group reported having stronger feelings of course satisfaction than those in the non-project group. The mixed-methods approach provides a better interpretation of reality and therefore offers greater internal validity to the study (Merriam, 2002, p. 25). This is the topic of Chapter Four.

Before discussing the research questions it is necessary to first address a concern that appears to be foundational to this study. The question is whether project and non-project students are naturally dissimilar before project work even begins. It is the project instructor's contention that these groups are not significantly different academically. The project and non-project groups are thought to have similar distributions of weak and strong students.

While this researcher feels that it is safe to trust the project instructor's assertion of group similarity, it has been judiciously decided that the first and second common tests should be considered as a way of verifying this assertion of commonality. The reason for desiring reassurance about this cross-group similarity issue is that if there's already a significant difference in mathematics achievement between the two groups before the third test, it is impossible to compare the groups' third test results without adjusting for the difference. The academic similarity prior to project work is but a conjecture, however, so it is legitimately included as a research question. With the conjecture relative to

Research Question 1 supported, the pivotal hypotheses, namely that grades on the common third test for undergraduate non-math majors in application projects were *superior* to those of non-project students, was subsequently considered.

Added to the bank of research questions is the “initial student similarity” question. It is placed prominently as Research Question 1 for this assumption of similarity plays into the research that follows. It was considered sufficient to collect students’ grades on the first and second tests (referred to as “Test 1” and “Test 2”) during the sample period from the fall of Year 1 through the spring of Year 3 to examine students’ math abilities prior to project work. The rationale behind Research Question 1 is that the third test data cannot be used as a comparative measure if there is dissimilarity in the academic performance of the groups at the start. Therefore, this foundational question is first explored by considering students’ first and second tests prior to considering the third, and final, common test. In summary, Research Question 1 considers whether students who are more mathematically proficient (or less mathematically proficient) tend to choose the project option or to take a Final Exam. Means may be computed for each group to see if the two groups are quantitatively different. Research Question 2 then explicitly considers the results of the third test grades.

Research Questions

This study focused on five fundamental research questions. The subsequent description of research processes are referred to as “phase one”

(Research Questions 1 and 2) and “phase two” (Research Questions 3, 4, and 5):

1. Do non-math major undergraduate students who are more mathematically proficient (or less mathematically proficient) tend to choose the project option rather than taking a Final Exam?
2. Is there any significant difference in the common third test grades among non-math major undergraduates who completed one of the two mathematics courses (MAC 2242 Life Sciences Calculus II and MAC 2282 Engineering Calculus II) with application projects as compared to students who took these same courses without electing the application project option at one large, urban university?
3. As indicated by interviewee responses of the non-math major undergraduates enrolled during the spring of Year 3 in MAC 2242 and MAC 2282 (the same two mathematics courses specified in Research Question 2), with an application project option and those who did not elect the project option: is there a difference between the two groups' perceptions toward mathematics?
4. From comparisons of interviewee responses (currently enrolled non-math major undergraduates electing application projects and those who did not elect the non-project option): is there a difference between the two groups' levels of course satisfaction?

5. By comparing the interview data for students electing the application project option with those responses of non-project option interviewees: is there a significant difference between the two groups' reported levels of time on task?

Hypotheses

Corresponding to the five research questions above, it was predicted that data analyses would demonstrate that:

1. There is no particular tendency for academically weak or strong students to elect the project option (or take the Final Examination).
2. Grades on the common third test (in MAC 2242 and MAC 2282) for undergraduate non-math majors participating in application projects are superior to those of nonparticipating students.
3. Undergraduate students in the project group report having more positive perceptions toward mathematics.
4. Undergraduate students in the project group report higher levels of course satisfaction than those in the non-project group.
5. Undergraduate students in the project group report higher levels of time on task than will non-project students.

Definitions of Terms

In order to seriously discuss a subject, it is important to have clear definitions. The need for the term "application project," as used in this study, warrants a careful explanation as to why the inclusion of this term is deemed

necessary. To maintain order to this section two, subsections are presented; namely, “*Adding a New Term*” followed by the “*List of Definitions.*” “*Adding a New Term*” is a peripheral note in recognition of possible problems one might encounter upon establishing a new phrase.

Adding a New Term

Only when a concept is completely new should one create a new term for that concept. This parsimony makes discussions more universally understandable without needlessly creating new terms. In the context of this study it seems necessary, however, to define one new term, namely “application project.” As mentioned elsewhere in the manuscript, service-learning and project based learning might quite aptly mirror the sentiments behind application projects, but even these terms fall short or exceed the definitions commonly applied to them. Adding the term “application project” provides clarity to this, and subsequent discussions, about the particular projects discussed in this study.

It has been observed that application projects fall short of the full definition of service-learning (Grinshpan, 2005, p. 61). The community service element is not requisite to application projects, for instance. Neither do application projects fall neatly under any other previously defined label. A new label is therefore assigned to application projects. There is further discussion about the similarities and differences between the application project program and related programs in the section on “Defining Application Projects.”

List of Definitions

Agency is the general term used to include any profit or not-for-profit business, any recognized academic unit, or any community service organization including government agencies that might allow students to conduct application projects.

Application project refers to the optional experiential learning portion of an undergraduate's coursework. An *application project* ". . . is an innovative feature of some credit-bearing mathematics courses designed to allow students to participate in experiential learning outside the classroom . . . [and a] way for them to make tangible connections between mathematics (calculus, in particular) and the physical world" (Grinshpan, 2005, p. 61). The section in Chapter Two entitled "Defining Application Projects" includes both a real and a fictitious example of an application project. Appendix C provides what the researcher has envisioned as "an average" application project that is intended to illustrate the write-up format. The hypothetical application project described in Appendix C is designed to exhibit a possible way in which the mathematical content is to be integrated into the write-up. It is the mathematical component that distinguishes an application project from a general educational project (see the definition for "project" below).

Application project course refers to any of the small number of mathematics courses offered at the large, urban university in this study where an application project is offered. These are all undergraduate liberal arts mathematics courses.

Application projects director is the title of the person who is in charge of approving and evaluating student projects. Due to the vast range of interest application projects cover, the *application projects director* must have a firm conception of mathematical applications in all its myriad forms (A. Grinshpan, personal communication, February 17, 2006).

Application project instructor (or alternatively, *project instructor*), within this context, refers specifically to the instructor whose students were selected as participants in the two phases of this study. In general, a project instructor is the facilitator in a course that utilizes application projects.

Application project student (or alternatively, *project student*) refers to any undergraduate mathematics student who has produced or is currently producing an application project within the application project program.

Experiential learning welds academic learning to a student's “. . . ordinary life experience. [*Experiential learning* is preferred over passive learning because it is] . . . less contrived and artificial, and students will grow more and become better citizens” (Posner, 2002, p. 17).

Incomplete is a term used here to include all grades outside those that generally equate to course credit, i.e. all *Fs*, *Ws*, *Is*, *Us*, *Ms*, and other assigned codes that do not indicate satisfactory course completion. It might be best to say non-complete, since the idea behind collecting these grade types together is that they are all numerically zero. Only letter grades, *D-* and better, yield equivalent

non-zero values related to degree of understanding. (This is discussed more fully in the Method chapter.)

Institutionalization is the formalized recognition of an entity within a larger structure. *Institutionalization* of educational programs manifests itself in the establishment of bureaucratic structures with their own administrative personnel and with structured plans of operation.

Observer effect refers to the error of observations due to the presence of a researcher. All interview results include some amount of error that comes about from the desire of the interviewee to provide the interviewer with “correct” or “impressive” responses. To a lesser extent, an observer effect occurs whenever participants in a study know they are being studied.

Pattern coding is the process of gathering qualitative data and systematically organizing each datum into an appropriate category. From the distribution of similar or dissimilar data, inferences can be drawn as to the tendencies of a sample and its host population.

Pragmatism is the philosophical concept in which application projects seem to be most favorably viewed. *Pragmatism* asserts that “[t]ruth is the outcome of experience” (Dickstein, 1998, p.7).

Project, in the educational sense (as recognized by the *Oxford English Dictionary*, sense 5, variation b), is “[a]n exercise in which pupils are set to study a topic, either independently or in co-operation, from observation and experiment as well as from books, over a period of time” (*Oxford English Dictionary*, 2006).

Project based learning, project learning, and problem based learning are all programs focusing on an active, experiential element in the learning process. As mentioned elsewhere, there have been numerous versions of the definition for this concept. For the purposes of this study, Bringle and Hatcher's (1995) definition is applicable; namely, a

- . . . course-based, credit-bearing educational experience in which students
- (1) participate in an organized project activity and
- (2) reflect on the project activity in such a way as to gain
 - (a) further understanding of course content,
 - (b) a broader appreciation of the discipline, and
 - (c) an enhanced sense of civic responsibility (p. 112).

The Bringle and Hatcher definition lacks the all-important inclusion of a mathematical connection that is demanded of application projects, but otherwise the concept is much the same. Neither does the concept of problem-based learning capture the required mathematical component vital to application projects. Application projects do, however, share the elements of being active and experiential learning approaches with problem-based and service-learning. These various learning approaches all emphasize the desire for authentic learning in which “. . . knowledge arises from work on the problem” (Davis & Harden, 1999, p.132); in the case of application projects, “project” can replace “problem.”

Service-learning, as described by Barbara Jacoby and her associates (1996), is

. . . a form of experiential education in which students engage in activities that address human and community needs together with structured opportunities intentionally designed to promote student learning and development. Reflection and reciprocity are key concepts of service-learning (p.5) .

Service-learning and application projects share several positive elements. Among these shared elements are authenticity of learning, connecting coursework with real world experience, and, with a somewhat narrower view of “the community,” service to the community.

The *Structure of the disciplines perspective* asserts that learning works best by “. . . engaging students of all ages in genuine inquiry using the few truly fundamental ideas of the disciplines, and students will develop both confidence in their intellectual capabilities and understanding of a wide range of phenomena” (Posner, 2002, p. 17).

Substantive significance (according to Patton, 2002, p. 467) is a means by which qualitative findings, in lieu of statistical significance, are judged.

Time on task refers to chronologically measured periods of a student’s study. Since time on task is meant to indicate time spent with course matters and does not necessitate “book” study, one can include time spent thinking about a problem that is relative to a student’s coursework. Due to the difficulty of

determining precisely when a student is “on task,” the actual measurement of time on task is problematic. In this study students were asked to provide their own numbers for this variable. The study was approved early enough to enable this researcher to ask students to keep a log of their time on task during the last three weeks leading up to the third test and the students’ interviews. It is believed that this suggested record keeping allowed the researcher to obtain more realistic figures for students’ time on task.

Delimitations

A delimitation of this study is that only those undergraduate students at the particular large, urban university, who are enrolled in specific mathematics courses where application projects are being offered, are included as participants in the study. Furthermore, students are not randomly assigned to a group. Students either elect to produce a project, and therefore are members of the project group by definition; or they choose not to elect the project option and are considered to be in the non-project group. This element of student self-selection means that caution needs to be exercised whenever generalizations to the full population is inferred or implied. Since it is desirable to consider the particular project program in place at the particular large, urban university featured in this study, random assignments (in place of the current practice of student self-selection) would likely distort any findings, so student self-selection was allowed in this study, as well. The present researcher considers the self-assignment of students to either the Final Exam or project group to constitute an intrinsic

characteristic of the student. Students are identified with their groups in the same manner as they are identified with their gender. With this intrinsic view of group identification, random selection is absurd. There were no “approach change” operations in the study.

Another delimitation is the restriction of the data collection to courses taught by one instructor. It is reasoned that this restriction to a single instructor overrides certain confounding issues such as grading differences between instructors and various instructor biases. It is important to add that the application project instructor for this study has facilitated the vast majority (over 95%) of all application projects conducted by the mathematics department at the university. Limiting data collection to this one instructor’s students allowed adequate sample sizes (roughly 160 project students and 120 non-project, Final Exam students) for the first phase as well as about seven students from each group (for a total of about 15 students) for the second phase of the study. The actual number of interviews conducted by this researcher continued until no new themes emerged. This matter is considered in greater depth in the Instrumentation section of Chapter Three and the actual description of the interview results described in Chapter Four.

Limitations of the Study

A limitation to phase one of the study results from the decision to consider only the common third test for the students as a measure of “conceptual understanding” of course content. While it would be desirable to include the

students' final course results, the deviation from the standard test evaluation afforded to the project group would make the final course evaluations across groups incomparable. Consequently, a lesser limitation (to the common third test) is preferred since it incurs no cross-group evaluation discontinuity.

Another limitation lies in the exclusion of “incompletes” from the phase one analysis. This limitation reduces the population size for phase one by as much as a third, however it will be explained later (in the section in Chapter Three entitled “Phase One: Common Third-Test Comparison”) why it is necessary to impose this limitation on the study.

In addition, the use of tests one and two as a means of ensuring that students are academically similar prior to project work has the same limitation of only really showing “grade” similarity. There is no problem with using grades to this point, since (having few other resources for measurement) grades are used for the remainder of the phase one part of the study. Again, the ultimate concern that the grades themselves don't tell the whole story. As will be discussed in Chapter Four, the qualitative portion of the study has added to the literal quality of the current research. Further limitations, largely of a qualitative nature, are advanced in the Conclusions chapter.

Organization of Remaining Chapters

Chapter Two contains a literature review including historical and theoretical concepts surrounding application projects, curricular perspectives including civic engagement, and philosophies regarding active learning. The

focus of the chapter is on application projects and undergraduate students taking mathematics courses. It also explores various curricular theories such as progressivism, the structure-of-the-disciplines approach, and the goals of general education. In addition, Chapter Two explores the desire of liberal educators to promote appreciation and deeper understanding of the disciplines; mathematics in particular. Chapter Three describes the methods underlying the study. Chapter Four reports the findings and Chapter Five discusses their implications.

Summary

This chapter describes the background for this study. Its focus is application projects, which is a program in which non-math major undergraduate mathematics students and the community may benefit. The application project program offers students several ways to profit from their participation in undergraduate general education math courses. The examination of commonly graded objectives provides an avenue for assessment of the academic benefit provided by application projects. In addition to the common third test grades, the use of student responses to interview questions provides insight into project and non-project students' expectations and motivations. This study also elucidates ways in which application projects effect the time on task of students in certain undergraduate, non-math major, mathematics courses.

Since the benefits of project based learning and service-learning are readily accepted (Astin and Sax, 1998), it would appear that the benefits of application projects would also be seen as beneficial. Nevertheless, these

programs are not heavily used in mathematics courses, primarily because extensive effort is required to implement such programs (Antonio, Astin, and Cress, 2000). Before administrators can endorse an application project program, there should be little doubt that educational gains will result from the extra effort required of them and their instructors. One of the major purposes of this study is to determine whether it is worth the extra instructor effort in terms of student gains such as an improved understanding of, and regard for, mathematics.

Chapter Two

Review of Related Literature

This chapter presents a review of the literature relevant to the particular educational approach of application projects as practiced with non-math majors taking mathematics courses at the large, urban university considered in this study. Application projects are well adapted to liberal education, so literature pertaining to general and liberal education are also presented. The chapter also considers students' motivations for project work, which was evaluated by student interviews. In addition, examples of a real and a hypothetical application project are described.

Overview

Application projects by their nature connect to a wide variety of interdisciplinary topics. This heterogeneity of subject matter justifies the broad approach to surveying the literature that is used here. Since, the particular application project program considered in this study is “a unique form” in higher education, a description of the program is first provided in the section on “Defining Application Projects.” The “Defining Application Projects” section looks directly at the required write ups that project students submit as assessment instruments. The full definition of application projects necessitates some

discussion of authenticity of learning and the student-community symbiosis; this rounds out the “Defining Application Projects” section.

In order to more fully appreciate the benefits to students afforded by application projects, a brief historical sketch of the development of application projects in higher education is presented in the section on “Foundations of Application Projects.” The section entitled “Evaluating the Effects and Implementation of Application Projects” presents some ideas concerning recent research into project types of educational practices. The chapter includes some philosophical considerations into learning experiences in general, and application projects in particular, beginning with the section on “What Educational Approach is Best?” Finally, the section entitled “The Application Project Experience” discusses some of the elusive educational aspects underlying application projects.

While researching application projects it becomes evident that few studies have considered the potential benefits from application projects or similar types of programs. Two studies have been located that illustrate the intended directions of research in this study. Quantitatively, the Eyer and Giles study found a weak positive correlation between a form of projects and student benefits (1999). From a more qualitative viewpoint, Pajares and Miller have shown that students’ beliefs in their own abilities to succeed was reflected in their grade measures (1994). It is reasoned that course satisfaction directly aligns with Pajares and Miller’s findings. Included in this study are the extremely fertile areas of research that

center upon the ideas of active and experiential learning, as well as those of civic education and service-learning, that are clearly related to the application project program.

Defining Application Projects

The phrase “application project” refers to the optional experiential learning portion of an undergraduate non-mathematics major’s coursework at the large, urban university in this study. Service-learning, project learning, and application projects all focus on general education. Of particular importance is the common thread of civic engagement that connects the three areas. The “civic engagement” in application projects is ideally the same as that implicit within Posner’s description of learning integrated with “. . . life experience . . . [as being] less contrived and artificial” (2002, p. 17).

As discussed at greater length in the Methods chapter, all students (project and non-project students, alike) begin by taking three common tests and class assignments. Project students produce an application project rather than taking a Final Examination. Some students appear to use the application project as an opportunity to demonstrate their abilities in a different manner instead of taking the Final Examination. Non-project students, naturally, must take the Final Examination. Projects are completely optional and roughly 60% of students enrolled generally elect this option.

This study does not seek to explore the minutia of the project instructor’s way of assessing his students. (Hopefully, the paragraph to follow suffices). This

omission is not disruptive to the study, however, since in a project situation an instructor has the capability of using what Peter Rennert-Ariev and others have called “authentic assessment.” Rennert-Ariev suggests assessment is “revitalized” by including ideas like seeing that assessment is “. . . conducted within the context of [the] student’s work, including their perception of roles, experiences, and practices; . . . [allowing assessment to] challenge the institutional and bureaucratic structures; . . . [and] where students and their evaluators enter into dialogue . . .” (2005, p. 8). Authentic assessment is just the kind that the project instructor uses in assessing real world application projects. Consequently, the particulars of the grading process may be safely assigned to constants within this study.

What is made available to students by way of a description of what is expected should they elect to produce projects is a template showing the desired format (see Appendix C which uses this template) and the basic grading option description provided in the instructor’s syllabus. The instructor provides verbal descriptions of projects in class to complete the project description (A. Grinshpan, personal communication, February 17, 2006). The section entitled Grinshpan’s Particular Bridge gives a very primordial rubric for grading projects and describes somewhat more fully what motivates this particular instructor to offer projects as an option in his courses.

The choice to avoid “treatment” in this manuscript is merely to be humanistic in this study. While a project might technically constitute an

experimental “treatment,” since projects are unique to project students, it is referred to more descriptively and less clinically as an “educational approach” in this study. Whether “treatment” or “educational approach” it should be clear that, for the purposes of this study, the non-project students constitute a “non-treatment” comparison group, with the proviso that all students are expected to self-select their group by virtue of either project selection or non-selection. In this vein, project students are “treated,” however, there is no standard “treatment” to administer and the approach is never the same for any two students, so it seems that “educational approach” is a more appropriate way to label the project experience. In addition, the project instructor encourages students to follow their own paths, and this educational approach works best without the moniker of “treatment.”

Among the varied topics represented by project work are chemistry, engineering, volunteer management, and computing. For example, one student considered the swimming pool design and construction, with its “. . . system of filtration and chemical treatment to continually clean large volumes of water” (Smit, 2005). Smit’s project may have allowed him to form a personally meaningful connection with swimming pool intricacies and higher mathematics. Another student’s project involved calculating the metallic surface areas of circuit boards; surfaces that quickly become quite convoluted upon elimination of areas immediately occupied by electronic components such as diodes (Lopez, 2005). Lopez may have had a vague sense that math could be useful in circuit board

manufacturing, but she may not have clearly understood how mathematics is actually applied in this area until after completing her project. There are student projects with topics as far reaching as the modeling of volunteer activities (Lee, 2005). The Lee project demonstrates a case where a mathematical connection is actually somewhat surprising. It shows that it is good not to direct students down particular paths, but rather allow them to explore whatever they wish. These first three examples are all “community” related, since they take place in an extra-institutional setting. It takes very little imagination to see that these and other “community” related projects are beneficial to the community.

An example of an academically oriented project is one that was devised by Brian Smith (2002). Smith demonstrated the cost-effectiveness of cluster computing, and he pointed out that by clustering smaller machines one can obtain the same computing ability as the “. . . supercomputers like the massive Cray computers that were made famous in the early [‘]nineties” (p. 9). Smith’s project was deemed “academically oriented” since the agency supporting the project was the Academic Computing department found on the institution’s campus. The work of Smith demonstrates that projects can not only *aid* research, but also actually *be* research. The extent of “research potential” that projects may contain is not an area of specific inquiry in this study, however it is one element to be considered during interview probing. It may be that stimulation of students’ interest in conducting research may be an important area for future research.

The physical project “product,” which has been simply called a write-up, is an important part of the project student’s work. In order to convey a sense of what the write-up entails two examples are provided. Described below are both a real project and a hypothetical project. The hypothetical sample is more “formally presented” in write-up form in Appendix C. Following the two examples are two additional subsections: “*Authenticity of Learning*” and “*Societal and Student Benefits from Application Projects*.” These latter subsections are presented to complete the definition of application projects.

A Real Project

It appears that it would be an easy task to select a “representative” project to serve as an example; however, this is not the case since this writer does not wish to show bias to any particular project type or topic. As a compromise, one real project is described and one that is purposefully contrived to serve as a more generic example in the following subsection entitled “A Hypothetical Project.” Because of the emphasis on *reality* in application projects, it is necessary to actually include a true project with real mathematical applications. The project selected is not atypical of those produced by the non-mathematics major undergraduates who elect to do project work. This particular project uses an interesting mathematical approach and includes a real concern for a fuller understanding of Alzheimer’s disease.

