2008 AIR RESEARCH GRANT PROPOSAL

Making the Connection: High School Mathematics Course Taking and Pathways into Postsecondary Science, Mathematics, Technology, and Engineering

Datasets of interest: National Education Longitudinal Study of 1988 (NELS: 88/2000) & NELS:88/2000 Postsecondary Transcript Files

Grant Amount Requested: $40,000

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2. Project Summary

Policymakers have a strong interest in reforming math and science education because these subjects are seen as critical to economic competitiveness through their impact on innovation in scientific research and technology. Yet long-term trends in degree taking not only show a decline in student completion of natural science and engineering degrees compared to other countries, but point to the uneven participation in science and engineering in college across different demographic groups (Science and Engineering Indicators-2006). Pre-college education, as the National Science Board (2006) emphasizes, is the foundation for fostering leadership in science, technology, engineering, and mathematics (STEM). Very few empirical studies exist, however, that examine carefully the connection between students' pre-college foundational preparation in mathematics and science and their college participation in math and science related majors. To strengthen the collaborative effort between K-12 and postsecondary institutions in designing intervention to increase STEM participation in college and workforce, policy makers need to know what and how different factors influence students' persistence and participation in STEM.

This proposed research intends to examine the connection between students' secondary school experience in math and science and their postsecondary participation in math/science related college majors, as well as contextual factors that predict the likelihood that students major in math, science, and engineering fields. In particular, the proposed research explores these issues for traditionally under-represented groups such as women and ethnic minority students, paying special attention to patterns among sub-groups of students defined by gender, race/ethnicity, and social economic status.

The proposed project intends to address these issues using two interconnected data files, namely, the National Education Longitudinal Study of 1988 (NELS: 88) and the postsecondary education transcript study (PETS: 2000) that was conducted at the conclusion of the NELS: 88 fourth follow-up study. The NELS:88 followed a national sample of 8th graders as they progressed through high school, postsecondary education, and into the workplace. The PETS:2000 contains detailed information about the types of degree programs, periods of enrollment, majors or fields of study for instructional programs, specific courses taken, grades and credits attained, and credentials earned. Taken together, these two data sources provide rich information for examining high school to college transitions, college course taking, and degree attainment in STEM majored fields. In addition, the longitudinal data enable us to use family background and secondary school experiences to predict postsecondary participation in math and science related majors and therefore generate useful information about the differential processes leading to different postsecondary pathways into math and science.

The key statistical technique for the proposed project is Hierarchical Models for Multinomial Data (Raudenbush & Bryk, 2002) where the key outcomes will be students' college majors (differentiating among math/science vs. non-math/science; and natural science vs. social science within science, for example).

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4. Project Description

Introduction

Does the timing of students' taking algebra 1 in secondary schools tell us anything about their participation in college introductory math and science courses? Does their performance in college introductory math and science courses predict whether they will choose to major and eventually earn a degree in science, technology, engineering, or mathematics? How is the study of mathematics in secondary schools associated with the advanced study of mathematics and science in college? This proposed project intends to address these issues using the National Education Longitudinal Study of 1988 (NELS: 88/2000) and the postsecondary education transcript study (PETS: 2000).

Policymakers have a strong interest in reforming math and science education because these subjects are seen as critical to economic competitiveness through their impact on innovation in scientific research and technology. Yet long-term trends in degree taking not only show a decline in student completion of natural science and engineering degrees compared to other countries, but point to the uneven participation in science and engineering in college across different demographic groups (Science and Engineering Indicators-2006). Pre-college education, as the National Science Board (2006) emphasizes, is the foundation for fostering leadership in science, technology, engineering, and mathematics (STEM).

Very few empirical studies exist, however, that examine carefully the connection between students' pre-college foundational preparation in mathematics and science and their college participation in math and science related majors. To strengthen the collaborative effort between K-12 and postsecondary institutions in designing intervention to increase STEM participation in college and workforce, policy makers need to know what and how different factors influence students' persistence and participation in STEM.

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Conceptual Framework and Empirical Research Highlight

In his seminal work on college dropouts, Tinto (1987) suggested that institutions develop "early warning systems" that can spot and track students who may have difficulty completing college programs. In the case of students' "dropping out of" STEM majored fields, one of the early warning signals could be the timing of taking algebra 1 in secondary schools. It is well known that high school mathematics is largely structured in a highly hierarchical and sequential manner (Bozick and Ingels, 2007), namely access to higher level mathematics courses (e.g., geometry and algebra 2) depends on successful completion of a prerequisite course (e.g., algebra 1). Because of this sequential feature of course taking patterns, the timing of taking the gatekeeper course, algebra 1, can be important for further participation in advanced mathematics and science in high school and beyond.