The real example is taken from an engineering calculus course and is attributed to the student, Brandon Faza, who worked with specialists in

Alzheimer's research (Grinshpan, 2005). Such research is likely to involve many issues of significance to humanity, but Brandon is considering an issue of peripheral importance, namely the cost of maintaining genetically engineered mice. Cost is usually of extreme importance and it turns out to be quite important in this example. There is clearly a need to estimate staffing requirements or the size requirements of the laboratory facilities needed to care for our fuzzy friends. The rodent inventory has to be given proper care and must be adequately housed because they are expensive and valuable, life-enhancing research depends on them. Naturally, the Alzheimer's researchers also need to know about how many mice they'll have to maintain in the future.

The mathematical craftsmanship of Brandon Faza's project is only surpassed by its educational effectiveness. This project successfully brings all aspects of the problem together, arrives at a solution, establishes an alternative solution, and finally shares the results. Faza's project exhibits all of the redeeming qualities of undergraduate research, a positive educational advantage mentioned earlier. Another more subtle advantage, but certainly a real factor in the power of projects, is that students produce something meaningful. This "meaningfulness" was already mentioned as being a positive inclusion for an authentic learning experience. Connecting learning with the real world allows students to contribute to the community, and this can naturally be quite rewarding to the student and everybody involved. One of the most prolific writers and editors on service-learning, Zlotkowski, reassures instructors that it often requires

only that students be made aware of the advantages of project learning to get students involved in these programs (1998). In the case of this example, it seems that Faza's results would have gone unrealized had he not initially been made aware of the benefits of this approach and then decided to get involved.

Faza's problem involves determining future mouse populations given minimal initial conditions. "One might consider the Fibonacci sequence and his rabbit population model . . .," Grinshpan observes, but ". . . the mouse population problem still requires a mathematician's eye on recognizing and handling recurrence relations" (2005, p. 65). The Fibonacci sequence is probably the best known non-trivial sequence of integers: 1, 1, 2, 3, 5, 8, . . . , $f_n = f_{n-2} + f_{n-1}$ (beginning with the third term, each successive term in the sequence is the sum of the previous two terms). The incredible number of mathematical results derived from the Fibonacci sequence is astounding, and certainly it comes up when considering population growth. Although Fibonacci considered pairs of rabbits at each incrementation of the sequence, the related sequences for all mice (denoted $\{m\}$) and reproductive female mice (denoted $\{f\}$) are determined in a manner analogous to that of the original Fibonacci sequence.

Beginning with

$$(1) \quad m_0 = 2 \text{ and } f_0 = f_1 = f_2 = 1$$

as initial conditions, one finds that $\{m\}$ and $\{f\}$ are related by the formula

$$(2) \quad m_n = m_{n-1} + 6 f_{n-1} \text{ for } n = 1, 2, \dots,$$

Since reproductive female mice beyond $n = 2$ can be determined from

$$(3) \quad f_n = f_{n-1} + 3 f_{n-3}, \quad n > 2,$$

double iteration can be used to determine successive values for m_n and f_n . These values are provided in Figure 1 where diamonds are used to plot the number of “all mice,” m_n , and squares are used to plot the number of “reproductive females,” f_n . From the shapes of the two curves in Figure 1 it is evident that the two populations, m_n and f_n , are related. Even with the limited range of n in Figure 1, one gets the sense that these prolific populations are rapidly increasing. Figure 1 provides only the first ten iterations, but by the twentieth iteration (the time period of immediate concern to the researchers) the numbers explode, as seen by

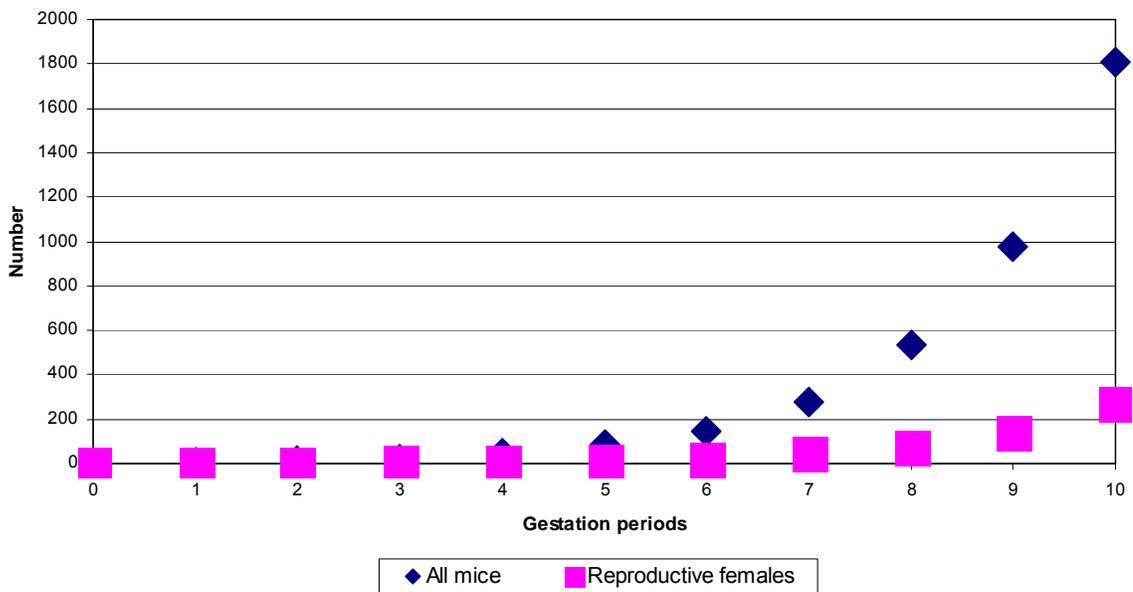


Figure 1. Graphical Illustration of m_n and f_n Populations over Time

$m_{20} = 921,362$ and $f_{20} = 132,706$. Grinshpan reports that Faza finds that at a unit reports that Faza finds that at a unit housing cost of \$6.40 per mouse, for mice that largely require separate quarters, the total cost at the conclusion of twenty periods “. . . is about seven million dollars!” (2005, p. 68). The researchers behind the Faza project will certainly want to allocate a fair amount of resources toward storage facilities for the eventual horde of mice that might result. As noted, there are portions of the real world situation that are not specifically considered in Faza’s mathematical model “. . . including the cases when reproducing females die in the end of the sixth reproduction period” (p. 65). Nevertheless the model is useful for gaining a sense of magnitude of the potential mouse population.

A full description of the presentation above appears to be enough to constitute a complete “application project,” however the mathematics can be modernized and intensified so that a superior (and more mathematically meaningful) project results. In this case, Grinshpan asserts that the new project goal becomes to “. . . use the classical approach to derive a closed formula for m_n . . . [from] a cubic equation and elementary properties of complex numbers” (p. 66). Finding a classical result (free of recursion) now serves to exemplify how a problem can be further crafted. It turns out that more can be said about mouse populations using techniques of higher mathematics. Furthermore, the new (closed) approach should certainly agree with the old (recursive) approach.

Like the aesthetic beauty of nature, one doesn't have to understand precisely how mathematics works in order to appreciate its appeal to the human senses. In that vein, the present writer has foregone a full explanation of the mathematical processes that take the initial conditions and recurrence relations (2) and (3) presented earlier, together with some complex analysis, to arrive at

$$f_n \approx .5189765 (1.863707)^n - .5215636 (1.268738)^n \cos(157.2605^\circ + n109.9001^\circ),$$

$$m_n \approx 3.605226(1.863707)^n - 1.679117(1.268738)^n \cos(17.06058^\circ + n109.9001^\circ).$$

Grinshpan adds that “. . . Viet Bui, another student contributor majoring in Biology, provided a detailed numerical analysis . . . [and found that] $f_{20} \approx 132,707$ and $m_{20} \approx 921,366$. The corresponding exact values are 132,706 and 921,362” (2005, p. 67). So the new model validates the first approach, and it is more convenient since it doesn't rely on recursion. With this insight into the power of complex analysis, the Faza project fully serves to illustrate the desired mathematical connection expected of student projects.

Although it is rather ironic to describe a *real world* project in hypothetical terms, it is instructive to consider the following fabricated project as well. The next section emphasizes the process of initiating a project and linking mathematics to the project. It is judicious to create a fictitious project rather than to select an actual student project, since by doing so no student's work is threatened by possible negative commentary and, more importantly, details can be included that might intentionally (and positively) prompt development of the

project in desired mathematical directions. Normally, such developmental details are not transmitted within a student's project write-up, so it is reasonable to contrive these details in order to best illustrate how mathematics is applied and "written up."

A Hypothetical Project

The actual project discussed above is perhaps more of an "ideal" project since it uses powerful mathematical techniques as it connects to the real world. It is impossible to exhibit a "typical" project; since there is no typical project or project student. As previously noted, there is a certain irony in abstracting a representation of a "real world" project when there are so many of the "real" real world projects available. However, there are good reasons to provide a fictitious project. For one thing, there is a desire to avoid favoritism for a particular project, or even project concept; and, as mentioned above, by using a contrived project one is able to ensure the inclusion of those elements of a project that are being immediately illustrated.

The written portion of the project is clearly an important concept to discuss. The hypothetical, "generic," project described below, is intended to more fully provide a sense of what is required (or at least desired) of the student when producing an application project. The hypothetical project write-up (included as Appendix C) clarifies how mathematical concepts are used and described, but its purpose is more structural. What the write-up discussion shows is that describing the process of learning helps the student internalize the

material. Students are expected to describe what they learned and how they performed the mathematics in a real situation. By its nature, a project generally develops somewhat differently from any intended design. Any design changes reflect on the learning that is taking place and should be described in the project. These are the kinds of details that that instructors might find interesting in a student's write-up.

Again, it is not possible to definitively capture even the write-up product, but having a reference example may be helpful. Therefore, a hypothetical project write-up is provided as Appendix C. The hypothetical project is entitled "Plants and Water." The discussion that follows in the next few paragraphs considers the "reality" of the project and how a project student might select a project. The important element of employing mathematics for this hypothetical situation is mentioned here, but is specifically placed in Appendix C where it can be seen within the "structure" of a write-up. As mentioned above, and as considered more fully later, it is the requirement of applying mathematics that is unique to application projects, so it is clearly appropriate to include an example describing in detail how a project student might apply mathematics; in particular, how the student might apply calculus. Conscious restraint has been placed on the mathematical concepts in order to keep this example project simple. The sample merely employs the derivative, a basic mathematical concept introduced early in most undergraduate calculus courses.

Suppose the student (her fictitious name is chosen to be “Leslie”) knows people who care for indoor plants. An individual (say, the gardening manager) agrees to supervise a project involving the process of mechanically watering indoor plants that applies mathematics. Suppose further that Leslie is able to vary the amount of water provided to similar plants in separate beds. She measures the plant growth and charts the growth versus the amount of water provided to specific beds. The results might suggest that watering is related to plant growth in a way that can be mathematically modeled. Leslie’s project supervisor agrees with her findings and might now use her results in order to grow the plants at an optimal rate. This example shows that a simple idea can be used for an application project. It also serves to demonstrate that things aren’t always as simple as they appear. At first glance (and since no mathematics has yet been exhibited here), the plant watering project may seem ridiculously trivial. Naturally greater water equates to greater growth, but at some point excess water will likely negatively impact the plants. One might even speculate that our gardening manager desires a certain intermediate growth of his plants. If the student has supplied the supervisor with a formula that sufficiently models the effect of watering (as obtained from Leslie’s empirical data), then the gardener should be able (using the inverse relationship) to get the plants to grow to a desired size. In this way, water might be saved and some extra pruning may be avoided in the long run. From her reports (written and verbal) the project instructor concludes that Leslie has learned and properly applied calculus to a

real world problem. The relationship described in this example is certainly non-linear, so the mathematical concepts needed to solve the problem are nontrivial and worthy of the methods of calculus. Besides the abstract concepts of the derivative that Leslie may have assimilated without having produced a project, the project experience has gained her some hands-on knowledge about how models truly compare to real world situations. If Leslie truly enjoyed the project experience, and the interaction with those she worked with, her enjoyment would naturally translate into greater course satisfaction.

The situation described above is adequate to elicit a sense of how a project idea might be developed. Project students are expected to incorporate mathematics into their projects. As mentioned, a hypothetical write-up demonstrating the practical use of mathematics in this example is provided in Appendix C. Once a definition of an application project begins to congeal, one can begin to see how the application project program is intended to work; and what it can accomplish.

As Bringle and Hatcher put it, the application project program can be described as a

course-based, credit-bearing educational experience in which students (1) participate in an organized project activity . . . and (2) reflect on the project activity in such a way as to gain further understanding of course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility (1995, p. 112).

The concept of problem-based learning is also similar to the application project concept. Davis and Harden (1999) carefully describe approaches to problem-based learning in various arenas of medical education. As with project-based and service-learning, problem-based learning does not have a required mathematical component and therefore it cannot be properly compared to application projects. The concept of active, experiential learning in problem-based learning is again analogous to that concept in application projects. The researchers Davis and Harden assert for problem-based learning what can be said of application projects, namely “. . . knowledge arises from work on the problem” (1999, p.132). While not restricted to medical education, problem-based learning seems to thrive in the medical environment. Problem-based learning works well in environments where students go on to complete lengthy internships. In a real sense internships are themselves forms of problem-based learning.

The application project program is not equivalent to any of the various community service or project-based learning programs that are attached to higher education. Application projects differ from service-learning which, as mentioned earlier, tends to restrict the host agencies to not-for-profits. Application projects program is not a form of project learning or project-based learning, because the latter two can usually be performed in a classroom environment and application projects cannot. Application projects are not problem-based learning, either, as discussed above. Application projects are instead an amalgam of many active program types. The application project

program contains, for instance, portions of service-learning's civic responsibility and portions of project learning's concept of academic enhancement. While in some areas the application project program may fall short of full project learning, problem-based learning, and full service-learning, it exceeds project and service-learning in the area of mathematics appreciation through real world applications.

The application project program under investigation in this study is one that allows non-math major undergraduate students enrolled in mathematics courses to apply math to a real world situation. Students entering this program design their own service opportunities and no restrictions are placed on the type of agency with which students can work. In this study the term "agency" is used to include any profit or not-for-profit business, any recognized academic unit, or any community service organization including government agencies. The only requirement for project acceptance is that an individual within the host agency must agree to supervise the project student's work and to possibly assist in evaluating the student's contribution to the agency provided by the mathematical results. Application projects include an administrative feature that ensures that proposed projects comply with the necessary inclusion of mathematical applications. In particular, the project instructor does not approve students' projects until he has received a signed letter of acceptance from the project supervisor and the agency representative stating that the supervisor will work with the student in the design and development of a pertinent mathematical application contributing to their agency in some specific way. The required letter

also serves as a confidentiality agreement between the project instructor, student, and host agency. Agency representatives generally agree to allow a “non-sensitive” summary of the students’ work to be published on the Internet.

One advantage of application projects is that they allow for students’ diverse learning styles (Denig, 2004). Successful project work relies largely on both the instructor’s comprehensive mathematical and educational expertise in order to accommodate students’ diverse learning styles while providing them with direction in their chosen areas of exploration. In this way, learning opportunities are provided that recognize students’ learning style diversity. Conscientious undergraduate instructors are therefore required to employ a wide range of teaching methods. If application projects work, instructors in general, and mathematics instructors in particular, can use the application project approach to better teach a wider student population. But we also need to know whether or not students truly benefit from their experiences with application projects. Findings from studies of similar programs have left this question unanswered (Lewis, McArthur, Bishay, & Chou, 1992). This investigation into application projects attempts to obtain an answer to the elusive question of whether real student benefits accrue to those involved in the program.

Another defining element of application projects is their holistic usefulness in promoting community involvement. It is good practice for instructors to include potential connections to the “working world.” Indeed, educators do well to offer their students opportunities for outside learning activities that students could

never get from a textbook or any professor's lecture (Gottfredson, 1996). This element of "world exposure" is perhaps the single most definitive concept connected to application projects. Students' benefits from real world exposure as part of project work have been recorded to some degree. For example, in his 10-year study, Helwig found that early "career-mindedness" led students to be more capable socio-economically in later years (2004).

Additionally, in agreement with the constructivist basis of application projects which takes the individual student's perspective into consideration, there are two concepts concerning the larger educational picture surrounding application projects to be discussed. These concepts are described separately in the following two subsections entitled "Authenticity of Learning" and "Societal and Student Benefits from Application Projects." Active and authentic learning experiences are positive learning elements of application projects. Furthermore, application projects provide students with many opportunities to develop socially, which is another positive learning element (Bandura, 1986). These features are all a part of project work and have become defining concepts for application projects.

Authenticity of Learning

The concept of "authenticity of learning" is a hallmark of application projects, since projects are expected to relate authentically to reality. With projects, the related learning is necessarily authentic, because students address their applications from their individual perspectives. It appears that there are

enough undergraduate students who wish to apply the mathematics they learn to the real world to warrant the inclusion of project options.

Learning, when partnered with experience, has more impact on the student than if a student reads a written account of an experience. Authenticity of learning manifests itself in a student's faith that useful learning is valuable learning. Elizabeth Murphy employs constructivist approaches to describe authentic learning experiences. According to Murphy, authentic learning is powerful, meaningful learning, since ". . . learning situations, environments, skills, content and tasks are relevant, realistic, authentic and represent the natural complexities of the 'real world'" (Murphy, 1997). Finally, application projects, with their active and authentic learning, promote the practices for effective undergraduate learning (Chickering & Gamson, 1987). Authentic learning is undeniably a powerful learning aid in all but the most theoretically based disciplines (where it might not be applicable).

Societal and Student Benefits from Application Projects

A final fundamental concept connected to project work is the notion of civic engagement. Application projects offer an exchange of "societal and student benefits," i.e. mutual benefit. We can agree that, like all citizens, students seek an exchange of opportunity with society. Students have a sense that their education has value to the society as a whole, as well as for themselves. Students know that skills and knowledge aid in securing their monetary needs, can assist in their environmental concerns, and can support their pursuits of

happiness, for example. More importantly, students are quite likely to understand that they are, or will be, active members of their communities. Society serves the student, and the student returns some measure of service back to the community and thus, back to society. In short, there are societal and student benefits from service related project work.

The bottom line is that civic engagement has been, and continues to be important to students' academic and social development. Application projects, through their potential to promote community involvement, can encourage students to embrace positive attitudes toward benevolence and civic engagement. Application projects also act as a means of allowing students to learn how they can impact their community positively. The reciprocity of benefits between students and society can help students to see that civic engagement is beneficial. Therefore, it appears that one could hypothesize that application projects help students connect with society.

To conclude this section on defining application projects it would be negligent not to include the information provided to students when they enter into an application project course. It's unlikely that enough students would appreciate the details hinted at in the previous paragraphs. In a course syllabus the instructor must attempt to be concise and still be sufficiently explicit concerning student requirements including, of course, how they will be evaluated for their efforts.

It is worth recognizing that the grading specifics involving projects at the large, urban institution featured in this study has purposefully been modified over the past seven years (1999-2005) and that the current arrangement could certainly change in the future. The grading process currently employed is consistent over the period of this study. As will be further described in Chapter Four, using the current and three previous semesters (Fall Year 1 to Spring Year 3) for phase one provides an adequate sample size for statistical testing. With phase two, the Spring Year 3 semester, statistical testing was not used with the obtained sample size of about seven participants per group. As further discussed below, the project instructor considers three common tests and class assignments to constitute 55% of a student's course grade. The study concentrates its quantitative inquiry on the third test because it is an element common to the assessment of both the project and non-project groups and it occurs after students have made their choice as to the election of the project option. The remaining 45% is made up of the student's in-class, written Final Examination or the student's out-of-class project work (potentially having both written and verbal elements).

Students are explicitly told on their course syllabi that there are two grading options for students in this particular class:

1. Three tests and class assignments will contribute 55% to a student's final grade and a Final Examination that will contribute 45%.

or

2. Three tests and class assignments (covering the parts of the text noted elsewhere in the syllabus) will contribute 55% to a student's final grade and an Application Project will contribute 45%.

Students are also told where they can view summaries submitted by previous application project students. A list of some application projects is made available on-line at the Mathematics Umbrella Group web site (MUG, 2007).

Foundations of Application Projects

If the heart of application projects is the community, then the body consists of students and the mind is comprised of project instructors and administrators. There are several fundamental purposes to application projects. First, application projects effectively employ authentic and active learning approaches and are intended to benefit students, as well as their communities. A recent article by Harold Shapiro (1997) reminds us that community and civic responsibility are the foundational soul of American colleges. Consequently, application project types of programs have shared the historical developments of universities in the United States. One of the missions of higher education has always included serving the community, and application projects are consistent with this mission. The focus of application projects on student development and community service merits respect and further study.

In the first half of the last century, Alfred North Whitehead (1929) advised higher education administrators and faculties not to lose sight of the fact that universities need to support the advancement of practical knowledge. The

experience-oriented learning promoted by application project activities embraces Whitehead's pragmatic philosophy. Bill Donovan (2000) asserts that several factors following the end of World War II have led to the concept of the "corporate university" which appears to be in vogue in the present day. Application projects might thrive in the business-minded environment of today's colleges and universities.

As Donovan (2000) also points out, there has been particular emphasis in recent years on research—particularly undergraduate research—and a third purpose for application projects is that they can promote undergraduate research. An example of a project that has undergraduate research potential involves investigating the process of organic breakdown by a particular enzyme under different concentrations and temperature conditions. In this example, one item of potential research interest might be the chemistry behind food preservation (Alcuaz, 2002). Of the roughly 300 projects summarized on the institution's web site for this study, no fewer than 100 suggest areas of fruitful research. The business-mindedness of today's higher education, together with a heightened sense of the importance of undergraduate research, provide a logistical setting that appears to stimulate applications project endeavors.

One does not need to be overly civic-minded to attach social value to application projects. In this regard application projects have much the same "community value" as does service-learning. Robert Rhoads adds his own personal accounts of social awareness to assist in describing the need for a

caring society. Rhoads nicely elucidates the concepts of civil cohesion and “value in caring” in his work. Application projects have the potential to extend “the good” beyond the student’s own learning experience by providing society with a potentially valuable source of mathematically oriented advice through students’ project work. There are also opportunities for meaningful social exchanges between project students and those persons they collaborate with in the process of producing their projects. As Rhoads suggests, the germ of social awareness is often contagious; it’s likely that others become socially aware upon contact with a person who genuinely cares (1997). Application projects, with their allowance for a sentiment of “caring,” appear to be particularly desirable in the field of mathematics since many students view the field as “cold” and “uncaring.”

In addition to the reasons mentioned above, there are solid academic purposes for application projects in undergraduate mathematics courses. Project students may acquire important skills associated with mathematical applications; projects may also help students with conceptualizations that non-project students might fail to attain. Madison provides an insightful description regarding the condition of the modern mathematics curriculum:

Over the past century, while introductory college mathematics courses have changed little, major changes have occurred around them. First, U.S. society of the 21st Century is vastly different from that of a century ago. Second, the college population now consists of the majority of typically eligible Americans while a century ago only a select few even finished

secondary school. Third, remarkable technological developments have added potential cognitive power along with educational challenges about how to use the extra power. The quantitative demands on Americans for work, personal welfare, and citizenship have increased enormously. No longer is it acceptable to be mathematically or quantitatively illiterate, but there is convincing evidence that many, if not most, college graduates are unequipped for the quantitative demands they will face daily (2004, p. 4).

The changes Madison has identified are undeniably real and their impact on American higher education is becoming increasingly evident as we progress further into the twenty-first century. Since it is the role of higher education to properly prepare students for their participation in the world, the promotion of any program that helps students better understand mathematics would appear to be good practice. Application projects encourage some students to involve themselves with the community and this means incorporating the use of technologically advanced equipment in their project work. This technological exposure is important in addressing Madison's third change. It is reasonable to consider experiential approaches to be a superior way to educate students and prepare them for the real world including, what Madison calls, its ". . . societal demands" (2004, p. 4).

Evaluating the Effects and Implementation of Application Projects

There are two fundamental levels, and one "bridging" level to the application project program. The first is student level, and this is pragmatically

the most important since students are required before further academic entities can be considered. The subsection entitled "*The Student Level*" begins a discussion of the effects of application projects on students that is continued with the subsection entitled "*The Institution Level.*" The instructor's role in a project program is one that effectively includes the student and institution levels since instructors both represent their institutions and work first-hand with their students. The final subsection entitled "The Instructor Level," which looks at the bridging function of instructors, caps the discussion.

The Student Level

Assessing the effects of any component of higher education is a complex and difficult task. As noted, there are no studies available that specifically concern application projects. By considering a few cases in the similar areas of service- and project based learning some sense of the workings of application projects can possibly be gleaned, however. It seems reasonable to begin with a consideration of real world application projects from the perspective of the student.

One reason why students might elect application project options is that they feel that they will ultimately learn more by going this route. In a study conducted by Eyler and Giles a positive correlation was reported between a student's project participation and the student's ability to demonstrate understanding of course objectives (1997). While the project program Eyler & Giles considered was conducted within a classroom setting so that any

generalization to the application project program of concern to this study is not possible, their results may still have some relevance here. Eyler and Giles concluded that it was the participation in the experiential activities that aided many students in the understanding of basic concepts. Their study offers encouragement to the planned use of grades in phase one of this study.

Astin, Vogelgesang, Ikeda, and Yee (2000) conducted a multi-institutional study involving academic outcomes that also concerned the distinction between the two groups: course-based service-learning and generic community service where students served without any course connection. These researchers emphatically conclude “. . . [f]or all academic outcomes as well as for some affective ones, participating in service as part of a course has a positive effect over and above the effect of generic community service” (p. 15). The authors noticed that both course-based service-learning and generic community service had positive effects on academic achievement, but course-based service-learning showed an even greater effect in their study. Even though service-learning is not equivalent to application projects, the results still suggest why project students may similarly demonstrate academic achievement that is comparable to, or exceeds, that of non-project students. The findings of the study are compatible with those of the Astin, et al. study, as will be described in Chapter Four.

Pragmatism connects any program assessment to the broader concept of improving society. Dickstein’s description of pragmatism elucidates the concept

that “[t]ruth is the outcome of experience” (1998, p.7). Dickstein descriptively adds that through pragmatism one “. . . sees things not in isolation, not as essences existing in and of themselves, but as belonging to contexts that shape their meaning and value . . . [and that] truth . . . [is] always in formation” (1998, p.8). Furthermore, Fish asserts that the current thinking about pragmatism is that it ideally “. . . leads to forms of behavior that make the world a better place and you [the individual] a better person . . .” (1998, p. 425). This is in total agreement with the goals of general education. Educators at all instructional levels uphold the democratic principles pragmatism incorporates.

The student often knows what she or he wants from a course and can get more of those desired elements if allowed some discretion to self-direct his or her learning. This self-direction can be facilitated through an application project, especially when mathematics courses are involved. Projects allow for many elusive concepts of college mathematics to be internalized. Furthermore, application projects are pragmatically appealing because they improve citizenship and, consequently, society (Fish, 1998).

Students’ motivations for involving themselves in “service” were considered by the researchers Bringle, Phillips, and Hudson. Adapting what these authors present, one might assert that project students have various motivations for electing the project option and that “. . . [t]hese motivations could include humanitarian concerns, increasing the students’ academic knowledge, providing opportunities to make connections with other students, clarifying career

decisions, and obtaining experiences that will make the student attractive to employers” (2004, p. 38). Application projects might even allow some students to enhance their academic careers, and in the long run these students may prove to serve the community to a larger degree than they would have had they not undertaken an application project.

The present research takes place entirely on the “student level;” however the extended arena of application projects certainly includes the institutional and instructor levels. Since institutions and instructors are also of importance to application projects, the discussion continues with consideration for these elements.

The Institution Level

The individual institution’s position on application projects and its involvement in the program are certainly important. The application projects program, as with any other student program at a given institution, could not persist without the institution’s endorsement. Measures of the level of “institutionalization” of application project types of programs have been gaining acceptance over the last decade (Bringle & Hatcher, 2000). Institutionalization is the formalized recognition of an entity within a larger structure. In the context of this study, the institutionalization of an application project type of program manifests itself as a bureaucratic structure with its own administrative personnel and with a structured plan of operation. Some researchers have pointed out, however, that administrators and instructors often do not connect (Carson,

Lanier, & Carson, 2001), so that institutionalization of application projects may not actually yield the desired benefits.

In a report produced by Skinner and Chapman concerning U. S. K-12 public schools, they found that “[f]our-fifths of all schools (84 percent) that reported they had some level of service-learning and/or community service also reported they did not receive outside financial help to fund the program(s)” (1999, p. 11). (As noted in the Definition of Terms section in Chapter One, service-learning and application projects are not synonymous, although they do share characteristics.) This finding seems to suggest that some administrators of service-learning and community service programs at the K-12 levels are not motivated to seek the available funding for these programs. One possible reason administrators might have for failing to participate in government funded programs may be a general unwillingness to defer control of their program to the funding agencies. These same authors also exhibit results showing that from 1984 to 1999, a period of only fifteen years, the percentage of high schools that reported offering community service programs increased from 27 to 83 percent. Over the same period the percentage of high schools that reported to have service-learning programs increased from 9 percent to 46 percent (p. 12). Clearly, community service programs are gaining popularity at the K-12 level, despite an apparent aversion to applying for funding. These results provide a sense of the educational and civic value of service programs that higher education may share with the remainder of the educational system.

The Instructor Level

In a case involving Franklin Pierce College, Pratt observes that some of Franklin Pierce's faculties are forced to examine their own civic awareness in applying the school's Individual and Community program. Pratt further informs us that ". . . any approach designed to enhance [program] coherence . . . is likely to entail some sacrifice of our customary autonomy in the classroom" (2002, p. 161). This sacrifice of autonomy is evidently a significant barrier to instructor acceptance of experiential learning in general. Instructors may be threatened by a loss of power associated with the usual instructor-structured objectives, and they may fear that they will lack expertise in an externally developed problem area that might lead to a loss of prestige and, as instructors may view it, power.

In addition to instructors' fears of disempowerment that may arise from the consideration of application projects, there seems to be an underlying "suspicion" that project approaches are academically inferior to traditional ways of teaching undergraduate mathematics. Perhaps due to the "service" nature of some application projects, few seem to question whether the students involved actually benefit from their project work. After all, many application projects promote community service, and student involvement in service to the community would appear to be good. Still, there is a desire to better understand why students choose to do projects, what they seek academically and socially from project work, and whether they actually experience any academic or social gains from them.

Mathematics is a unique field. On one hand, the principles are pervasive to all other fields of study; on the other hand, mathematics stands alone in its abstractness. But, regardless of its abstract nature, Rogers and Freiberg comment that mathematics need not be ". . . devoid of any emotional content . . . [and] teaching . . . [need not be] independent of any emotional content" (1994, p. 134). There is no reason for mathematics to be cold and emotionless. Application projects allow some students to enjoy learning mathematics as demonstrated by the interviews conducted as phase two of this study. Student responses provide evidence that enjoyment and course satisfaction is linked to project work. The details of these findings, together with students' motivations for choosing (or for not choosing) the project option and their views on the "non-academic benefits" of project work, are discussed in Chapter Four.

From the available literature it appears that some students are perfectly satisfied to conduct their studies within a "pure test" structure. In particular, an important study by Romey (1977) suggests that the "status quo" of maintaining order by limiting educational "freedom of choice" finds no objection from the student population or from the faculty. Indeed the idea of educational autonomy may truly overwhelm some students. This appears to be the findings of the Romey (1977) study where an attempt was made, at a certain liberal arts institution, to completely remove the standard classroom environment. Every student at the university began independent projects. As it turned out there were some students who were able to do well under the reformed approach, but about

as many wished there were those familiar structures of classes and standard testing practices to give them the structure they needed. Today, the institution offers both educational approaches. As Rogers and Freiberg put it, the university administrators were “. . . even democratic enough to permit divergence from innovation. Neither faculty nor students are *forced* to be free. They can choose the mode of learning and teaching with which they are most comfortable” (p. 131). As in the Romey (1977) study it appears that the best solution is to give students a choice, and project courses allow students to follow either the familiar written Final Examination approach or to embark on an application project approach. The availability of optional application projects is at the discretion of instructors, so its up to them to supply a bridge for those students who may choose to cross it.

Grinshpan's Particular Bridge

The project instructor as bridge analogy is a reasonable one for it is by way of the instructor that many students are able to academically succeed. One might visualize project instruction as a sturdier bridge that allows for more traffic. The “project instructor bridge” allows a student to cross in different ways. A student might cross in a traditional manner (like walking) or try something a bit different (like taking a train across). A student might prefer to do things in a non-traditional manner and, if so, that student would be pleased to know that he or she can at least consider trying a different approach. What follows was drawn from a personal interview (cited upon conclusion of this section) with Dr.

Grinshpan that was conducted on February 17, 2006 explicitly for the purpose of addressing the method of grading.

To continue the bridge analogy, one might wish to observe that a bridge has no purpose if people don't use it. Furthermore, one might surmise that the best bridges exhibit the largest measures of traffic. This illustrative description applies expressly to the project instructor of concern to this study. Grinshpan is motivated to provide project options primarily as a means of increasing the traffic flow; that is to say that he wishes to see more students become academically successful. The project instructor featured here is the only instructor offering project options at the institution of concern to this study.

Grinshpan believes that projects have multiple positive effects on students, and directly or ultimately, on society as a whole. He has himself used a similar bridge analogy as regards himself and undergraduate mathematics education. Grinshpan has stated that he sees the condition of poor academic performance (seen most blatantly in the overall failure rate) in undergraduate mathematics to be one that cannot continue. From an administrative standpoint project options are to be considered an improved product, i.e. a better way of teaching. He has also mentioned the 'fact' that there is no increased concern of potential academic dishonesty since he can generally tell when project work is performed primarily by the student. If there's a question as to a student's real contribution to the work he or she may present, he speaks with him or her about

the details of the project. Grinshpan reports being aware of only a couple of cases where academic dishonesty was suspected.

When questioned about what criteria are expected in project work to correspond to the institutionally accepted grading scale, Grinshpan has specifically identified usefulness as a hallmark of superior work. He says that good projects describe real world applications of mathematics, and provide something “useful to the community.” Good projects describe the students’ learning and discovery processes as their application projects develop. Grinshpan uses a mental rubric involving these and other concepts that may or may not be active elements of a given project (for example, the additional element of direct community service may or may not exist). He wants students to experiment openly with their application projects and not worry about the grade. He says that when students come to him with problems, he attempt to calmly work with them to get the problem solved. Grinshpan speaks of the personal interaction between himself and his students as a way to gauge the students’ levels of understanding and aid in the grading process. Grinshpan appears to provide students with their grades using his mental rubric. For purposes of research validity, this grading rubric is described below.

In describing the project option, Grinshpan first points out that project work is personal. He explains that he must speak with the students in order to understand the particular microenvironment of the student and their application problem. At the very least a project must convey an application of one or more

mathematical concepts focused upon in the course. If this were done minimally, it would be awarded a similarly minimal grade. A demonstration of deeper understanding awards a higher grade. Relative levels of applicability and fuller understanding elevate mediocre D and C projects into the more academically desirable B and A levels.

Furthermore, Grinshpan states that he really doesn't view projects as being greatly different from Final Exams as means of evaluating his students' work. He points out that many students have jobs or otherwise have a readily available project scenario in which to develop a project. These students can learn something that might benefit them and their employers directly. Other students may lack a readily available environment or simply do not wish to go the project route. Either way, students are graded first for their basic understanding of the concepts (this much is expected and is generally awarded an average grade), and then it is determined how far they take the concepts, work them, and understand them (Grinshpan, personal communication, February 17, 2006). While there is the application component that seems to be without an approximate written test component, it appears that it is possible to deliver relatively valid scores across groups using the very basic criterion of "basic conceptual understanding" as a guideline. It is beyond the scope of this study to investigate the matter of validity and replicability of grades. This remains a limitation of the study as was noted earlier.

Grinshpan concluded the interview that yielded the above information by noting that things are still being developed, including the grading process. Another important recent development is that there is a current push toward generalization of education. This is the interdisciplinary concept mentioned earlier. It is interesting that educators are coming back to an appreciation of general education and its ability to allow students to integrate the “best of multiple disciplines” (A. Grinshpan, personal communication, February 17, 2006). This much is in agreement with the mantra of twenty-first century education: things are always changing; only now, they’re changing faster.

What Educational Approach is Best?

The question as to what and how to teach undergraduate students is undeniably one of society’s most enduring and relentless queries. As many researchers, such as several of those presented in Clark and Wawrytko’s (1990) work, have observed, the use of experiential approaches in education is not new and such approaches allow for fuller student involvement in their own educational processes. “Experiential approaches,” as used here is indicative of learning that is hands-on whenever possible. Experiential learning is usually personally meaningful to students, since they may better relate to the concept being explored when their learning involves first-hand experience. Posner aptly suggests the following definition: *Experiential learning* connects more easily with “. . . their [students’] ordinary life experience . . . [and it is] less contrived and artificial, and students will grow more and become better citizens” (2002, p. 17).

The concept is founded on ideas concerning educational improvement proposed by John Dewey (1933) in his work *How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process*. Posner describes the continuing Deweyan “challenge” of experiential education, one that now extends into a new century, “. . . to understand how curriculum can be considered in the broadest possible way, as whatever experience fosters the healthy growth of further experience, and to develop clear and workable principles to guide practical decisions about such curricula” (2002, p. 10).

One way to meet the curricular challenge described above was suggested by Knowles (1950) who proposed the concept of “directed self-direction” in education. Knowles’ idea is compatible with application projects since the instructor “mathematically mediates” the largely self-directed studies of project students. A review of write up drafts, together with the instructor’s student interviews, allows the project instructor to maintain the desired curricular framework. In order not to stymie the students’ experiences, the instructor appears to allow for a vast variety of project topics. Students are encouraged to go beyond the basic curricular framework, however. Such was the case with the Faza project, where the solution of a closed form extended beyond the usual calculus curriculum.

Another key element to a “good” learning experience is active learning. Chickering and Gamson recognize active learning as being part of competent undergraduate teaching practice (1987). When learning is exciting and the

learner is personally involved in her or his studies, learning is enhanced. Bonwell and Eison fully support this assertion, providing many examples that demonstrate how learning can be made active and consequently more effective (1991).

Chickering and Ehrmann state that “[g]ood practice uses active learning techniques” and further explain that internalization of the subject matter is facilitated through a constructivist perspective on learning. As Chickering and Ehrmann assert,

[L]earning is not a spectator sport. Students do not learn much just sitting in classes listening to teachers, memorizing prepackaged assignments, and spitting out answers. They must talk about what they are learning, write reflectively about it, relate it to past experiences, and apply it to their daily lives. They must make what they learn part of themselves. (1996, p. 5)

Accepting Chickering and Ehrmann’s description of good practice, and because the application project is an active, experiential approach, one might be tempted to infer that the application project is to be endorsed as a superior form of teaching model. However it is prudent to consider this matter with caution.

The core educational mission behind application projects is reassuringly similar to that described by Hadlock (2005) for service-learning in mathematics. The educational advantages Hadlock attaches to service-learning can easily apply as readily to application projects. As mentioned, application projects are not required to fulfill the strict service-learning repertoire. In particular, application projects need not have extra-institutional connections at all, but they often do

have valuable civic elements. Those projects that delve into the real world first hand, rather than those limited to the “real” research world have most of the components shown in Hadlock’s “educational mission” diagram (p. 9). Hadlock’s diagram helps one to visualize how application projects encourage and support positive areas of higher education. Figure 2 is a modified “Hadlock” diagram illustrating many of the defining features of “typical” application projects. Perhaps the most important of these are found near the top of the figure, namely mathematics, interdisciplinary activity, general education, and real world experiences.

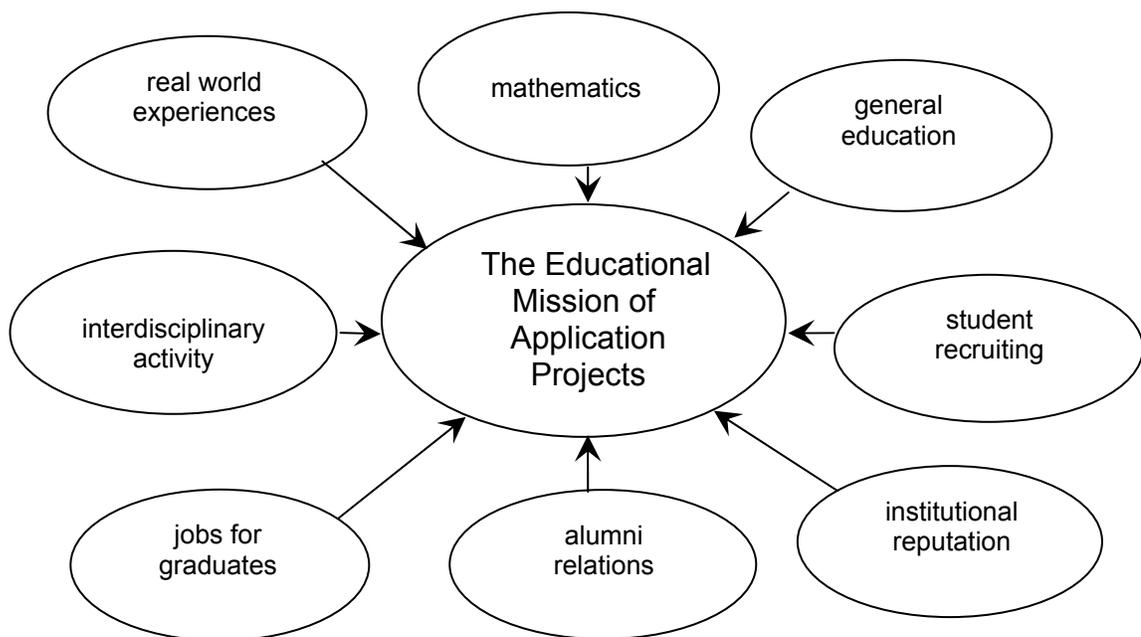


Figure 2. Illustration Depicting the Educational Mission of Application Projects
(Source: Adapted from Hadlock’s “educational mission” diagram, 2005, p. 9)

Zlotkowski (2005) emphasizes that “[o]ver a dozen national disciplinary associations have sponsored special projects, forums, or publications focused on engaged teaching and research” (p. viii). Undergraduate instructors are usually recognized to be experts in their respective fields, yet few of them are experts in education. Many instructors of undergraduate mathematics courses present their material in the same traditional lecture format that they encountered as students in their own college days. This lock with tradition is prevalent in science education, and the “lecture and test” approach is well entrenched across disciplines. Without some additional background into educational theory, “traditional professors” are likely to uphold their teaching methods as adequate and democratic. An undergraduate instructor trying to justify the lecture and test method might quote the wisdom of the old gospel song and say “it was good enough for Paul and Silas, so it’s good enough for the rest of us.” There appears to be apprehension on the part of instructors to try new approaches. In their results pertaining to a national study that utilized faculty interviews, Stark, Lowther, Ryan, and Genthon found that instructors in general taught “. . . as they had been taught” (1988, p. 227). Gardiner expresses similar concern for students that “. . . have difficulty learning abstractions from lectures. These students require active methods to grasp important concepts” (1998, p. 78).

Teaching well is what teachers aspire to do, and it can be argued that there is no approach to teaching that is inherently better than some other method. Nevertheless, researchers such as Stark and Lattuca (1997) have

considered historical trends in undergraduate teaching practices and have suggested that experiential approaches to teaching are being viewed more favorably as contrasted with other comparatively “static” teaching practices. Ehrlich (2002) explores four particular learning strategies: community service learning, problem based learning, collaborative learning, and interactive technology. Ehrlich promptly follows his optimism for the potential gains to education from these strategies with the sober reminder that “. . . strategies can make a difference, of course, only to the extent that they are actually being incorporated into the undergraduate classroom” (2002, p. 132). Additionally, Tellez (1996) and other researchers uphold the benefits of “authenticity” that give students more control over their learning. Application projects may offer students a way including their perceptions and experiences in their work and thus makes their efforts more meaningful and authentic.