Studies on early access to algebra indicated its positive effects on mathematics achievement in high school (e.g., Bozick, R., and Ingels, 2007; Oaks, 1993; Smith, 1996). In addition, research on transition from high school to college in terms of taking introductory mathematics and science found that more advanced study of mathematics in high school was one of the two pillars supporting college science (Sadler and Tai, 2007). Though research has provided elements for understanding the relationship between early access to algebra and advanced course work in high school math and science, and some evidence of more advanced course work in high school mathematics for introductory college science, few empirical studies exist that investigate systematically the curricular pathways from secondary schools into and through postsecondary education (Adelman, 2004).

The curricular pathways from secondary schools into and through postsecondary education are both complex and conditioned by many factors (Adelman, 2004; US Department of Education, NCES, 2003). Borrowing the concept of path dependence from studies of political science (e.g., Pierson, 2000), sociology (e.g., Goldstone, J., 1998), and economics (e.g., Nelson & Winter, 1982), this proposed study considers the timing of taking algebra 1 in secondary schools as a critical juncture which could potentially set students off on different trajectories in terms of pathways into STEM majored fields in college. The concept of path dependence is a useful metaphor for thinking about developing "early warning systems" (Tinto, 1987) that spot and track students who may opt out of STEM majored fields, since today's choices constrain tomorrow's options. This path-dependent feature is especially true for attracting more students into STEM majored fields in the sense that more advanced math and science studies depend or are built on a solid foundation in these subjects at lower levels.

Besides the timing of taking algebra 1 in secondary schools, other key factors affecting students' participation and persistence in math and science include students' demographic characteristics (e.g., gender, race/ethnicity) and various social-psychological measures (e.g., peer influence, attitude towards math and science). Long lines of research have documented extensively the relative low representation of women and minority students' participation in advanced math and science courses and in STEM majored fields (e.g., Adelman, 1998). Researchers from different disciplines and with different perspectives have offered a variety of explanations for this disparity, ranging from affective/psychological (e.g., Frost, Hyde, and Fennema, 1994), sociological (e.g., Fennema and Peterson, 1985), to economical status as proxies for opportunities to learn (e.g., Bozick and Ingels, 2007).

However, despite the previous extensive research, it is not clear whether students' decisions to pursue further studies in STEM majored fields are a joint function of their demographic characteristics, social economic status and attitude towards STEM majored fields. For instance, it is possible that students from wealthier families might have wider career options than students from less privileged background. And some of the appealing or lucrative career professions, such as lawyers, do not necessarily require a strong background in math or science. Therefore, even though students from higher SES overall tend to enroll in advanced math and science courses more than those from lower SES (Bozick and Ingels, 2007), the SES could play a nuanced role, depending on students' career aspirations. The preliminary data exploration of high school students' participation in and performance on the A-level math and science (biology, chemistry and physics) exams in Britain suggested the possible interaction effect of students' SES and demographic background such as gender.

Furthermore, depending on the specific STEM fields, the relationship between students' demographic characteristics and participation in these fields could be different. For instance, using the Beginning Postsecondary Student Longitudinal Study (BPS 96/98/01) data, Newton and Tao (2007) explored the relationship between gender, ethnicity, types of institutions (private vs. public), and baccalaureate degree production in natural sciences and engineering. They found that when comparing degree production in natural sciences vs. engineering, females were more than two and a half times likely to have a major in natural science instead of engineering; in contrast, when comparing degree production in natural sciences vs. other disciplines (excluding engineering), females had a close to one sixth of a chance to major in natural science compared to other disciplines. These preliminary analyses point to the complex and nuanced differences among different STEM majored fields. In other words, patterns of participation among different demographic groups could be different depending on the specific STEM fields (e.g., biology vs. mathematics).

Taken together, these studies provide a foundation for studying the connection between students' preparation in math and science during secondary school years and their postsecondary participation and persistence in math/science related college majors, for exploring various psychological and social factors that might predict such differences from a longitudinal and contextual perspective, and for examining the patterns of transitioning from secondary math/science to college math/science for underrepresented groups defined by gender, race/ethnicity, and social economic status.