The composition of the student population will tend to alter the effectiveness of any particular teaching approach. Consequently, diligent instructors approach their teaching with an eye toward student-centeredness. In this context “student-centeredness” is in the realm of a student’s community engagement and social awareness. The full sense of the “student-centeredness” concept is perhaps best elaborated in Carpenter’s work where he suggests that “[t]he question isn’t really about the ‘sage on the stage,’ versus the ‘guide on the side,’ but about how may we help ourselves and our students be delightful people?” (2000, p. 205). Carpenter makes sure that “we” are included in the

answer. All instructors are different and consequently they have different ways of doing their jobs. By the same token, all students are different, and allowing for a variety of educational experiences can heighten “our delight of diversity.”

Schneider offers various descriptions of innovative learning approaches and asserts that institutional approaches are often outdated and fail to properly meet the needs of the modern student (2004). Application projects may prove to be an effective part of a liberal education and a judicious way of addressing students’ needs and to make them cognizant of their individual societal importance.

The Application Project Experience

It is easy to understand that students learn best when they have a stake in the outcomes of their learning. A “stake” is a personal investment, and good outcomes are the ones students see as being particularly meaningful to them. The educational experience that undergraduates expect includes opportunities for social interaction, self-evaluation, and career exploration. A student’s success in any course will instill confidence that she or he will be similarly successful outside the classroom. The student-community interaction necessitated by application projects constitutes a very important aspect of project work.

Application projects may offer relief from inaction, but projects may also be responsible for distracting students and instructors from the primary course content. Researchers McArthur and Lewis, for example, have reported that assignments similar to application projects may exhibit certain drawbacks relative

to students' inability to make the desired connections between their project work and specific mathematical concepts (1991). However, it should be considered that the educational assignments McArthur and Lewis studied were of a very specific and technological nature. It is likely that revisions to the design of their "microworlds" could have corrected the problem of failed objectives. The application project program, being less formal and having a wider subject range, may not encounter the problems that McArthur and Lewis discuss. One of the components of the analysis in this investigation, the comparison of grades from students' third tests, is expected to show that application projects do not distract from the mathematical content of project courses. Results suggest that application projects actually enhance the understanding of mathematical concepts.

The concerns for the typical undergraduate non-math major entering into an applications project experience extend beyond the particular objectives in a given mathematics curriculum. For project students the concept of "distraction" from the normal course objectives does not apply; instead the opportunity to undertake an applications project can be an exciting endeavor for the student. Indeed application projects may elevate learning to the status of a far-reaching educational experience. Application projects adhere to a curriculum philosophy referred to as the "structure of the disciplines perspective," which Posner (2002) describes as being somewhat of a compromise between liberal arts and specialized training. As Posner explains, educators who extol the virtues of the

structure of the disciplines perspective believe that learning works best by “. . . engaging students of all ages in genuine inquiry using the few truly fundamental ideas of the disciplines, and students will develop both confidence in their intellectual capabilities and understanding of a wide range of phenomena” (2002, p. 17). The structure of the disciplines perspective reminds educators that the disciplines are dynamic, and it reminds undergraduate mathematics educators that there are always different approaches to the exploration of a mathematical concept. There is value in the breadth of the structure of the disciplines perspective as applied to mathematics or to any field of study. For instance, the variety allows more students to find a related element with which to connect.

While pure mathematics is supposed to transcend usefulness, the undergraduate non-math major normally isn't concerned with the “pure” world of mathematics. Part of what the structure of the disciplines perspective offers is the idea that non-math majors should be free from the minutiae of advanced mathematical theories. For all but those few students dedicated to becoming mathematical scholars (i.e., math majors rather than the non-math majors featured in this study), theory does not need to be the instructor's primary learning objective (Lewis, McArthur, Bishay, & Chou, 1992). Learning is more meaningful when students can use what they learn, and “usefulness” is a central idea in any application project.

According to the foundational education theorist Benjamin Bloom, application demonstrates a higher form of learning than does acquisition of knowledge (1956). “Doing” generally requires more than simply “knowing,” therefore, it would be expected that students who demonstrate higher forms of learning would earn higher grades. This further justifies the use of the grades from the third test as an appropriate measure of students’ outcomes in phase one of this study.

In a recent publication, Carol Geary Schneider informs us that while there are concerns about the undergraduate curricula, we can salvage their educational experiences through “. . . more active connections with the community, intercultural and collaborative problem solving, and a new focus on helping students integrate the disparate parts of their learning” (2004, p. 6). From this description, Schneider suggests that curricular improvement might be possible through the integration of application projects. Furthermore, Schneider’s view of “holistic integration” is consistent with the subjective spirit of project teaching.

Application projects require the inclusion of written descriptions of mathematics in real-world settings, and the mathematics must be part of the content covered in the particular course in which the project student is enrolled. Both the concept of “mathematics in action in a real-world setting” and the question as to what is a sufficient “part of the course content” are intentionally left rather vague. Students are required to personally discuss their project proposals

with the instructor if they are not certain that their designs are appropriate. Most of the time a student's idea can be properly adapted for project purposes (A. Grinshpan, personal communication, 2005).

Summary

This chapter investigates the available literature concerning programs similar to application projects. Research to-date has uncovered little indicating positive relationships between an undergraduate, non-math-major's grades, time on task, or positive regard toward mathematics and application project participation. One study actually indicated no positive advantage to project learning assignments. In the Gray et al. study, for example, students self-reported that they did not see any academic improvements by taking part in a type of project program (1999).

Reviewing related literature concerning application projects brings reassurance that overall, application projects provide a desirable method of learning. The desirable aspects of application projects include their potential abilities to provide opportunities for students to make mathematical connections with the real world and to participate in personally meaningful activities. The rationale behind application projects is nicely summarized by Posner's (2002) words: Students gain ". . . confidence in their intellectual capabilities and [an] understanding of a wide range of phenomena" (p. 17).

The literature concerning application project types of programs probes into the aspects of student motivation; however, the research is very sketchy. Several

studies, for example Bringle et al. (2004), derive important student outcomes from community service participation. Another study of importance is that of Switzer et al. (1999) where undergraduate “feelings” were measured in comparison to other groups. These studies support the contention that undergraduate students (not only project students) feel strongly about matters of civic engagement.

Chapter Three

Method

This study seeks to assess application projects both quantitatively and qualitatively from two separate data sources, within a common environment. The first portion to be described is a quantitative approach that considers student benefit measured by academic achievement on a common third test. The second, qualitative portion seeks a better understanding of the reasons students undertake projects, and seeks to more fully account for student benefits by allowing students to describe their project experiences and to describe the knowledge and skills gained while working on their projects. The intent of this study is to investigate whether there is a relationship between application project participation and enhancement of students' course performance and their valuing of mathematics. This chapter presents the research questions and hypotheses, participants, instrumentation, and process of data analysis.

There are five research questions to be addressed. The subsequent description of research processes is referred to as "phase one" (the quantitative portion) concerned with Research Questions 1 and 2, and "phase two" (the qualitative portion) pertaining to Research Questions 3, 4, and 5.

1. Do non-math major undergraduate students who are more mathematically proficient (or less mathematically proficient) tend to choose the project option rather than taking a Final Exam?
2. Is there any significant difference in the common third test grades among non-math major undergraduates who completed one of the two mathematics courses (MAC 2242 Life Sciences Calculus II and MAC 2282 Engineering Calculus II) with application projects as compared to students who took these same courses without electing the application project option at one large, urban university?
3. As indicated by interviewee responses of the non-math major undergraduates enrolled during the spring of Year 3 in MAC 2242 and MAC 2282 (the same two mathematics courses specified in Research Question 2), with an application project option and those who did not elect the project option: is there a difference between the two groups' perceptions toward mathematics?
4. From comparisons of interviewee responses (currently enrolled non-math major undergraduates electing application projects and those who did not elect the non-project option): is there a difference between the two groups' levels of course satisfaction?
5. By comparing the interview data for students electing the application project option with those responses of non-project option interviewees:

is there a significant difference between the two groups' reported levels of time on task?

Corresponding to the five research questions above, the findings were hypothesized to respectively reveal the following five specific results:

1. There is no particular tendency for academically weak or strong students to elect the project option (or to take the Final Examination).
2. Grades on the common third test (in MAC 2242 and MAC 2282) for undergraduate non-math majors in participating in application projects will be superior to those of nonparticipating students.
3. Undergraduate students in the project group will report having more positive perceptions toward mathematics.
4. Undergraduate students in the project group will report higher levels of course satisfaction than those in the non-project group.
5. Undergraduate students in the project group will report higher levels of time on task than will non-project students.

The practice of application projects in certain mathematics courses is critically analyzed using the common third-test grades (phase one) and student responses to personal interviews (phase two). The findings suggest that there are possible benefits to students who undertake application projects in certain mathematics courses. The basic procedure involved comparing outcomes and attitudes of application project students and "traditional," non-project students.

Participants

Table 1 provides a quick reference to the participant groups for the complete study. It should be made expressly clear that the first phase was comprised solely of data that was already (at the time the study began) collected and recorded. This researcher was not in any way involved with the grade data in phase one until the instructor had gathered it. On the other hand, this researcher was intimately connected with the gathering of phase two data, the student interviews.

Table 1.

Numbers of Data Points for Phase One (PI) and Participants for Phase Two (PII)

Course ^a	PI: Fall Year 1—Spring Year 3 (<i>n</i> =273)		PII: Spring Year 3 (<i>n</i> =15)	
	Non-project	Project	Non-project	Project
MAC 2242	82	107	4	3
MAC 2282	34	50	3	5
Total	116	157	7	8

^aMAC 2242 is Life Sciences Calculus II and MAC 2282 is Engineering Calculus II.

The first phase employed a sample of 273 participants, namely those undergraduate mathematics students who have taken mathematics courses that provide an optional application project during the four semesters from Fall Year 1 to Spring Year 3 at one large, urban university. Of the 273 total Test 3 scores,

116 were derived from non-project students and 157 from project students. In order to maintain student anonymity, participant demographics were not considered and no personal information was collected during either phase of this study.

Following the initial consideration of data relative to tests one and two associated with Research Question 1, the primary process of quantitative analysis, students' third test grades, was analyzed in association with Research Question 2. To answer Research Question 2, a comparison was made between those who were application project students and those who were not. The resulting set of 273 data points were employed for the first phase comparison of the study. Chapter Four goes further into the initial question of academic homogeneity between groups and the subsequent consideration of the test three results.

Since students who were currently enrolled were more accessible than those who had been enrolled during previously semesters, the participants for phase two of the study were solicited from the subset of those who were enrolled during Spring Year 3 in courses allowing for application projects, namely, MAC 2242 Life Sciences Calculus II and MAC 2282 Engineering Calculus II. In addition, those students who were currently enrolled could report their experiences more contemporaneously to their interviews than could those who had taken their courses in previous semesters. Thus, it was reasonable to target this subgroup of the entire application projects population. Of the 415 students

enrolled overall in the 12 sections (8 Life Sciences and 4 Engineering), fully one-third (142) had either withdrawn from their courses or failed to obtain a grade of *D-* or better. The one-third figure for “incompleters” was generally consistent across courses with a slight increase in Engineering sections. The dismissal of consideration of the large number of “incompleters” has been recognized as a serious limitation of the study, however the difficulty of including these students made it necessary to accept the restriction to completers in the design protocol. While it is possible that a Final Exam student may have been interviewed and still subsequently classified as an “incompleter,” this is thought to be unlikely. No project student was so classified, since all students who completed projects during the spring semester of Year 3 (in either the one Engineering or two Life Sciences sections) obtained a *D-* or better (A. Grinshpan, personal communication, June 23, 2006).

Students were approached and interviewed with relative convenience, often before or after their classes. Interviews were administered during the spring semester of Year 3, near the conclusion of their project courses, at a time when most students had finalized their decision as to whether or not to elect the project option. Interviews continued in number up to a point of saturation. Effectively, no new information was likely to be obtained by interviewing more than fifteen. The minimum number of students was originally set at seven from each group. One additional interview was performed in the project group prior to the decision to

halt the interviews. The additional interview was included in the descriptive portion of the study.

The instructor agreed to allow his students to be contacted personally by this researcher upon the completion of appropriately sequenced class sessions (nearing the third test event). The students either voluntarily remained after class, or met in a nearby area in the same building, in order to respond to the interview questions. The details of the information provided to students are outlined below.

Students were assured that their participation in the interviews was completely voluntary. They were also told that they were participating in an important educational research project, the results of which would be published. Students were provided with a copy of the Participant Letter of Information (see Appendix A) in compliance with the University of South Florida's Internal Review Board (IRB). The letter is a document ensuring that "Informed Consent for an Adult" has been provided to human participants in Social and Behavioral Sciences research. The form made very clear that potential interviewees should consider all consequences before volunteering. The risk to participants was minimal, and every effort was made to fully comply with the regulations of the IRB.

For the complete interviews it was desirable that interviewees participate voluntarily. Seven or more student interviews were administered in each group. Students were not monetarily compensated in any way for completing their interviews. No new themes emerged during the last couple of interviews in each

group (that is, after five or so interviews), so interviews were concluded after seven or eight interviews per group. The theme base seemed to stabilize rather quickly. It appears that “common theme saturation” was obtained from the fifteen interviews conducted, and that these fifteen were sufficient to provide desired insights into the election of project work. These insights are described in Chapter Four, and possible related implications are considered in Chapter Five. The interview portion of the study was conducted entirely during the spring semester of Year 3.

Instrumentation

Phase one involved no instrumentation for obtaining data beside the necessary protocols attached to making students’ test grades available for research purposes. As discussed in section “Phase One Data Processing,” the phase one data was collected from one source: the project instructor. In phase one, student names and any other personal information that might normally be attached to the test grades were suppressed.

The instrumentation for phase two was a protocol containing a series of interview questions. The three basic areas touched upon in the interviews involved students’ (a) course satisfaction, (b) appreciation of mathematical applications, and (c) time on task, that is, the amount of time the student spent toward meeting the course objectives. Questions 2, 5 and 6 were intended to add potential detail to students’ responses concerning the areas of course satisfaction and amount of time spent toward meeting course objectives.

With the rationale that there may be differences between the levels of academic and real world experiences between students who attended day versus evening sections, questions were included to determine what year of college the students were in, the time of day students attended classes, and whether they attended part- or full-time. The interviewer attempted to allow appropriate time between questions for the interviewees to mentally compose and deliver their responses. Interviewees were asked the following fifteen questions.

1. Did you complete a project or did you take the Final Examination?
2. What year of college are you in right now?
3. What area was the focus of the math course you completed:
Engineering or Life Sciences?
4. If you completed a project, what do you think about including projects in the course curriculum?
5. At what time of day did your section of the course meet: morning or evening?
6. Were you a part-time or full-time student during the past semester, and were you employed during this time?
7. Why did you take the Final Examination, rather than completing a project? Or, why did you complete a project, rather than taking the Final Examination?

8. What is your opinion about having two options (the project and non-project options) in this course?
9. Do you feel that your conception of the usefulness of mathematics has changed as a result of this course? Why or why not?
10. Has your attitude toward mathematics changed as a result of doing a project / preparing for and taking the Final Examination? If so, please describe.
11. How many hours do you think you studied (and/or did project work) for your course last week?
12. How many hours do you think you studied (and/or did project work) for your course the week before last?
13. How many hours do you think you studied (and/or did project work) for your course the week before that (in other words, 3 weeks ago)?
14. What is your current estimated overall grade point average (before this semester)?
15. Is there anything else about the class (or math education in general) that you would like to add?

Several of the above questions anticipated quantitative responses, however these self-reported values were not statistically tested. Interview Questions 11 through 13 were included to challenge the hypothesis that project students demonstrate higher levels of time on task than do non-project students. Most of the questions were designed to elicit open-ended responses that require

some probing to prompt a fuller qualitative account. There are numerous ways to handle qualitative data of this type, however it was reasonable to use pattern coding. The idea is to gauge and categorize interviewee response. Using pattern coding, responses to the interview questions were analyzed. From this analysis a “degree of attitude toward mathematics” was inferred. In particular, the pattern coding involved certain recurring themes in interview responses. These themes were noted and then looked for in the responses of other interviewees. As Bazeley (2004) notes, “. . . the supporting text is available for review or further interpretation” (p. 397), meaning that the researcher is able to return to the text transcriptions for further consideration of what particular respondents offered at a later date. Bazeley is only one of many scholars who endorse the methodical consideration of qualitative data. Also of particular importance in composing the present study are the writings of Creswell (2003), Patton (2002), and Tashakkori and Teddlie (2003).

This use of the interview data for further cross-referencing has proved to be quite valuable to the present research. The pattern coding approach contributes to an evolving and emergent overall understanding of the general themes that students have provided. As promised, this developmental process allowed the researcher “. . . the ability to retrieve supporting text to increase the interpretability of the results or to verify coding” (Bazeley, 2004, p. 398). The essence of qualitative exploration is a search for insight, rather than truth. It is this subtle emergence that may allow for a better understanding of the overall

respondents' dispositions as concerns learning mathematics with an option for project work. It is also expected that students' overall feelings toward application projects can be deduced. These interview questions on pages 93 and 94 are again presented in Appendix B.

Process of Data Analysis

Data were analyzed in two related phases; and were collected in two separate and unrelated processes. These phases are described separately in the following subsections. The phase one portion of the study was conducted using data from the fall semester of Year 1 through the spring semester of Year 3. The phase two portion of the study took place toward the end of the spring semester of Year 3 and involved only those students enrolled during the spring semester of Year 3.

Phase One: Common Third-Test Comparison

Data for quantitative analysis in phase one were the instructor's assigned grades for the common third test for the population sample, $n=273$, of undergraduates previously enrolled in an application project course at the large, urban university involved in the study. Data for the common third test grades were categorized into project and non-project groups.

It should again be mentioned that the initial similar mathematical ability question of Research Question 1, which asks if non-math major undergraduate students who are more mathematically proficient (or less mathematically proficient) tend to choose the project option rather than taking a Final Exam,

initially considers students' grades on the first and second tests during Spring Year 3 to examine students' mathematical abilities prior to project work. Tests one and two provided a means of investigating whether students were academically similar prior to project work (or Final Exam preparation). As previously noted, the data relative to tests one and two served a different function from that of test three. The rationale for collecting data on tests one and two was to use the early tests to show that no academic bias (weak or strong) existed between the two groups, i.e. the groups were not overwhelmingly comprised of students with lesser or greater mathematical abilities. The third test would then more faithfully gauge any greater academic strength in the project group over the Final Exam that might relate to project production. (The matter of equal ability is discussed further in Chapter Four.)

Collecting Instructor's Data for Phase One

As noted previously, common grades for test three were gathered for all students who took an application project course over the four-semester period from the fall semester of Year 1 to the spring semester of Year 3. The two courses being considered are Engineering Calculus II and Life Sciences Calculus II and data were first separated by these courses. A distinction was later made between morning and evening sections of the two courses, and then between various semesters. There was also a breakdown for particular course sections (classes) that served as the unit of analysis.

The analysis excluded incompletes, as explained below. The goal was to determine whether application projects have an effect on students' third test grades. Appropriate statistical tests, in particular *t*-tests (with $\alpha=.05$), were used to compare the project and non-project groups throughout the first phase. More is said of this in the Phase One Data Processing section that follows.

The instructor provided the data for each student included in the study in an anonymous and standardized format. The information needed for each student in phase one is summarized in Table 2 below. A separate analysis was conducted within the course, section, and semester subgroups. Since there was no significant deviation between these initial subpopulations, an aggregate analysis was performed. Details of the analyses are presented in Chapter Four.

Table 2.

Information Obtained for Each Student in Phase One

Item number	Label	Description
1	Student label	Anonymously distinguishes individuals
2	Approach	"Project" or "Non-project"
3	Subject	Course subject
4	Section	Course section
5	Year	Academic year course was taken
6	Semester	Semester course was taken
7	Time	Course met during "Day" or "Evening"

8	Test 1 grade	Used to initially gauge math ability
9	Test 2 grade	Also used to initially gauge math ability
10	Test 3 grade	Used to gauge ability by approach

Phase One Data Processing

The instructor's assigned grades for Test 3 for the population being considered were drawn from one source, namely, the instructor's records. The collection of data included all third test grades awarded to completers. This meant that only the third tests for each section involved were considered during this first phase. The students' final grades were not comparable due to the choice given to students of taking a Final Exam or doing a project.

All non-mathematics major undergraduate students in MAC 2242 and MAC 2282 who were students of one particular instructor over a four semester (two year) period, and who received a final course grade of *D-* or better, as described below, were included in phase one of this study. The method involved compiling common third test grades and producing statistics for the two groups: project and non-project, as mentioned above. First, it was necessary to evaluate groups within a specific course. Since there may have been unexpected differences between the two courses, between two sections of the same course, or between semesters, immediately combining the participant subgroups may have been imprudent, and statistically improper. Again, pooled statistics were

obtained after the course, section, and semester variations were shown to be insignificant (see Chapter Four).

Choosing the described method allowed phase one of this study to have a sample of 273 participants. This sample size was large enough to provide power to any statistical results. Both phase one and phase two of the study includes students electing to participate in application projects as well as those who chose the non-project option. The design of the analysis was to use the last common test grade and compare the results for the two groups. Since students who ultimately elect the project option may have directed little or no effort toward their project at the time that the first or second test is given, it was determined that it would be best to use grades from early in the semester as a means of establishing students' academic homogeneity prior to their finals or project submission. Later in the semester, certainly by test three, students have decided to either prepare for the Final Exam or produce a project, so that their results on test three could more properly be viewed as being connected to their Final Exam preparation or their project work.

As noted in the Limitations section in Chapter One, there was a concern that academically stronger students were the ones predominantly electing to do projects. In phase two of this study students were asked to provide their grade point averages (GPAs). The GPA data served as a means for further establishing the academic similarity between groups. The limitation inherent in the use of grades as a measure carries through to GPAs, of course. Moreover, it was

possible that students who elected projects were academically stronger in mathematics in particular, but not necessarily in overall GPA. With this in mind, the GPA measure may not be an adequate control for reliable resolution of the “initial similarity question” of Research Question 1, but it does at least provide something limited to work with. To reduce, while not eliminating, the concern about the inconsistency of grade values returned by the small sample of interviewees, the two common tests prior to the third were considered in order to obtain a measure of mathematics achievement prior to test three.

Proper categorization of the student data to either the project or non-project group is not difficult when the student either took the Final Exam or produced a project; however, some confusion would arise as to the proper placement of those students who neither took the Final Exam nor produced a project. This potential uncertainty made it necessary to eliminate from the study those students who failed to pass their project courses due to “insufficient effort” (i.e., not taking the final or producing a project). An attempt was made to provide proper categorization of all other instances of grades (*A* through *D-*), which historically comprise roughly two-thirds of those students initially enrolled. Were the failures to be included, these cases would *all* be assigned to the non-project group (since project production defines project student status), biasing the results in favor of the project group. It would not be appropriate to classify all project course failures entirely to the non-project group, so the only recourse is to exclude the cases where students failed to secure passing grades. As a matter of

preference, the term “incomplete” is used here to include all grades other than those that generally equate to course credit, i.e. all *F*'s, *W*'s, *I*'s, *U*'s, and *M*'s.

Phase Two: Student Interviews

Phase two involved the use of student interviews to obtain information regarding Research Questions 3, 4, and 5. The responses were analyzed and compared across the project and non-project groups. There were seven participants from the non-project group and eight from the project group, for a total of fifteen, participating in phase two. The interview approach had the advantage of being able to probe the interviewee for in-depth responses. The interview questions are listed on pages 93 and 94, and again in Appendix B.

Conducting Phase Two Student Interviews

Three informal pilot interviews were performed in order to gauge the appropriateness of the interview questions, the length of time required, and the resources needed to conduct each actual interview. Two pilot students did projects and one did not. The results of the pilot interviews were that about fifteen minutes were required for each interview, additional questions concerning time spent studying were added, and superior audio recording equipment was deemed desirable. The rationale for adding the additional questions about time spent studying (Questions 11, 12, and 13) derives from the concern that project students may benefit from the extended period of mathematical application, or equivalently, to increased time on task. It is of interest then to inquire as to the average time on task for the two groups and note the proportion of time on task

dedicated to projects for those who produced them. Interviews were conducted in convenient, on-campus locations outside of class time. The researcher read the questions to the students, and their responses were audio recorded and subsequently transcribed. Transcriptions were made right after the completion of each interview for greater accuracy.

The facilities used for the pilot interviews were in or near a classroom or an office where the students' were taking classes or consulting with their instructor. The researcher offered to conduct interviews at locations convenient to students, such as the campus coffeehouse, however all interviews were conducted in the same buildings in which students took their courses, usually after a class meeting.

As mentioned, the results of the pilot interviews indicated that fifteen minutes is a good estimated length of time to allow for each of the actual interviews to be conducted. Students were told that they could end the interview at any time and at no penalty. All of this is detailed in the Participant Letter of Information presented in Appendix A. In particular, students were told that their records would be kept confidential and anonymous.

All students who took project courses during the spring of Year 3 were asked to voluntarily participate in interviews. This voluntary participation was a limitation of the study due to the bias inherent in convenience sampling. While most students chose not to participate in the interviews, the researcher successfully obtained seven student interviews for the Final Exam group and

eight interviews for the project group and determined that theme saturation had been reached. The seven Final Exam interviews comprised 26% of the total number of Final Exam students available (27). For the project group, the eight interviews constituted 15% of the total number of project students enrolled in the most recent semester (53). As in phase one, all students, whether they choose the project option or not, were included as potential respondents in this interview phase.

As noted, this second phase used a qualitative approach and thus it was preferable to get thorough responses from a smaller number of students rather than getting a larger number of shallow responses. Since students were not individually identified, the first question in the interview is used to determine whether students belong to the project group or the non-project group. Also, it is desirable to collect roughly equal numbers of completed interviews, to determine if differences appear between project and non-project respondents. As noted in Chapter Four, interviews revealed facets of application projects that had not been previously considered. Beyond this, interviews were a means of assessing how students felt about having been enrolled in their project option courses. The personal interviews were conducted during the spring semester of Year 3, at which time students were well into conducting their projects or had chosen to be in the traditional, non-project group.

As in phase one, phase two again involved two groups of students classified as being either project students or non-project students. One important

finding from phase two deserves special notice. It is understood that the findings derived from qualitative data are of an exploratory nature. As researchers Creswell (2003), Patton (2002), Tashakkori and Teddlie (2003), and others would extol, the idea is to seek insight, rather than truth. It is also understood that even the quantitatively oriented results fall short of being “truthful,” since there are always elements of uncertainty in any study.

Phase Two Student Interview Data Processing

Each piece of subjective interview information required some coding. Determinations were made as to what themes emerged as the interviews proceeded. This was not the only way that qualitative data was considered. It was also considered important to provide an overall descriptive account of the responses as is presented in Chapter Four. Some accounts stand on their own to illuminate an elusive element about project options. Until the data were collected, however, it was difficult to imagine what directions this may take. This is why it was best to allow the themes to emerge progressively from interview to interview. In particular, there was a desire not to presuppose what responses would be obtained. It was necessary to probe deeply to get at feelings students had about having a project option, and this information did not fall neatly into predetermined categorical coding.

Summary

The application project student group and the non-project student group comprised the participants and respondents in the two separate phases of this

study. The first phase considered the common third-test grades for both groups. The second phase relied on voluntary student responses to interviews from both the project and non-project students currently enrolled during the spring of Year 3.

Phase one involved the collection of data relative to enrollment for the four semesters from the fall of Year 1 to the spring of Year 3 at one large, urban university. The second phase involved interviews from those students enrolled in project courses during Spring Year 3. The goal was to investigate whether differences between these groups existed with regard to the third test grades and certain areas of interest such as course satisfaction, appreciation of mathematical applications, and time-on-task. Table 3 summarizes the study's participants for its two phases.

Table 3.

Summary of Data Points and Participants for the Two Phases of the Study

	Phase one	Phase two
Dates for sample:	Fall Year 1 – Spring Year 3	Spring Year 3
Sample size:	273 data points	15 participants
Description:	Pre-existing student data	Students enrolled Spring '06
Data source:	Common Test 3 grades	Personal interviews

Chapter Four

Results

This chapter summarizes the findings from the study described in the preceding chapters. The study concerned the effects of project options on certain students taking undergraduate mathematics courses. The two groups identified were the project and non-project groups. A mixed methods approach in data collection and analysis was chosen since research requires a “. . . variety of methods to be responsive to the nuances of particular empirical questions and the idiosyncrasies of specific . . . [student] needs” (Patton, 2002, p. 585). The current chapter will first present a recapitulation section that reviews the design and method employed in the study. This recap is followed, first, by a discussion of the quantitative findings. This Results chapter then concludes by presenting the findings from the qualitative portion of the study.

Recapitulation

Chapter Three discussed the virtues of mixed methods approaches to this particular research. First, quantitative methods were used to assess students' learning. Then, qualitative data from student interviews were used to glean a more in-depth and “personally informative” sense of application projects and the learning connected to project work. Both the quantitative and qualitative portions of the study were limited to non-mathematics major undergraduate students in

MAC 2242 Life Sciences Calculus II and MAC 2282 Engineering Calculus II who were students of one particular instructor. The quantitative portion (phase one) considered data for the four semesters from Fall Year 1 through Spring Year 3. The qualitative portion (phase two) involved interview data collected during Spring Year 3. Data were collected only for those students who received a final course grade of *D-* or better. This restriction to completers (as described in Chapter Three) was deemed necessary in order to remain conservative in the overall comparison of group results.

Quantitative Findings

The quantitative portion of the study concerned Research Questions 1 and 2. Each of these questions will be considered respectively in the separate subsections below.

Research Question 1

Research Question 1 asked whether non-math major undergraduate students who are more mathematically proficient (or less mathematically proficient) tended to choose the project option rather than taking a Final Exam. From the instructor's records, four semesters of students' assigned grades for Test 3 were drawn. Data were collected for all third test grades awarded to course completers. In addition, their grades on the first two common tests were collected in order to verify the assertion that the two group populations began the course with similar academic abilities. Data relative to the first and second tests were considered separately. Throughout the phase one analysis the base unit

was taken to be the course section. Statistical analyses were conducted for (a) the 12 course sections (three sections per semester for four semesters), and then additional analyses were run (b) by course subject (Life Sciences or Engineering) and semester (eight combinations), (c) by time-of-day and semester (eight combinations), and (d) by semester (four combinations). Following the affirmation of general student grade similarity provided by these first four steps [(a) through (d)], a final step in the analysis was performed, namely, (e) by the aggregate of the test data over the four-semester span.

The approach of using repeated *t*-testing was determined to be an appropriate way of searching for a significant difference in any of the various situations where one might occur. The 33 combinations [items (a) through (e) above] were considered for both Test 1 and Test 2, so that a total of 66 separate tests were performed in consideration of Research Question 1. In no combination did a significant statistical difference occur between the means of the two groups occur at the 95% confidence level. The same breakdown was later used to analyze the data from Test 3.

In Tables 4 through 9 that follow, the unit of analysis was the course section. The 12 sections were designated roughly chronologically as “Sec1,” “Sec2,” . . . , “Sec12.” The 12 course sections span four semesters, and within each semester two Life Sciences sections, one morning and another evening, and an evening Engineering section were offered with the project option. Since it was the case that all of the Engineering Calculus sections were delivered during

the evening, the data obtained from the “by course” and “by time-of-day” analyses were accordingly limited. The Life Sciences sections (unlike the Engineering Calculus sections) were discriminated “by time-of-day,” so that some data differentiation was provided by the time-of-day distinction. The consistent pattern of course subject and time-of-day is illustrated in Figure 3 below.

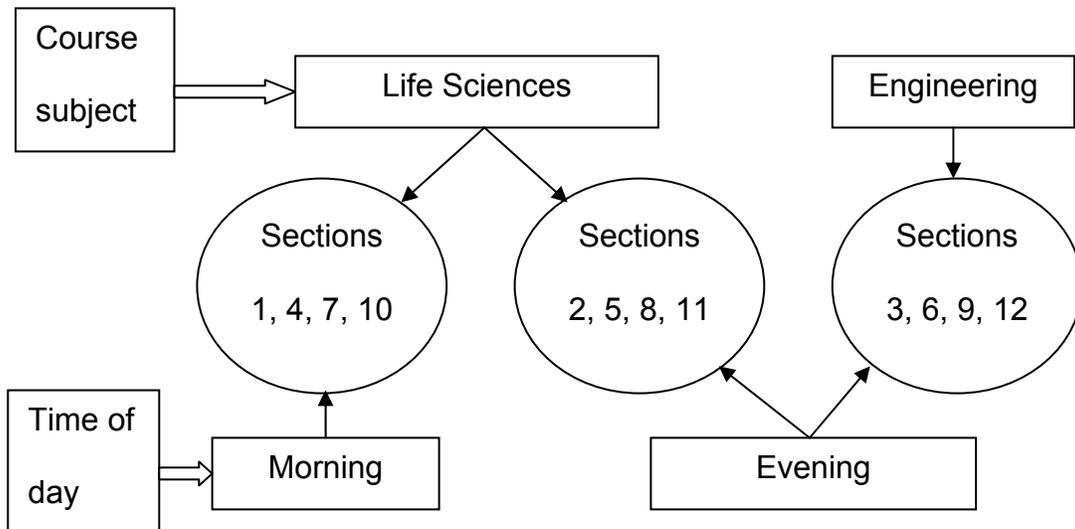


Figure 3. Illustration of the Course Subject and Time-of-Day Distribution for the Three Sections in Each of the Four Semesters

Table 4 below exhibits the Test 1 and Test 2 data for the 12 course sections. As noted, none of the corresponding analyses resulted in statistically significant group differences. The results of the final aggregated analysis are presented in the last line of Table 4 (designated 1 – 12). Table 4 summarizes the results of the preliminary Test 1 and Test 2 data. In particular, these results verify

Table 4.

Results from Initial Comparison of Final Exam and Project Students' Test 1 and Test 2 Grades for Spring Year 3

Sec (df)	n		Test 1			Test 2			Crit t
	FE	Proj	M: FE/P	p	t	M: FE/P	p	t	
1 (24)	12	14	13.6/12.8	.4200	-.8206	13.3/12.9	.9005	-.1264	2.064
2 (20)	9	13	13.4/13.8	.3372	.9833	13.0/13.8	.1461	1.5124	2.086
3 (17)	8	11	13.1/13.6	.8737	.1614	12.9/13.3	.6761	.4251	2.110
4 (19)	9	12	13.9/12.5	.2581	-1.1659	13.6/13.7	.9633	.0466	2.093
5 (23)	12	13	13.2/12.8	.7507	-.3216	13.4/13.8	.5476	.6104	2.069
6 (18)	9	11	13.7/13.0	.4553	-.7631	13.7/13.4	.8903	-.1399	2.101
7 (15)	9	8	13.1/12.8	.5886	-.5527	13.0/12.6	.5051	-.6829	2.131
8 (18)	10	10	13.6/13.8	.8089	.2454	12.9/13.3	.4061	.8508	2.101
9 (21)	11	12	12.9/13.5	.1903	1.3533	12.2/12.9	.3447	1.1968	2.080
10 (36)	17	21	13.2/13.5	.3560	.9350	12.8/13.1	.4999	.6815	2.029
11 (18)	4	16	13.2/12.8	.6273	.4939	12.0/12.3	.5045	.6811	2.101
12 (19)	6	15	12.2/12.9	.1356	1.5553	12.1/12.0	.9031	-.1233	2.086
All(270)	116	156	13.0/13.3	.1148	1.5821	12.7/13.2	.2424	1.1716	1.977

the first hypothesis. In particular, it is found that there is no significant difference between group means. This indicates that there is no tendency for academically

weak or strong students to elect the project option (or to take the Final Examination).

Of note regarding the overall analysis is that it was determined that multiple *t*-tests were to be performed rather than ANOVAs, since the small *n*'s prohibited the use of ANOVAs for the analysis. Also, it is again mentioned that only Test 3 was used to compare the two groups quantitatively regarding project work. Most project students defer their project work until they have at least completed Test 2. If this is a fair observation, then the choice of using Tests 1 and 2 to verify academic homogeneity is reasonable. Given the environment described, Research Question 1 is answered affirmatively. In particular, non-math major undergraduate students who are more mathematically proficient (or less mathematically proficient) do not tend to choose the project option rather than taking a Final Exam. The results do not support the counter assertion that the “mathematically strong (or weak)” gravitate toward application projects.

It is necessary to be clear about the reliability of data presented in Table 4 above (as well as much of Tables 5 through 7 below). Many of the *n* sizes are small. The small cell sizes are of concern since there is already the limitation of having employed a non-random sample selection process. As was discussed earlier, it was not possible to make random assignments in this study, since “assignments” would have misrepresented the important feature of choice that is attached to application projects. The point here is that, because of the inability to assign students to groups randomly, large values of *n* were desired in the study

so as to better curtail the possibility of confounding the assignment limitation with cell size concerns.

The “large” values of n seem to have been obtained at the semester level, which will be considered shortly. As McKillup (2006) notes, “. . . the distribution of the means of samples of about 25 or more taken from *any* population will be approximately normal, provided the population is not grossly non-normal . . .” (p. 93, McKillup’s emphasis). Thus, the present study conforms to the desired normality assumption needed when applying Student’s t -test for data combined at the semester level. While there is no reason to believe that the smaller samples (like many of those indicted in Table 4 above) depart greatly from normality, it is unwise to make this assumption. Results have been provided in cases involving small n sizes, but it is recognized that there are size issues in these cases and no conclusions have been directly drawn from them.

Research Question 2

With the reassurance that students had similar initial academic abilities in mathematics offered by the resolution of Research Question 1 as described above, the results of the third common test could then be considered. Research Question 2 asked if there is any significant difference in the common third test grades among non-math major undergraduates who completed one of the two mathematics courses (MAC 2242 Life Sciences Calculus II and MAC 2282 Engineering Calculus II) with application projects as compared to students who took these same courses without electing the application project option at one

large, urban university. Sections were first examined independently, and the basic descriptive statistics pertaining to “Final Exam” (FE) and “Project” (P) students are summarized in Table 5.

It should be clear that while Table 5 below exhibits all 12 sections, two sections were not included in later analyses since their student numbers were too low. The remaining 10 sections were utilized in subsequent analyses. Of those remaining 10, two revealed significant differences—one favoring the project option students (Section 4) and the other favoring the non-project option students (Section 10). Therefore, overall results revealed no real differences.

The first interesting item to consider about the Test 3 data is the significant difference found in Section 4 (indicated by a superscripted “a” in Table 5). This finding from Section 4 data contradicts the proposed hypothesis applied to this one course section. In Section 4, Final Exam students had a mean Test 3 grade that was significantly higher than the project group’s mean grade. Section 10 (indicated by a “b” in Table 5) offered a positive example where a significant difference was found. In Section 10 the Final Exam group’s mean grade was significantly lower than that of the project group. It is noteworthy that in the first ten course sections, the numbers of students in each group were roughly pairwise equal.

As noted in Table 5, students who participated in projects outnumbered the students who elected to take the Final Exam in Sections 11 and 12 (indicated

Table 5.

Descriptive Statistics for Final Exam vs. Project Students' Test 3 Grades

Sec	Educational approach								<i>p</i>	Crit <i>t</i>	<i>t</i> -val
	Final Exam				Project						
	<i>n</i>	Mean	Var	<i>SD</i>	<i>n</i>	Mean	Var	<i>SD</i>			
1	12	10.00	5.23	2.29	14	10.15	8.95	2.99	.8885	2.064	.1417
2	9	11.80	3.92	1.98	13	10.76	6.82	2.61	.3262	2.086	-1.0064
3	8	12.66	1.50	1.22	11	12.40	2.39	1.55	.6962	1.220	-.3971
4 ^a	9	13.09	1.42	1.19	12	10.93	4.37	2.09	.0121	2.093	-2.7742
5	12	11.58	5.22	2.28	13	11.36	8.56	2.93	.8243	2.069	-.2246
6	9	9.88	7.83	2.80	11	10.91	4.89	2.21	.3688	2.101	.9219
7	9	10.78	3.01	1.73	8	9.83	4.71	2.17	.3335	2.131	-.9993
8	10	12.06	4.03	2.01	10	12.50	5.15	2.27	.6441	2.101	.4698
9	11	11.98	5.14	2.27	12	11.55	4.94	2.22	.6495	2.080	-.4611
10 ^b	17	11.27	5.13	3.81	21	13.20	2.26	1.95	.0077	2.029	2.8202
11 ^c	4	13.50	5.67	2.38	16	11.88	3.18	2.28	.2213	2.101	-1.267
12 ^c	6	9.42	7.24	2.69	16	9.38	3.35	1.83	.9670	2.086	-.0419

^aSection 4 shows a significant contradictory finding.

^bSection 10 demonstrated significant difference with 95% confidence.

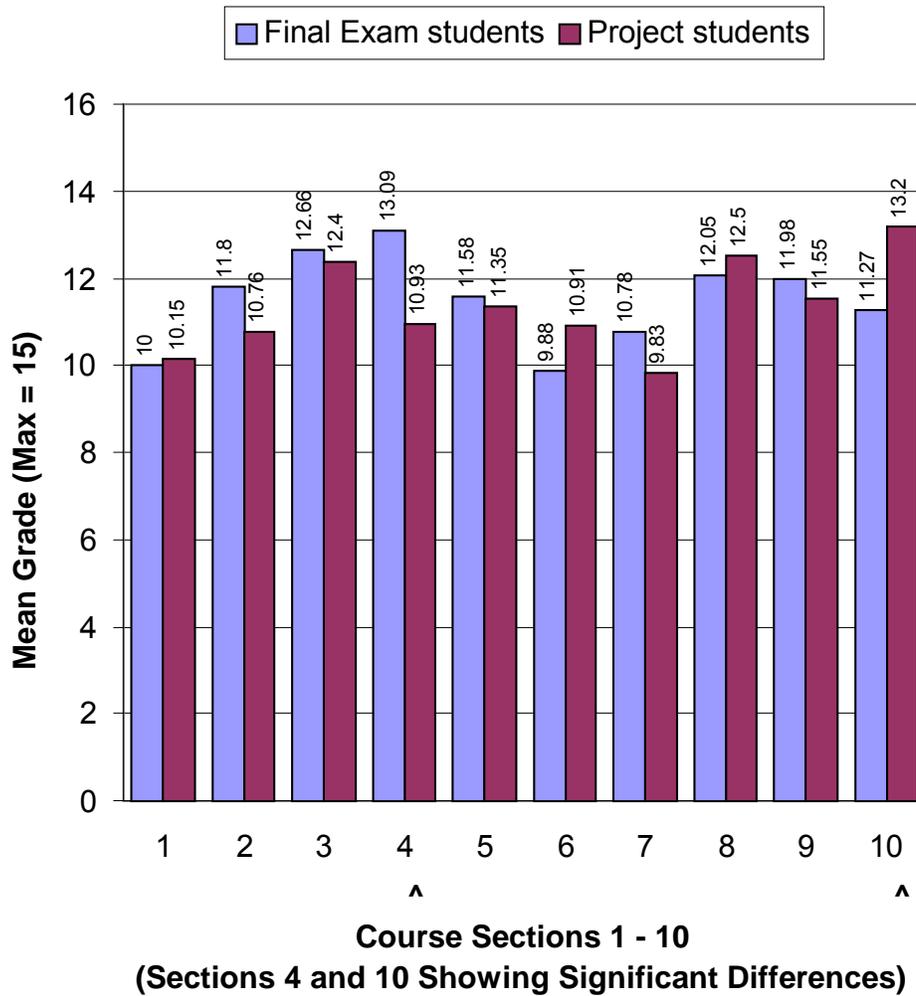
^cIn Sections 11 and 12, the FE samples were too small for proper analysis.

by “c” symbols). Unlike the exploration of Tests 1 and 2, which yielded no significant differences between groups, there were significant differences between groups for Sections 4 and 10 in the Test 3 analysis. The last three sections listed in Table 5 occurred in the spring semester of Year 3, and this semester deviated from the roughly equal numbers of project and FE students that had generally been the norm in other sections.

Figure 4 below provides a visual illustration of the mean variance in Final Exam vs. project students' Test 3 grades by section over the four-semester period. The significance observed in Sections 4 and 10 was not observed in other sections. Sections 11 and 12, which had too few participants in their Final Exam groups to allow for statistically meaningful results, have been omitted from Figure 4. Figure 4 shows that, over all sections, results for the Project group were roughly the same as those for the Final Exam group regarding grades on Test 3. In particular, Sections 4 and 10, with their relatively well-balanced pairs of group numbers (see Table 5 for the actual values), had offsetting effects.

The next series of analyses considered courses by subject (Life Science and Engineering) and semester. The two cases of interest once again corresponded to the latest semester. Table 6 is a detail from the full analysis in which the data corresponds to the final quarter section of Table 5, the Spring Year 3 semester. It is of interest that the section breakdown of Table 5 showed a

Figure 4. Histogram Showing the Mean Test 3 Scores between the Final Exam and Project Groups by Course Section



significant group difference that is not seen in the “by subject” analysis detailed in Table 6 below. It was observed that during the final semester of the study, of those students who completed their courses, project students outnumbered the

Final Exam students two to one (53 to 27). The reason for the unanticipated imbalance of numbers is not known; however it is possible that the infusion of the interview process (e.g., requesting the logging of time on task) may have given projects greater exposure than they would have otherwise had.

Table 6.

Spring Year 3 Detail of Course Subject (Life Sciences or Engineering) Analysis of Final Exam vs. Project Students' Test 3 Grades

Sec	Subj	Educational approach								p	Crit t	t-val
		Final Exam				Project						
		n	M	Var	SD	n	M	Var	SD			
10+11	LS	21	11.70	5.76	2.40	37	12.63	4.72	2.17	.1362	2.004	1.5117
12	Eng	6	11.91	7.24	2.69	16	11.78	3.35	1.83	.9670	2.086	-.0419

In the analysis by course subject detailed in Table 6 above, the two items presented, Life Science (Sections 10+11) and Engineering (Section 12) demonstrated the most pronounced instances of group numeric imbalance. As noted, this unanticipated imbalance has the effect of making any associated results suspect. It appears that there is no significant statistical difference (with $\alpha=.05$) when the arrangement in Table 6 (by course subject) is constructed.

Upon analyzing the data from a class time viewpoint, no additional significant differences were observed beside the one instance, detailed in Table 7 below, where the morning project group's Test 3 scores were significantly higher than the morning Final Exam group's Test 3 scores. The results of interest once again centered on the data from the fourth semester. The basic descriptive statistics for the two groups "Morning" and "Evening" (for the most recent semester) are given in Table 7.

Of the two analyses for which results are presented in Table 7, only the first listed, the morning class time (designated by a superscripted "a"), showed a significant difference between group means for Test 3 grades. This single case of significant difference does not allow for a verification of Research Question 2, which asked if there is significant difference in the Test 3 grades between Final

Table 7.

Spring Year 3 Detail of Class Time (Morning or Evening) Analysis of Final Exam vs. Project Students' Test 3 Grades

	Educational approach								<i>p</i>	Crit <i>t</i>	<i>t-val</i>
	Final Exam				Project						
Class time	<i>n</i>	<i>M</i>	Var	<i>SD</i>	<i>n</i>	<i>M</i>	Var	<i>SD</i>			
Morning ^a	17	11.27	5.13	2.26	21	13.20	3.81	1.95	.0077	2.029	2.8206
Evening	10	11.70	10.36	3.22	32	11.33	5.74	1.83	.6548	2.021	-.4505

^aThe Morning case demonstrated a statistically significant difference ($\alpha=.05$).

Exam students and project students. Clearly the counter findings of significant differences in group means for Test 3 grades by course subject for Sections 4 and 10, shown earlier in Table 5, do not offer verification of Research Question 2, either. Research Question 2 concerned the entire population of students over the four-semester period, and subsets of the full population were considered only in hope of gaining insight into the possibility that certain subsets might show differences that could be worth exploring further in future studies.

It is possible that project students attending during the day were able to spend more time in their overall course studies relative to the Final Exam students. The hypothesis attached to Research Question 2, namely that project students would generally have superior grades on the Test 3, was not confirmed through these analyses. As shown in Table 8 below, the data by semester

Table 8.

Analysis of Final Exam vs. Project Students' Test 3 Grades by Semester

Semester	Educational approach								p	Crit <i>t</i>	<i>t</i> -val
	Final Exam				Project						
	<i>n</i>	<i>M</i>	Var	SD	<i>n</i>	<i>M</i>	Var	SD			
Fall04	29	11.29	4.88	2.21	38	11.01	6.88	2.52	.6420	1.998	-.4671
Spr05	30	11.52	6.13	2.48	36	11.07	5.75	2.40	.4561	1.999	-.7498
Fall05	30	11.64	4.18	2.05	30	11.41	5.71	2.39	.6839	2.002	-.4092
Spr06	27	11.19	6.75	2.60	53	11.65	6.51	2.55	.4543	1.994	.7520

exhibited no significant differences ($\alpha=.05$) between the Final Exam and the project students' Test 3 grades for any of the four semesters.

It is interesting that data presented in Table 5 showed that in only one case (Section 10) were project students' Test 3 grades significantly higher than the Test 3 grades of Final Exam students. In fact, it would have been possible to answer Research Question 2, namely "Is there any significant difference in the common third test grades among non-math major undergraduates who completed one of the two mathematics courses (MAC 2242 Life Sciences Calculus II and MAC 2282 Engineering Calculus II) with application projects as compared to students who took these same courses without electing the application project option at one large, urban university?," in the affirmative had the sample been restricted to the morning, Spring Year 3 course (Section 10 of Table 5). An affirmative conclusion cannot be drawn, however, since a significant difference occurs in only this one section.

The result exhibited in Table 8 answers Research Question 2 negatively. In particular, there is no significant difference in the common third test grades among non-math major undergraduates who completed one of the two mathematics courses (MAC 2242 Life Sciences Calculus II and MAC 2282 Engineering Calculus II) with application projects as compared to students who took these same courses without electing the application project option at one large, urban university.

Qualitative Findings

The qualitative portion of the study concerned Research Questions 3, 4, and 5. The results presented in this section are derived from a total of 15 student interviews (seven non-project, eight project). The key points of interest in analyzing students' responses were statements on their perceptions toward mathematics (addressing Research Question 3), levels of course satisfaction (Research Question 4), and levels of time on task (Research Question 5). The first subsection below, Coding Considerations and Examples, introduces the full spectrum of interviewee responses. The responses relative to Research Questions 3, 4, and 5 are specifically considered in the subsections that follow.

It is worth stating at the onset that the qualitative component injected through student interviews did indeed provide enhancement to the findings. An important observation was that students in *both* groups reported a heightened awareness of the applicability of mathematics from the general discussions in their classes concerning their option to produce a project. This is not surprising, since the very actions of considering how they might develop a project naturally awakens in students any otherwise dormant notions about real world connections with mathematics. Since even non-project students reported benefits from project discussions, it may be well worth mathematics instructors' efforts to at least include discussions of this kind as a means of heightening awareness of the real world applications of mathematics.

Coding Considerations and Examples

The chosen design for analyzing the qualitative data in this study combines the design guidelines provided by Bazeley (2003) and Creswell (2003). The combined approach is referred to as pattern coding. Bazeley reiterates Patton's (1988) view of eclectic, pragmatic approaches stating ". . . any data or approaches to analysis that contribute to an understanding of the issues at hand are seen as worthy of consideration" (Bazeley, 2003, p. 389). Creswell's (2003) very efficient method of qualitative analysis involving "coding and theming" (pp. 265-268) was adopted in the present study. In essence, the approaches proposed by both Bazeley and Creswell rely on being able to categorize transcribed responses into appropriate overall themes.

The qualitative analysis in this study relied on the recognition of recurrent patterns or themes, together with non-statistical consideration of the quantitative responses (e.g., "What is your current estimated overall grade point average [before this semester]?") made by students upon prompting during their interviews. Each student's responses were coded and entered into a spreadsheet so that recurrences could be easily noted. As stated above, the goal was to assess, by group, students' perceptions toward mathematics, their levels of course satisfaction, and their levels of time on task. Because all of these assessment areas were self-reported by the students, the researcher added further subjective details concerning student responses that were useful in the

overall qualitative analysis such as, describing the “gratitude” factor, that students were grateful for being given the option to do an application project.

As noted earlier, students were encouraged to volunteer to be interviewed whether or not they completed a project. Special emphasis was given to elicit volunteers from the non-project group since there was initially some concern that those in the non-project group would feel that the interviews did not apply to them and thus would not volunteer for an interview.

The procedure for conducting interviews included contacting students while in class several weeks before the interviews were to begin to express the need for volunteers from both groups, and to suggest that students maintain a log of their time on task (see description in Chapter Three). This early appearance of the interviewer, together with the request that potential interviewees keep a log, is thought to have stimulated students to later participate in the interviews. Seven students from the non-project group completed interviews. Upon completion of the seventh non-project interview, it was determined that no new themes were emerging and the administration of interviews to this group was discontinued. Together with the seven students from the non-project group, eight students from the project group also completed interviews. The administration of interviews to the project group was discontinued after the completion of the eighth project interview. Again, enough theme saturation occurred in the eight project interviews to supply the study with an adequate theme base.

Generally interviews of project students were easier to secure, since most of the students in the project group appeared to exhibit feelings of gratitude about having been provided with the opportunity to produce projects. The researcher made notes following the interviews concerning any emotion that the interviewees' imparted through their body language or tone of voice. The "gratitude" category, as will be discussed below, is a case where emotional states were clearly considered when coding responses.

An initial list of themes, consisting of about 30 codes, was developed after all student comments were considered. A second coder was used to assist in making proper notations for the interview data. The coders agreed upon the convergent set of six categories (Career, Grade, Gratitude, Math, Merit, and Option) listed in Table 9. In research ". . . the validity, meaningfulness, and insights generated from qualitative inquiry have more to do with the information-richness of . . ." data (Patton, 2002, p. 185).

In order to capture full, descriptive responses from students, and get that "information-rich" data desired, the interviewees were encouraged to discuss any matter connected to the option of a Final Examination or an application project. The researcher remained neutral to particular comments and used generic probing (for example, "Tell me more about that. / How do you feel about that?"). In terms of depth, each interviewee who participated in this part of the study contributed roughly two pages of transcribed narrative. Responses were transcribed verbatim whenever possible. In total, there were approximately 30

Table 9.

Major Theme Frequencies from Final Exam and Project Students' Interviews

Theme	Educational approach	
	Final Exam (n=7)	Project (n=8)
Career	3	6
Grade	5	4
Gratitude	5	6
Math	4	5
Merit	4	5
Option	4	8

written pages of data, which were then transferred to a spreadsheet to aid in the determination of the major and minor themes.

Each major theme listed in Table 9 included several minor themes. For example, it was decided that the theme “gratitude” includes the minor themes of “pleasure,” “appreciation,” “improvement,” “enhancement,” and “opportunity.” The codes were manipulated so that each minor theme fell predominantly into one and only one of the chosen major themes. The various responses were placed into the six categories summarized in Table 9 above.

In composing any convergent list of categories, Patton (2002) reassures researchers that their “. . . qualitative findings are judged by their *substantive significance*. . . . [U]ncovering patterns, themes, and categories includes using

both creative and critical [thinking] . . . about what is really significant and meaningful in the data” (p. 467, Patton’s emphasis). Patton (2002) also promptly observes that “. . . [d]etermining substantive significance can involve the making of the qualitative analyst’s equivalent of Type I and Type II errors . . .” (p. 467). In effect, Patton calls for researchers, first, to not overlook something that might be significant in a study, which would be equivalent to committing a “qualitative Type I error.” When dealing with quantitative data, a Type I error is the mistake of rejecting the null hypothesis (H_0) when H_0 is actually true. Secondly, Patton is cautioning researchers not to place false significance in a finding, as in a Type II error. Continuing the quantitative analogy, a Type II error is the mistake of not rejecting H_0 when H_0 is actually false, and the researcher can similarly apply the notion qualitatively. This researcher while establishing the categories appearing in Table 9 above, used similar concepts to those behind Patton’s substantive significance, and these ideas are apart of the overall qualitative analysis in this study. This seems to be a reasonable choice, since it would be a bigger mistake to allow any negative aspects to remain undetected than to miss the confirmation of the various positively phrased hypotheses employed in the present study. This rationale appears to, among other things, “err on the side of caution” by not presupposing that positive aspects to projects exist.

The six categories are best described by including appropriate quotes as examples of the theme behind the label. There were many such statements that were collectively viewed as comprising the “Career” category. The career

instances weighed heavier (six to three, see Table 9) with project students; however, there were clearly “career” instances across groups. One project student said, “I was surprised that I was able to tie calculus to warranty pricing.” A non-project student made the statement, “It’s great that options let you involve the work that you’re already doing.”

Another convergent category was labeled “Grade.” “Grade” responses were about evenly distributed between the two groups. Five Final Exam students expressed that the “grade” was a concern for them in some way. There were four project students who voiced similar “grade” concerns. This was the appropriate code for one project student who stated “I was hoping to get a better grade by taking the option,” for example. A non-project student said, “I thought my grade would suffer if I tried to do a project,” which was also coded into “Grade.” Another project student boldly stated “I was expecting to do poorly at first, but . . . [I was told] . . . that I actually did alright in here. The option was a good deal.”

Most project students (six of eight) and over half of the Final Exam students (five of seven) expressed some form of “gratitude.” In attempting to establish students’ emotional states, this researcher consistently found that an “air of gratitude” was often present during both the project and non-project students’ interviews. For instance, one project student said, “I was happy to have the opportunity to tie my math work to my other studies.” Another project student smiled while explaining that, “The project just clicked. I had already been thinking about the area/volume connection before the class even started.” A third project

student noted that “I really didn’t think I’d be able to use what I learned from my Calc course, but I was able to put it to work right away.” The reader can easily imagine that the previous statements were expressed with some degree of satisfaction, appreciation, or (as labeled here) “gratitude.” With only two exceptions was “gratitude” absent from a student’s responses completely. Gratitude was the most active category, as is demonstrated in Table 9 above. It should be cautioned that the proliferation of “gratitude” might to a large extent be an artifact of convenience sampling. Indeed the very act of volunteering to be interviewed may have been a show of gratitude. If this is true, then the “gratitude” result may have little, if any, substantive significance.

There was a well-balanced assortment of “Math” responses across groups, with the non-project group having four occurrences and the project group five occurrences. Non-project students tended to voice the opinion that the traditional approach was enough for them. The “Math” category included the project student’s response: “I wanted to get close to the numbers and this seemed like a good time to try to make use of calculus.” “Math” was also coded with the non-project student’s statement: “I like to go by the book. It sounded like there were too many details to worry about with a project. It’s better for me just to work problems and, after a while, I usually know what’s going on.” Responses suggesting that the student thoughtfully selected her or his particular approach in order to most efficiently and effectively learn the mathematical concepts were coded here. One comment was “There were plenty of examples in the book. I

didn't need to come up with another one to get derivatives." On the other hand, project students saw their own selections as allowing them to more directly acquire the skills they felt were useful or required for them. One project student said, "There are many details to calculus that I don't really care about. My project emphasized only a few big ideas. It might be worth knowing how to deal with partial fractions, but I don't think I'll ever need them."

"Merit" was used as the category for one project student who said, "I wanted to see how much calculus could really be applied to staffing and H. R. [human resources], and I showed [my supervisor] how we could get more done with the people in our unit." There were four non-project responses in addition to the five project responses. Both the Final Exam and the project student groups expressed the desire to extend and further refine the basic tools of calculus in such a way as to "advance" themselves in the eyes of others. The label "merit" was used for responses that suggested that the interviewee wished to elevate himself or herself through his or her work in the course. A non-project student said, "It's important for me to get as much as I can from a course. The Final Exam seemed like the best way for me to connect it all up. With the Final I knew what to expect, anyway." Students who made mention of "going farther" or "getting more," were included as instances of "merit." Most references for project students were more concretely connected to someone (usually the project supervisor) who might consider their work "meritorious;" however, non-project students might derive some "merit" from their instructors.

Finally, “Option” was coded when responses suggested that students were generally pleased about having had the project option available. A concern with the “Option” response is that students were asked explicitly what they thought about having an application project option, and their responses may have obligingly leaned toward approval, if this was what they felt the researcher wanted to hear. Four Final Exam students expressed that they liked the option and all eight of the project students liked having the option. The researcher observed that students’ responses generally coded into “Option” regardless of their group. Three of the seven Final Exam students suggested any “dislike” toward the option, and only “minimal” dislike at the worst.

It is evident from what was reported by interviewees that some students sincerely benefited from their project work. Some of the Final Exam students went so far as to say that they benefited from hearing about the project work of others. While the sampling protocol may have allowed some negative voices to remain unheard, if the responses are typical, it appears that students were in overall agreement that project options are good and that benefits could be derived from project work.

Research Question 3

Research Questions 3 asked “As indicated by interviewee responses of the non-math major undergraduates enrolled during the spring of Year 3 in MAC 2242 and MAC 2282 (the same two mathematics courses specified in Research Question 2), with an application project option and those who did not elect the

project option: is there a difference between the two groups' perceptions toward mathematics?" This question was considered over several interview responses.

Regarding the third research question, concerning higher levels of mathematical perception associated with project work, it was observed that several non-project students who reported that their attitudes toward mathematics did not change as a result of their course work, while no project student made a similar statement. Of those non-project students who reported no attitude change, the interviewer was either directly told, or led to conclude, that these particular students already had very good attitudes about mathematics, so that these students were not expressing dissatisfaction with the course. For instance, a student expressed that "My attitude toward math has always been good. It isn't better or worse at this point."

There were several instances where project students spoke specifically of their positive feelings toward their course work and their clarified perceptions about mathematical applications. There is subtle difference in the increased positive perception to mathematics attributed to the project group. The hypothesis that undergraduate students in the project group would report having more instances of improved positive perception toward mathematics is subtly supported by the theme frequencies (by incrementally tallying the frequencies over all the categories listed in Table 9, for example). The point is made less subtle when combined with the associated narratives where project students spoke specifically of enhanced learning experiences.

Several responses to the positive perception question are of interest. One project student remarked, "I've learned how techniques [of mathematics] can be applied to my field of biology." Another project student stated, "Of course, I have learned a lot during this period and I am proud of what I know." Still another project student asserted "Yes, I now view math as something that you can relate to if you think it through carefully first. And it might take days or weeks to think it out." This improved mathematical perception of the project group was anticipated. Furthermore, from the students' responses it was found that improvement of mathematical perception were expressed in slightly greater numbers, and generally with greater exuberance, by those in the project group compared to those in the Final Exam (non-project) group. While occasionally Final Exam students demonstrated improved perception and made comments accordingly, the number of such comments were slightly fewer and less emphatic than those in the project group. As before, this conclusion is made not from the Table 9 frequencies alone, but rather in conjunction with related verbal comments.

Overall, the results of the third research question indicate that, of the non-math major undergraduates enrolled during the spring of Year 3 in MAC 2242 and MAC 2282, the project group reported higher levels of mathematical perception than did the non-project group. As noted at the start of this section, an eye toward Patton's (2002) substantive significance was used while considering this, and the remaining two, qualitative research questions.

Research Question 4

Research Question 4 asks, “From comparisons of interviewee responses (currently enrolled non-math major undergraduates electing application projects and those who did not elect the non-project option) is there a difference between the two groups’ levels of course satisfaction?” It was hypothesized that undergraduate students in the project group would report higher levels of course satisfaction than those in the non-project group, and this finding was substantively supported.

While there was a shared theme of appreciation for the availability of the option across both groups, there was some expression of discontentment for project options among the non-project group. Since no other theme of “dissatisfaction” was discovered, the course satisfaction level became attached to the question of whether students liked having the option or not.

In response to the question about liking the project option, two non-project students stated “I would prefer having only the non-project option” and “I didn’t like having the project option.” Both students agreed that their “displeasure,” however, had not caused them overall dissatisfaction with the course. Instead, in this researcher’s opinion, in these two instances the students were expressing only personal annoyance with the project option, rather than their opinions as to the educational value of projects. It is this researcher’s opinion is that these instances of “displeasure” do not substantively suggest displeasure within the

Final Exam group. It is impressive in the theme of course satisfaction that four of the non-project students said that they liked having the project option.

Having connected the satisfaction concept to the question about liking the project option, many more student responses could be regarded as commentary on course satisfaction. One such response was: "I think that it's a great idea. Students are able to engage in mathematics and research on a higher level with this option. And I think they learn the material much better." Another said, "It's a nice idea, especially since the Final is extremely hard." A third noted, "Options are always good." These three responses are representative of most project students' responses concerning the project option, and demonstrate relatively higher levels of reported course satisfaction. This observation answers Research Question 4 positively.

To reiterate the finding just discussed, from comparisons of interviewee responses (currently enrolled non-math major undergraduates electing application projects and those who did not elect the non-project option) there is a substantive difference between the two groups' levels of course satisfaction favoring the project option group. It is the opinion of this researcher that there is sufficient substantive evidence to support the contention that students who elect the project option generally have greater course satisfaction than do the Final Exam students. Therefore, the results affirm Research Question 4.

Research Question 5

Included in the qualitative phase of this study is an investigation into whether or not project work is associated with greater time on task when compared to non-project work. In particular, Research Question 5 asked, “by comparing the interview data for students electing the application project option with those responses of non-project option interviewees: is there a significant difference between the two groups’ reported levels of time on task?” It was hypothesized that undergraduate students in the project group would report higher levels of time on task than would those in the non-project group. Three separate interview questions were used to address Research Question 5.

Interview questions 11, 12, and 13 asked “How many hours do you think you studied (and/or did project work) for your course last week . . . the week before last . . . [and] the week before that (in other words, three weeks ago)?” Since students provided three separate values for the three weeks leading up to the week of their interview, these values were averaged to obtain a time-on-task value. As mentioned in a previous section, students had been made aware that interviews would be conducted and that the questions would include consideration of time on task. Three non-project students and one project student volunteered the information that they had actually kept a record as had been requested. The responses of students who kept logs were in accord with the others, so no special handling of these data was thought necessary. It is possible that the early alert to students helped them to provide realistic values, thus

explaining why the logged values agreed well with those provided by students who did not keep logs. The lists of these averages, their means, and the standard deviations for each group appear in Table 10 below.

Table 10.

Comparison of Average Time on Task for Final Exam and Project Students

	Educational approach	
	Final Exam	Project
Ave time on task (hrs/wk)	3, 3.7, 3.7, 4, 5, 6.6, 9	4, 5, 6.3, 9, 10, 12.3, 17, 22
Mean average (hrs/wk)	5	10.7

It is evident from the data provided in Table 10 that project students felt that they spent about twice as much time (almost 11 hours per week) on their course and project work toward the end of the semester as did non-project students (about 5 hours per week) in their study time. Even if the two larger figures supplied by project students are removed from consideration, the responses suggest an important insight into project work, namely, that the perception of project students is that they spend more time on task than do the non-project students. The full range of project student responses showed greater time on task than the range of Final Exam student responses.

While it is a fact that the time on task measure is being applied to two different products, namely, Final Exam preparation or project production, the

redeeming notion is that “students are evaluated on their abilities to use calculus tools in *either* case” (A. Grinshpan, personal communication, September 14, 2006). It might be said that regardless of the setting, those students who spent more time honing their calculus skills and learning proper tool-handling are likely to be more proficient in the use of those tools than those who spent less time with their studies. The general course objectives that are of concern in the two project courses, MAC 2242 and MAC 2282, are conveyed in Appendix D. It is again noted that the objectives are evaluated for both groups: “Final Exam students deal with abstract problems and project students deal with applied problems, but they are all evaluated on how well they use calculus tools” (A. Grinshpan, personal communication, February 23, 2007).

As was noted at the outset, the duration of time on task can affect the quality of the task (Chapman, 2003). This study has shown that application projects increase of students’ time on task in working with mathematics. Because there exist definite problems of determining precisely when a student is “on task,” the actual measurement of time on task is rather fuzzy. Researchers must also contend with the subjective matter of task “intensity” when comparing dissimilar tasks. For instance, in the present study there was an additional element of “task intensity” that was not explored. Also unknown is whether there is a connection between task intensity, and levels of anxiety and/or the psychological well being of the students.

As concerns the reported values of time on task, it must be made clear that since the tasks are different (Final Exam preparation vs. project production), any time measures would naturally be different also. This task difference indicates that a qualitative approach recognizing such differences is the proper procedure for analyzing these data. One item of note regarding task differences is that project students are required to produce a write-up of their work, and the time involved with the physical production of the write-up might itself be rather extensive. Final Exam students, on the other hand, are free of the “production time” of projects. The overall finding must remain that project students spent greater time on task with their project work than did Final Exam students in test preparation. This is echoed in more than one response stating that a student didn’t have the time to do a project, thus implying that they did have time to prepare for a Final Exam. This might explain why the time on task was apparently less for Final Exam students. It seems reasonable to find that projects require, and are justifiably perceived to require, more time than test preparation.

Researchers have recognized that quality can be enhanced by duration, as noted previously in Chapter 2 (e.g., Chapman, 2003). As regards time on task, duration is one thing that project work appears to offer the student. It should be noted, as mentioned above, that time on task may be perceived to be greater due to the students’ processing time. This processing time (deciding what to do and how to do it) seems to vary greatly among project students. The variation is evident in the wider range of time values supplied by the project interviewees.

There is less variability and a narrower range of responses for Final Exam students who have little extra processing with which to concern themselves.

Future research should include a more thorough investigation of students' perceived time on task. A reasonable protocol for obtaining these responses might be to include a final query on the Final Exam and to ask project students to supply the figure as a concluding part of their write-up. In this way a future study could ask all students at the end of these math classes how much time they spent either studying for the Final Exam or on their project work.

With Research Question 5 a confirmation of the anticipated result was obtained. By comparing the interview data for students electing the application project option with those responses of non-project option interviewees there is, to use Patton's term, "substantive significance" (2002, p. 467) between the two groups' reported levels of time on task, and this substantive difference favors the project group.

It is necessary to include an unanticipated finding. In particular, it was observed that students who chose the project option evidently benefited from increased instructor involvement. This is a feature of projects that deserves further research. It was observed that students who chose the Final Exam were less likely to consult with the instructor than students who choose the project option (Grinshpan, personal communication, March 20, 2007). No attempt was made in the present study to evaluate or even explore possible effects that might

exist between project options and increased instructor involvement. Any consultation time would at least be considered added time on task for students.

Summary

An affirmative answer was established in response to Research Question 1, and it is asserted that there is no particular tendency for academically weak or strong students to elect the project option (or take the Final Examination). The negative answer that was found for Research Question 2 is not as well established. It was found that grades on the common third test (in MAC 2242 and MAC 2282) for undergraduate non-math majors who participated in application projects are *not* superior to those of nonparticipating students. However, the research showed that the two groups tended to be academically similar, with no particular skewing toward the mathematically weak (or strong) to either the project or Final Exam group (as was the case in Research Question 1).

To restate the quantitative results, first, data for tests one and two demonstrated (with a 95% confidence level) the similarity of the two groups in “mathematical academics.” This first result allowed Research Question 2 to be considered. Next, the second null hypothesis (which states that project students *do* perform better on their third test than do non-project students) was *rejected*. There was insufficient evidence to support the positive result anticipated for Research Question 2, and it was found instead, that project students *do not* perform better on their third test than do non-project students.

The qualitative data were helpful in clarifying the project option picture. Overall, the responses given during interviews indicated that generally all students liked having an option to the Final Examination available. Final Exam (non-project) students occasionally expressed a “vague dislike” for project work, while the norm was for those in project option student group to voice appreciation for having been provided with the project option. The project group also expressed more instances of improved positive perception toward mathematics.

The project group also reported substantively higher levels of course satisfaction than the non-project group. The analysis in this regard closely followed that of Research Question 3, discussed above.

Another qualitative finding of importance is that Final Exam students reported spending only about five hours per week during the last few weeks of their courses, as compared to over ten hours per week for the project students. The implications of these findings are the topic of the last chapter, Conclusions.

Chapter Five

Conclusions

This chapter begins with an Overview of the Study section, followed by an Overview of the Results, reiterating the key findings from Chapter Four. There are then three separate sections that discuss Implications of the Results in Terms of Theory, Implications of the Results in Terms of Research, and Implications of the Results in Terms of Practice. The Implications of the Results in Terms of Practice section presents observations from the study that may be useful in maintaining and possibly improving the project option program. The chapter concludes with a Summary of this chapter and the entire study.

Overview of the Study

A comparison of project and non-project students' common tests was used as a means of quantitatively assessing the academic benefit provided by application projects. In addition to their common third test grades, student responses to interview questions provided qualitative insights into project and non-project students' expectations and motivations in their non-math major mathematics courses. The overall goal in the research was to gauge the beneficial aspects of application projects. Related research into similar programs has demonstrated that extra efforts are required of instructors. One of the major purposes of this study was therefore to determine whether it is worth the extra

effort in terms of students' improved understanding of, and positive regard for, mathematics. Included in the self-reported student data were their perceived degrees of time on task.

Not all of the related literature concerning application projects attests to positive academic effects. In fact, the findings from this study do not show academic improvement as a result of project work. Qualitative investigations here and elsewhere (e.g., Astin and Sax, 1998), however, show that projects are a desirable means of enhancing the learning experience. The desirable aspects of application projects include their ability to provide students with opportunities to make mathematical connections with the real world and their experiential components which allow students to participate in personally meaningful activities.

The application project program may supply students with added motivation for learning mathematics. An important element of this study involved analyzing certain feelings undergraduate mathematics students (not only project students) had about application projects. The inclusion of the qualitative portion of the study was designed to supply support to any quantitative results. As noted in the following section, the qualitative phase proved to be the most informative part of the study.

Overview of the Results

In the quantitative phase, data were collected relative to enrollment for the four semesters from the fall of Year 1 to the spring of Year 3 at one large, urban

university. A comparison of students' grades on the first two of their three common tests (Test 1 and Test 2) showed that no particular tendency was exhibited for either mathematically weak or strong students to elect the project option as opposed to taking the Final Examination. This result affirmed Research Question 1, that there would be no such distinction academically (as measured by their first two tests) between Final Exam and project students.

From an analysis of the results of their last common test, Test 3, with a 95% confidence level it was found that similar mathematical ability (as measured by the instrument) existed between the two groups of interest. This finding contradicted the expected answer to Research Question 2 which asked if there was any significant difference in the common third test grades among non-math major undergraduates who completed one of the two mathematics courses (MAC 2242 Life Sciences Calculus II and MAC 2282 Engineering Calculus II) with application projects as compared to students who took these same courses without electing the application project option. The actual finding was that no significant difference in the common third test grades existed between the two groups.

The second, qualitative, phase of the study addressed Research Questions 3, 4, and 5, and involved interviews from a subset of those students enrolled in project courses during Spring Year 3. The goal was to investigate whether differences between these groups existed with regard to such areas as

positive perceptions toward mathematics, course satisfaction, appreciation of mathematical applications, and time-on-task.

The qualitative data provided a more holistic view of the project option through the analysis of students' feelings about the project option, and led to several revealing observations. Overall, students generally liked having an option, and some students reported that project options had been beneficial to them.

In response to Research Question 3, asking if there was a difference between the two groups' perceptions toward mathematics, only two of the seven non-project students responded that their attitudes toward mathematics had not changed as a result of their course work. All others in the non-project group, and all project students, reported a positive change. Thus the reported percentage of increased positive perception toward mathematics was apparently greater within the project group. From these data Research Question 3 was answered affirmatively. In particular, it was concluded that incidences of increased positive perception toward mathematics were higher in number among project students.

Research Question 4 asked if there was a difference between the two groups' levels of course satisfaction and this was also substantively affirmed favoring project students. Again it was found that course satisfaction was generally the norm across groups (students in both the project and non-project groups spoke of having high levels of course satisfaction following their course work); however the present researcher found a higher number of incidences of

course satisfaction within the project group. Overall, both groups reported some heightened awareness with some indication of a relatively higher level of heightened awareness occurring within the project group.

Time on task was the focus of Research Question 5, which asked if the project option group and the non-project (Final Exam) group were different in their reported levels of time on task. As was hypothesized, undergraduate students in the project group reported having higher levels of time on task than those in the non-project group. In particular, it was determined that Final Exam students reported spending less than half the time, about five hours per week, on task during the last few weeks of their courses, as compared to project students who reported over ten hours per week. Possible conclusions from these results are addressed in the sections below.

Implications of the Results in Terms of Theory

It has been determined that, in general, students performed equally well on Test 3 regardless of what approach they chose. Furthermore, no overall significant differences between the two groups' sample means emerged in analyzing their grades on Test 3. Since the present study was grounded on pragmatism, it is reasonable to observe that students appeared to select the option that worked best for them and view this as educationally positive. While there were no quantitative data supporting a positive conclusion regarding educational approach and grades on Test 3, there were qualitative data that

suggested positive distinctions for the project group in other areas, as is discussed below.

The qualitative portion of the study established that students like to have choices. Students in both groups were satisfied with their courses. It seems that even non-project students were grateful to have the project option available. The general response from both groups was that the option is a good idea. The finding that students positively regard project options is a demonstration of the value of these particular educational devices.

Also, of pragmatic interest is the finding that the project student group felt that they spent more time on task than did those students in the non-project group. While the data collected were students' self-reported measures, the large difference (about 5 hours per week for the non-project group compared to about 10 hours per week for the project group) does indicate that there was a real difference in time on task. There is a general consensus among educators that students will understand their course objectives better if they spend more time on task. The higher self-reported time on task values of project students were not supported by superior academic achievement as measured by Test 3, however.

There are implications in not finding a significant difference between the groups' mathematical abilities as measured by Test 3 while discovering the large discrepancy in perceived time on task. One possibility that this researcher has considered is that Final Exam students would most likely not include their *rumination* times in their total time on task values. In contrast however, project

students may have ruminated at length and included their “thinking” times into their time on task values. Most educators maintain that the quality of student learning is of greater importance than the duration of learning. It is reasonable to assert that with extended consideration of a given educational objective, students have proportionally extended opportunities to hone their skills and thus produce work of quality.

On the other hand, it may be that some forms of supplemental gains do exist for project students with their greater time on task, but that Test 3 did not allow for these gains to be measured in a quantitative way. Any such supplemental gains were not outlined in the course objectives, but may have been beneficial to the project students. A clever new research design would be needed before these supplemental gains could be identified and measured. Further thought on what these gains might be and how they might be measured is a topic for the following section.

Implications of the Results in Terms of Research

Since this study was of a pioneering nature, it is desirable to consider how the study may have been improved and thus suggest how future studies might be designed. For instance, the previous section mentioned supplemental gains that possibly accrue for project students. In the actual case of a project student who worked on a mathematical relationship between health service provision and the scheduling of health providers, for example, the student may certainly have gained highly specialized knowledge, such as an understanding of total provider

time needed as a function of the number and ages of health care recipients. In this case the gain would be specifically useful to that particular student, while not a gain that other students would be expected to obtain.

Student-specific gains, as might be acquired in the health provider example above, would certainly not be included as common course objectives. Specific gains might be allowed as part of a student-designed objective, however. Future research into application projects might attempt to measure and analyze such specific educational gains, for student gains of all kinds are important in any educational program. Assessing the value of personal gains might be possible through an interview process similar to the one conducted in the present study. It may also be possible to provide potential project students with a general outline of the desired project elements. Any general outline of this kind might be useful to students in the production of their projects and perhaps serve as an aid to them during their project's development. It is understandable that project instructors would not wish to be overly restrictive in what they want to see in a finished project; however, many of the fundamental elements might be listed, and so supply students with some desired direction.

The idea of "practical mathematical connections" includes the personal gains students obtain from project work. This enhancement through personal gains is exactly what is envisioned as an outcome of project work. There are many pragmatic reasons why educators should encourage application projects, not the least of which is our need to develop and support independent thinkers in

our nation. This argument may sound overly idealistic, however this researcher finds it to be in accord with the higher levels of learning that are professed to be institutional goals at most colleges and universities.

Implications of the Results in Terms of Practice

The data gathered show that project students did not get better grades on their third tests than the non-project students did. The results revealed that non-math major undergraduate students do not choose the project option rather than taking a Final Exam based upon their proficiency in mathematics. The implication from this finding for teachers of mathematics is that providing all students with the option of doing an application project in lieu of taking a Final Exam is not necessarily “watering down” mathematics.

The self-reported time on task values provided by students during interviews have been treated as qualitative data. As was described earlier, these values are more correctly referred to as estimates (except in the four or five cases where a journal of time on task was kept). Since the reported values are subjective, and since the groups are too small for statistical testing anyway, it is natural to conceptually treat these time on task estimates as qualitative data with some approximate ordinality (conveyed by relative number size).

Turning to the evidence suggesting that project students spend more time on task than do Final Exam students, it is reasonable to associate academic gains with higher instances of time on task. While one cannot conclude from this study that project students learn “more,” it was not shown that they learn “any

less” than the Final Exam students. Furthermore, from the many instances of overall approval of application projects captured in the student interviews, it appears that projects are desirable and pragmatically useful for many students.

It should also be noted that students who chose the project option might have benefited from increased instructor involvement. “Students who chose the Final Exam were less likely to consult with the instructor than students who choose the project option. Some interactions were brief, but others were for half an hour or longer. Some students consult dozens of times, and some would only be seen once or twice over the course of the semester” (Grinshpan, personal communication, March 20, 2007). While the effect of increased instructor involvement with project students was not an area of interest in this study’s initial design, it has become apparent that this result of the project program deserves consideration in future research. As mentioned in the Results chapter, the increased instructor involvement issue may be a potentially fruitful research topic. As noted in the section on Grinshpan’s Particular Bridge, the instructor may use the conference time with students to gauge their conceptual understanding of the use calculus tools. Given the disparity between Final Exam and project students’ consultation times, there may be a real need to consider the issue more fully in future research.

Another point of consideration for future research is the limitation imposed by non-random selection of students into the Final Exam and project groups. As explained earlier (p. 80), the restriction to completers was deemed necessary in

order to remain conservative in the overall comparison of group results. For this reason, the researcher has avoided discussions of final course grades. In a preliminary survey of final results for a separate population sample (Year 0), project students were found to have an average final grade that was half a point higher than that of Final Exam students (3.4 vs. 2.9). For this Year 0 study, the instructor provided the following data regarding final course grades. The sample consisted of 83 Final Exam and 51 project students who were “C or better” completers. The Final Exam students had 18% *As*, 55% *Bs*, and 27% *Cs*, and had a grade point average (GPA) of 2.9 (on a 4-point scale). The project group had 51% *As*, 39% *Bs*, and 10% *Cs*, and had a GPA of 3.4 (Grinshpan, personal communication, March 20, 2007). The instructor felt that *Ds* should be excluded and that students who earned *Ds* should be considered as non-completers of the course (Grinshpan, personal communication, March 20, 2007).

Those data included above demonstrate that project students can get higher grades, although this finding is subjective and should be treated with considerable caution, as in any discussion of classroom grades. But when cautiously connected to the present findings, this suggests that benefits may accrue to students at the project level. As discussed earlier, an examination of final grades was not independently conducted in the present study, since there were different grading approaches involved between the two groups at the point of final grade determination.

The numbers of project students in this study increased from year to year. Those preliminary data referred to on the previous page also serve to demonstrate the fact that project students' numbers have increased. The instructor noted that of the "C or better" completers from the Year 0 study, only about 38% produced projects, while 62% of the completers took the final exam. The instructor explained that at that time "a majority of stronger students preferred the project option" (Grinshpan, personal communication, March 20, 2007). Grinshpan's observation from this earlier period may not be as true in the later period (Year 3) where the number of Final Exam students (57) was about 41% of the completers and the number of project students (83) was about 59% of the 136 completers. The numbers in the intermediate year were closer to being equal. In particular, in Year 1 the number of Final Exam students (59) was about 44% of the completers and the number of project students (74) was about 56% of the 133 completers. Some analysis of the possible significance of these increased numbers of project participants might be warranted in future research. The present research has exposed this trend, but has not attempted to draw any inferences from the trend.

As mentioned on page 72, the instructor views projects and Final Exams as instrumentally equivalent means of evaluating students' work. In either case, students are first graded on their basic understanding of the concepts (this much is expected and is generally awarded an average grade), and then it is considered how well students understood the concepts and how far they went

beyond the basics (Grinshpan, personal communication, February 17, 2006). The instructor further explains that projects and Final Exams differ only in their approach. In particular, projects have an applied aspect that Final Exams lack. Final Exams expect results to be worked through abstractly and are more procedural than are projects (Grinshpan, personal communication, March 20, 2007). There remains uncertainty as to how the instructor determines relative project grades.

It is this researcher's belief that this instructor has developed a competency for using projects that has informally developed over the course of many semesters of practice. These informal developments, together with the usual terseness of mathematics instructors' syllabi, make it difficult to properly document the program. The instructor largely relies on his verbal explanations (as noted earlier) as the way to explain what projects are and what is expected of the student upon election of the project option. While educators outside of undergraduate mathematics might consider the lack of a fully descriptive syllabus as a deficiency, within mathematics departments this is often accepted (perhaps since it allows instructors to be more flexible with their course requirements). Future researchers may need to contend with the vagueness of course syllabi when attempting studies about project options. Similarly, the limitation regarding the instructor's "mental rubric" (see the earlier section on Grinshpan's Particular Bridge) as used in evaluating project write-ups will need to be addressed in future research.

Another issue for future research is the possibility of using in-class discussions of project scenarios as a means of heightening student awareness of the real world applications of mathematics. This is reasonable from the suggestion that non-project students, in addition to project students, reported benefits from project discussions. It may be sufficient, for instance, for undergraduate mathematics instructors to include discussions of this kind as a means of increasing general student interest. Good results may be possible without actually having students perform the projects themselves. It may be very helpful for students to see that their peers and actual classmates are the ones performing projects, however. Future researchers may wish to make accountings for projects vs. discussion-only variables.

Yet another particular topic of potential interest for future researchers is the exploration into any differences in day vs. night students regarding their tendency to choose application projects over final exams. As noted earlier, the night population may be more non-traditional (e.g., more career-minded, more mature) than the day population (e.g., those students who are enrolled full-time and who are generally younger). There was some suggestion from the present research that projects may work particularly well for those students who have already established careers and/or are taking their courses in the evening, so this situation might be explored further.

In addition to the relatively concrete finding that project students spend more time on task, this study suggests that there are additional benefits

associated with project work that may be hard to discern. One of the subtle benefits is that the project option may be a way for some students to successfully complete their mathematics courses, when they might not be so successful without the project option. Students with high levels of test anxiety, for example, may be just one group to benefit from project options. This hypothesis was not examined in the current study due to the inherent difficulty of identifying those students who were able to pass their courses by doing a project and who would not have passed otherwise. There is also a gray area to “passing” that would have required resolution, since a “D” is not considered a passing grade in all programs. If a student needs to repeat a course, then one can’t really say that that student passed the course, even if the grade involved was technically within the pass range of a “D” or better.

It is this researcher’s opinion that the benefit of course completion, described above, does exist. There are other reasons why the project option program should be maintained and developed. It seems reasonable, for example, to offer the project program if projects directly stimulate further research on the part of the student. Stimulation of research was suggested in a number of interview responses that were coded to “Merit.” It is possible that this study was inadequately designed to pick up on the heightened mathematical ability that project work provided, or that this ability is simply too subtle to measure. In terms of the Test 3 analysis, the heightened ability might have existed, but of a nature

that Test 3 failed to discern. As mentioned earlier, a more robust form of analysis might be designed in order to measure those subtle mathematical abilities.

Future studies into project options might attempt to measure mathematical abilities among all students, whether they completed the course satisfactorily or not. This approach could demonstrate another pragmatic benefit of project work, namely that the project group might have significantly fewer incompletes. In the present study, however, this condition of greater overall student success was not an issue. Instead it was hypothesized, and ultimately rejected, that Test 3 grades would be a distinguishing feature between the project and non-project groups for the four semesters featured in the qualitative portion of the study.

The possibility of greater overall student success in undergraduate mathematics with project options is a worthy suggestion for further study. An assessment of students' completion rates with application projects compared to the Final Exam approach might be informative and show that projects are indeed beneficial from the viewpoint of course completion. While the inclusion of data pertaining to incompletes might be included in the sample data collected for analysis, it has already been explained that the main difficulty in collecting the information on incompletes lies in the questionable categorization for most of these students who never completed their courses, and who never declared that they would attempt to produce projects. The researcher would need to somehow determine whether or not particular students might have attempted a project, if they had not withdrawn from their course, for instance. A comparison of the

number of withdrawals and failures (i.e., incompletes) in project courses and similar, but traditionally presented, courses might also be informative. In any case, it seems that a mixed-method approach would be a most favorable research design, since the researcher would need to communicate closely with students of all abilities, particularly those who might be described as “mathematically challenged.”

The qualitative portion of the present study suggested that project students’ perceptions toward mathematics were at least on a level with those of Final Exam (non-project) students. Project students consistently reported having similar heightened mathematical perceptions to those of Final Exam students, as well. Most clearly demonstrated was the finding that project students reported spending significantly more time on task (about 10 hours per week) toward the end of the semester than did non-project students (about 5 hours per week). This qualitative finding shows that a mixed-method approach can indeed be most revealing.

The mixed-methods approach proved to be useful to the overall discovery process surrounding the present study. In particular, interviews were found to be an excellent means of collecting students’ feelings and perceptions, and it would be reasonable to apply a mixed-methods approach to further studies. The number of interviews could be increased so that more information might be captured concerning issues such as time on task and personal gains.

It seems appropriate to conclude the general discussion with some final thoughts concerning personal gains from project work. The following ideas were derived from the personal interviews and observations of this writer. Application projects do not guarantee that students will enjoy their courses more, and satisfaction can be derived from a student's traditional course work; however, application projects may make courses more enjoyable for students and allow some students to synthesize the material better.

It also seems reasonable that projects may benefit individuals outside the classroom in addition to the students who undertake projects. This assertion is supported by the bulk of past project work, for in nearly every application project there were one or more supervisors and/or consultants who were also interested in the results of the student's project. Additionally, some projects would naturally be of further interest to others beyond the student and the project supervisor. This was evidently the case with the Faza project that was described in detail earlier (Grinshpan, 2005), for example. Students have the opportunity to use mathematics in a novel way, so results of their projects may even be of interest to mathematicians. It would seem to be a pragmatically sound decision to support programs such as application projects from which students can derive satisfaction and enjoyment, and from which they might develop connections to the larger community. Such programs would be extremely desirable, especially in mathematics courses where, by the "traditional" nature of the discipline, these direct community gains are perceived to be difficult to attain.

Another, tangentially related, point of interest derived from the interview responses of project students concerns technology. Since the majority of student projects were technologically based, many project students in this study demonstrated an appreciation for technology. This point is of particular interest in mathematics courses where teaching tends to follow traditional “chalk and talk” methods. This observation suggests other potentially fruitful areas of study regarding project work. In particular, one might wish to explore the extent to which technology is employed in students’ work, or perhaps consider the myriad technological applications and their related fields of use. (Projects may themselves be considered a form of technology in its wider sense, however this view is merely noted and not developed here.)

For the present, this researcher defers to another writer’s interpretation of how students learn technologically based skills. The following quote offers insight into how “book learning” relates to “experiential learning,” and corresponds nicely to the way textbook based activities and project work connect with application projects. Miller (1973) suggests that students need to

. . . see it firsthand. Once they have been exposed to it in person and experienced it as part of their own lives, they are ready to understand and put to use the information that is in the books. . . . There is a kind of nonverbal communication that occurs when students are personally involved in the technology and when they interact with people who are using and developing it (p. 656).

One of the benefits of application projects then, appears to be that students also learn to use technology as part of doing their projects.

Another possible area of investigation that wasn't a direct concern in the present study, but could be interesting for future research, might be to consider how particular students' project learning manifests itself in their later academic efforts, and in their professional lives beyond the ivory tower.

Summary

An appropriate and pragmatic way to summarize this Conclusions chapter, as well as to summarize the main findings of the present work in its entirety, is to specifically answer the Research Questions outlined earlier. The questions and corresponding answers are presented in concise fashion below.

For Research Question 1: "Do non-math major undergraduate students who are more mathematically proficient (or less mathematically proficient) tend to choose the project option rather than taking a Final Exam?" the answer was "no." It was found that mathematical proficiency was not skewed toward either group.

Research Question 2 asked "is there any significant difference in the common third test grades among non-math major undergraduates who completed one of the two mathematics courses (MAC 2242 Life Sciences Calculus II and MAC 2282 Engineering Calculus II) with application projects as compared to students who took these same courses without electing the application project option at one large, urban university?" This question was answered "no." From the data expressed in Table 8 of Chapter 4, it was evident

that the group means were not significantly different and that no assertion about common third test grades and group participation could be drawn from data collected.

Research Question 3: “As indicated by interviewee responses of the non-math major undergraduates enrolled during the spring of Year 3 in MAC 2242 and MAC 2282 (the same two mathematics courses specified in Research Question 2), with an application project option and those who did not elect the project option: is there a difference between the two groups' perceptions toward mathematics?” was answered “yes.” It can be said that the project group’s overall perceptions toward mathematics were more positive than those of the non-project group, with Patton’s “substantive” significance. When interviewed, undergraduate students in the project group reported having higher levels of positive perception toward mathematics than those in the non-project group. This was evidenced by remarks such as “I can now see how math relates to chemical engineering,” or “I’m able to apply calculus to veterinary medicine.” This is an encouraging finding for those instructors and students who may consider project options in the future.

Research Question 4 asked “from comparisons of interviewee responses (currently enrolled non-math major undergraduates electing application projects and those who did not elect project option): is there a difference between the two groups' levels of course satisfaction?” The answer to this question was “yes,” for a higher incidence of course satisfaction within the project group was exhibited.

Finally, Research Question 5, “By comparing the interview data for students electing the application project option with those responses of non-project option interviewees: is there a significant difference between the two groups’ reported levels of time on task?” was answered with a “qualified yes.” Self-reported levels of time on task differed by group. In particular, the project group spent roughly twice as much time on task per week going into the final weeks of the course than did the non-project group. It is possible that project students attending during the day were able to spend more time in their overall course studies. If this were indeed true, it may explain why the morning project students generally obtained higher scores than those project students attending during the evening in the spring of Year 3 (Chapter 4, Table 7).

The implications of these findings are that further research is warranted and the project option should be supported and further developed. It may be helpful to refine or abandon some portions of this study for use in any subsequent study. It is this researcher’s opinion that qualitative analysis is always a good compliment to hard numbers, so a qualitative component is likely to be valuable in future studies into project options. As already mentioned, without the complimentary qualitative analysis to the present study, a lot would have been missed; the positive perceptions about mathematics of students who chose application projects may have remained undiscovered, for instance.

Further study into application projects is most certainly desirable. This study was intended to demonstrate that there are matters to be learned about

application projects. This researcher has suggested some possible paths that future researchers may wish to follow. In the spirit of application projects themselves, future researchers may certainly wish to blaze their own trails. If the current research has in any way shone light on the application project program, and illuminated some of its important features, then the study has been successful.

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Appendices

Appendix A

Copy of Participant Letter of Information

Spring Year 3

Dear Participant,

My name is David Milligan, and I am a graduate student in the College of Education at the University of South Florida. I am doing research about how Optional Real World Application Projects effect the achievement of undergraduate mathematics students. To do this, I need the help of people who agree to take part in a research study. The purpose of this study is to identify student benefits and any negative elements that might be associated with project work. The focus will be on the important area of possible student gains in learning math. Findings may suggest that student gains are improved through project work.

We are asking you to take part in this study because you were given the option (whether you chose it or not) to produce a project. We will consider the responses of students in the project group and compare them to those of students in the non-project group to see what might be exhibited.

About fourteen people will take part in this study at USF. If you decide to participate, you will be asked to take part in an interview. The interview will be audio recorded and will be conducted at a time and place convenient for you.

Your participation in this study will take approximately 15 minutes.

Appendix A (continued)

The study is being performed strictly as part of research into the project option and the interview focuses on these. You do not have to take part in this research study if you do not want to. If you choose to be in the study, you will remain anonymous and you are asked not to sign this or any form so as to protect your anonymity. If you do not want to take part in this study, nothing negative will result. You are free to discontinue the interview at any time. Your course grade will not be affected in any way by your participation. Part of the reason for ensuring your anonymity is to allow you to be unconcerned about your grade.

We will not pay you for the time you volunteer in this study, nor will it not cost you anything to take part in the study. There are no known risks to those who take part in this study. If you have any problems during this study tell me (David Milligan) right away. There are no direct benefits to you, however your participation in the study may offer the indirect benefit of a better understanding of how the availability of the project option colored your learning experience.

Your privacy and research records will be kept confidential to the extent of the law. Authorized research personnel, employees of the Department of Health and Human Services, the USF Institutional Review Board and its staff, and other individuals, acting on behalf of USF, may inspect the records from this research project.

Appendix A (continued)

The results of this study may be published. However, the data obtained from you will be combined with data from others in the publication. The published results will not include your name or any other information that would personally identify you in any way.

If you have any questions about this study, please call David Milligan at 813-987-2852. If you have questions about your rights as a person who is taking part in a study, call USF Research Compliance at (813) 974-5638.

David Milligan

Appendix B

Interview Questions

1. Did you complete a project or did you take the Final Examination?
2. What year of college are you in right now?
3. What area was the focus of the math course you completed:
Engineering or Life Sciences?
4. If you completed a project, what do you think about including projects in the course curriculum?
5. At what time of day did your section of the course meet: morning or evening?
6. Were you a part-time or full-time student during the past semester, and were you employed during this time?
7. Why did you take the Final Examination, rather than completing a project? Or, why did you complete a project, rather than taking the Final Examination?
8. What is your opinion about having two options (the project and non-project options) in this course?
9. Do you feel that your conception of the usefulness of mathematics has changed as a result of this course? Why or why not?

Appendix B (continued)

10. Has your attitude toward mathematics changed as a result of doing a project / preparing for and taking the Final Examination? If so, please describe.
11. How many hours do you think you studied (and/or did project work) for your course last week?
12. How many hours do you think you studied (and/or did project work) for your course the week before last?
13. How many hours do you think you studied (and/or did project work) for your course the week before that (in other words, 3 weeks ago)?
14. What is your current estimated overall grade point average (before this semester)?
15. Is there anything else about the class (or math education in general) that you would like to add?

Appendix C

A Hypothetical Project Write-up

Since projects are unique and eclectic, there is no reason to suggest that any particular area is a better one to consider than any other area. This hypothetical write-up is provided in order to consider the requisite mathematical component of an application project.

The sample, which follows on the next few pages, lacks the detail that might be desired of an actual write-up, but the focus here is more on how a student might tie mathematics into the composition. It is likely that this sample could even serve as a sample write-up useful to prospective project students. With this potential future function in mind, the Cover page, Title page, Contents page, and Abstract page are included, as they might appear on a standard project write-up. Page numbers are included in angle brackets above the actual page numbers for this dissertation.

Regarding the mathematics employed in this example, there is absolutely no desire to display an illustration promoting any mathematical approach. In any of the calculus courses involved, the “change in the rate of change” concept is clearly one indicative of integration or differentiation. Students that hit on this idea are squarely capturing an appropriate application project concept. Getting this expressed in words and diagrams makes the project work.

Appendix C (continued)

[Note: A few editorial comments are included in parentheses in the example that follows.]

MATHEMATICS-ENGINEERING PROJECT

(This is an example, an AREA might be
“MARINE BIOLOGY” rather than “ENGINEERING”)

Plants and Water

(Project title)

Tampa, Florida

(company location)

Year 3

<no number>

Appendix C (continued)

Plants and Water

(Title)

Leslie Campbell

(Student name)

UNIVERSITY of SOUTH FLORIDA
MATHEMATICS UMBRELLA GROUP

La Hotel
Tampa, FL

Dr. Arcadii Grinshpan
MUG Director
(813) 974-9751
azg@math.usf.edu
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<http://www.sampleonly>

<Tampa, Florida >

Appendix C (continued)

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4. Mathematical Equations	6
5. Suggested Watering Improvements	7

(Students may, of course, include a different number of sections in your write-up. In addition to a problem description and solution, students are urged to include any of the following that they have compiled: calculations, graphs, analysis, pictures, spreadsheet information, conclusions, recommendations, references, or an appendix.)

Appendix C (continued)

Abstract

Plants and Water

This project involved determination of desired flow settings of a hotel's irrigation system. Carl Plantguy supervised the project with approval of Mr. Michael Noman. Their assistance in this project has been invaluable. The project was conducted over an eight-week period during the fall 2005 semester.

I was able to vary the amount of water provided to similar plants in separate beds. I measured the growth of the plants and tabulated and charted the amount of water provided daily versus the average plant height. After eight weeks it was decided that the plant heights had largely stabilized and that there should be enough information to determine what water amount had provided the desired plant height.

The process of watering the indoor plants at *La Hotel* has been mathematically analyzed. From my collected data a good mathematical model has been determined.

<ij>

Appendix C (continued)

Introduction

I happened to know a gentleman, Carl Plantguy, who cares for indoor plants for the La Hotel hotel. I discussed a plan that Mr. Plantguy, the gardening manager, agreed that it would be a good idea to experiment with the flow settings of the hotel's irrigation system. After presenting the idea to Mr. Michael Noman, the hotel manager, it was determined that my tests could be done.

Carl Plantguy agreed to supervise the project and Mr. Michael Noman graciously gave his written approval, making this project possible. Everything looked good since the whole thing could be done in eight or ten weeks, leaving plenty of time before Final's week to write up the project results.

The process of watering the indoor plants at La Hotel has been mathematically analyzed. From my collected data a good mathematical model has been determined.

I was able to vary the amount of water provided to similar plants in separate beds. I measured the growth of the plants and tabulated and charted the amount of water provided daily versus the average plant height.

Appendix C (continued)

The results suggest that increased watering is associated with increased growth in a way that can be mathematically modeled. My project supervisor, Mr. Plantguy, agreed with the findings and the plants are now being watered at the rate of 80 ccs per day.

I was able to supply my supervisor, who is the gardener at *La Hotel*, with a formula that sufficiently models the effect of water amount on the height of his specific plants. The gardener reports that he is now able (using the inverse relationship) to get his plants to grow to desired heights. He says, “water might be saved, as well as some pruning time, in the long run.”

The project gave me the opportunity to interact with others on a problem with real meaning. The manager seemed to be impressed when the results were presented to him. I have gained valuable experience and satisfaction from the civic nature of the project. *La Hotel's* gratitude was payment enough for my efforts and the experience has given me greater course satisfaction.

We determined that we didn't want to completely optimize the plant size. Instead a watering schedule was adopted that provides somewhat less water than the amount for optimal growth.

Appendix C (continued)

Watering Requirements

Carl Plantguy, who is very knowledgeable regarding the care of indoor plants, was responsible for determining the proper irrigation rate for the plants at *La Hotel*. I was allowed to experiment with the flow settings of the watering system. Plantguy stated that certain extremes existed and that there would be no reason to test outside these bounds. In particular, no less than 10ccs of water per day would be supplied to each bed (since the plants were known to desiccate if supplied with less) and no more than 100cc would be supplied (due to potential flooding). Eight beds were made available and water amounts of 20, 30, 40, 50, 60, 70, 80, and 90 ccs per day were provided. The experiment terminated when the plant growth had stabilized (after eight weeks). Final measurements were then made of average plant heights for each test bed (Table C1).

Table C1.

Hypothetical Sample of a Table: Water vs. Plant Height

Cubic cm	cm	Cubic cm	cm
20	5.00	60	7.50
30	5.50	70	8.00
40	6.25	80	8.75
50	7.00	90	9.50

Appendix C (continued)

The data has been compiled in the following graph. The empirical data are denoted by the large triangles in Figure C.

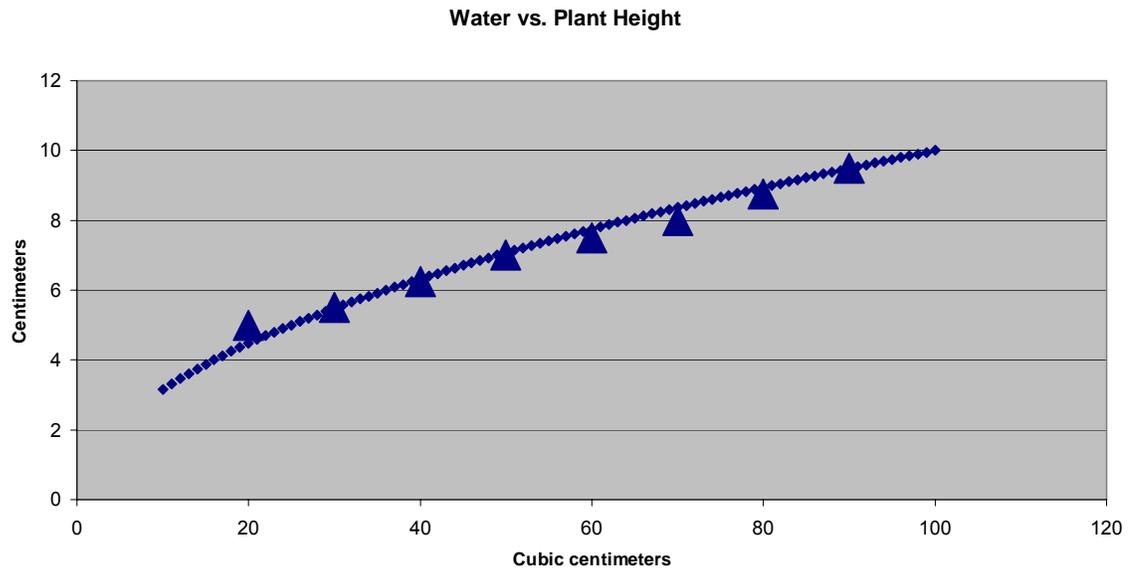


Figure C. Illustration of a Hypothetical Figure: Water vs. Plant Height

From the data collected a good mathematical model has been determined. It first appeared that a linear representation was the best model, however, after some trials it was found that

$$y = \sqrt{x}, x \in [20, 90],$$

where x is the daily allowance of water in ccs and y is the height in cms,

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Appendix C (continued)

models the watering data amazingly well. The curve plotted against the data measured is that of \sqrt{x} . The chosen amount of water is that which provides nine-centimeter high plants. From the chart above it is clear that we get nine-centimeter plants with 80 ccs of water per day.

To see this mathematically, we can take the derivative of \sqrt{x} to get $y'(x) = 1/(2\sqrt{x})$. This gives us the slope of the tangent line at a given x value (Table C2).

Table C2.

Hypothetical Sample of a Table: An Improved Mathematical Model

x	$y'(x)$	x	$y'(x)$
20	0.1118	60	0.0645
30	0.0912	70	0.0597
40	0.0791	80	0.0559
50	0.0707	90	0.0527

From the trend of first derivatives of increasing x values, it is evident that we have a gradual leveling off and that the tangent lines are progressively approaching horizontality ($y'=0$). This means that the benefit of increased water is reduced when x exceeds some large value.

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Appendix C (continued)

Mathematical Equations

There are a few interesting observations that might be made concerning the applicability of the chosen model to the real world situation of indoor irrigation. The main result was our square root relationship that

$$y = \sqrt{x}, x \in [20, 90].$$

For one thing, if we weren't physically restricted to x s within 20 and 90 ccs, it would be necessary to develop a better model. This is clear since the square root function continues to increase while we can be sure that at some point we will over-water the plants and cause a reduction in height.

We weren't concerned with the regions outside 20 and 90, but it's of interest to consider how fully our model might replicate the complete situation. A complete model would perhaps be modeled by a second-degree equation of some form where the growth would peak and then decrease as water becomes excessive. Still, in our problem we weren't concerned with the extreme case and the square root function worked well for the modeled portion. Finally, we should consider that if one wished to produce a plant of a given height (here we wanted nine centimeters), then the inverse, or square function would give the amount of water needed.

Appendix C (continued)

Suggested Watering Improvements

The primary result turned out to be a flow rate of 80 ccs per day to each of the beds. There were a few other nuances that came to light during this indoor irrigation system project. One concern was the actual precision of the release mechanisms. Some variation of as much as 4 ccs was observed during initial equipment testing. It appears that the mechanism averages out its water doses so that on a daily basis the amounts were within a reasonable tolerance of $\pm 5\%$.

Another concern was the introduction of varying amounts of fertilizing liquid to the water. It would be expected that plants would respond differently to equal quantities of treated and untreated water. It was decided to withhold the introduction of additives unless it could be accurately regulated. The regulator was soon added and this potential problem alleviated.

Finally, there was some initial concern about the source of water to be used, since both fresh tap water and well water were available. Interestingly, a two to three mix of well to tap water appeared to provide a good watering source. A brief period of hydraulic research demonstrated that mixing could be done with a reasonably inexpensive valve and pressure system. The cost of the equipment would be recovered in four years by savings on water.

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Appendix D

General Objectives Related to Project Courses

Life Sciences Calculus II (MAC 2242):

The student is to demonstrate an ability to solve problems involving

1. integrals of elementary functions;
2. first order differential equations;
3. limits and/or continuity of functions of two variables;
4. properties of vectors and linear maps;
5. probability/statistics; and
6. analytic geometry.

Engineering Calculus II (MAC 2282):

The student is to demonstrate an ability to solve problems involving

1. derivatives of a composition including a transcendental function;
2. geometric integrals (volume, surface area, etc.);
3. undetermined forms (e.g., those requiring L'Hôpital's Rule);
4. integrals involving special techniques;
5. Taylor polynomial approximations; and
6. convergence of a power series.

These objectives were provided by A. Z. Grinshpan, MUG Director (personal communication, February 23, 2007).

About the Author

David Milligan received a Bachelor's Degree in Education from the University of South Florida in 1993 and a M.S. in Mathematics from USF in 1997. His Master's Thesis explored a methodology of mathematics-engineering research. He taught several undergraduate mathematics courses at USF while in the Ph.D. program in Education during 1999 and 2000.

Mr. Milligan has also coauthored the publication "Complete monotonicity and diesel fuel spray" (*Mathematical Intelligencer*, 22 (2000), 43-53) with A. Z. Grinshpan and M. E. H. Ismail. This investigation into the mathematics surrounding diesel fuel spray might be considered an example of an "academic" mathematics/engineering project. Together with A. Z. Grinshpan, he has developed and maintained USF's Mathematics Umbrella Group (<http://www.math.usf.edu/mug>) web site that supports the project program from 1999 to the present.