Appendix A describes the conceptual and analytical model connecting key elements of high school course taking and preparation (highlighting the timing of taking algebra I), transition to college, and end of college degree attainment. The dotted lines imply uncertain paths. For instance, taking college introductory math does not necessarily lead to a STEM major field; instead, other factors might play a role such as whether introductory math leads to taking advanced math and other college experiences. One important point worth mentioning is that the conceptual and analytical model as represented in Appendix A does not intend to imply a simplistic relationship between pre-college preparation and transition to and go through college. Rather the framework is to highlight the key junctions of the pathway during an important stage of students' academic journey.

Research Questions

This proposed project intends to address the following questions:

- What is the relationship between the timing of taking algebra I and participation in college introductory math and science courses and what are the patterns of this relationship for different demographic groups?
- How does students' performance in college introductory math and science courses predict whether they will choose and eventually earn math, science, or engineering majors and what are the patterns of this prediction among different demographic groups?
- How is the study of mathematics in secondary schools associated with the advanced study of mathematics and science in college and what are the patterns of this relationship for different demographic groups?

Data and Methods

Data Sources. This proposed project will use two interconnected data files, namely, the National Education Longitudinal Study of 1988 (NELS: 88) and the postsecondary education transcript study (PETS: 2000) that was conducted at the conclusion of the NELS: 88 fourth follow-up study. Sponsored by the U.S. Department of Education, National Center for Education Statistics (NCES), NELS:88 followed a national sample of 25,000 8th graders in 1988 as they progressed through high school and postsecondary education (U.S. Department of Education, National Center for Education Statistics, 2003). Since 1988, the sample population of NELS: 88 respondents have been surveyed five times across 12 years. In addition to surveying the students, their parents or guardians (1988 and 1992), and their teachers and school administrators (1988, 1990, and 1992), the study also collected high school transcripts for the study participants in 1992, following the graduations of most of the students.

The postsecondary transcript data was collected in the year 2000 to supplement the postsecondary education information collected from the NELS: 88/94 and NELS: 88/2000 interviews. The NELS: 88/2000 Postsecondary Education Transcript Study (PETS) collected the transcripts from all postsecondary institutions attended after high school by the NELS: 88 fourth follow-up study's respondents. The transcript study included detailed information about the types of degree programs, periods of enrollment, majors or fields of study for instructional programs, specific courses taken, grades and credits attained, and credentials earned. Taken together, the two data sources provide rich information for examining high school to college transitions, college course taking, and degree attainment in STEM majored fields, which is the focus of the proposed project.

. *Sample and Weights.* Since the research questions focus on critical junctures of the pathways of students as they progress through secondary schools, enter and go through college, the samples will be constructed according to these critical junctures at two different stages. At the first stage, the NELS: 88 sample will be divided into three groups as follows: students who took algebra 1 at either the 8th or 9th grade, students who took algebra 1 at later grades, and students who never took (or passed) algebra 1 course. For these three groups of students, the project will examine the likelihood of taking introductory college math and science courses. At the second stage, students from whom NELS:88 collected the PETS information will be grouped according to the first two years' of college course work in mathematics and science as follows: introductory math, introductory sciences (biology, chemistry and physics), and remedial math or science. For these three groups of students, the project will investigate the likelihood of obtaining STEM majored fields. Proper sample weights and standard error estimates will be used to ensure proper populations of inference.

Variables. Appendix B lists the key categories of variables for the proposed project. These key categories of variables reflect their significant relationships with achievement, participation, and persistence in mathematics and science based on existing empirical research studies.

Statistical Analysis. The outcomes of the proposed project consist of multiple categories (e.g., participation in introductory college math, participation in introductory college science, or participation in remedial math or science courses). In addition, students are located within different organizational units (i.e., different higher education institutions). Therefore, the key statistical technique for the proposed project will be Hierarchical Models for Multinomial Data (Raudenbush & Bryk, 2002) where the key outcomes will be students' participation in introductory math or science courses, or college majors (mainly differentiated among math/science vs. non-math/science; and natural science vs. social science within science, for example).

In the proposed project, two sets of parallel HLM logistical analysis will be conducted. The first HLM logistical analysis will focus on examine the differential secondary school processes leading to different postsecondary destinations in introductory math or science courses. The second HLM logistical analysis will focus on investigating the differential postsecondary schooling process leading to different destinations in STEM majored fields.

Prior to the HLM analysis, extensive exploratory and descriptive statistics such as frequencies and cross-tabulations will be conducted so as to detect the complicated patterns of relationships among different variables before building the final multivariate HLM models.

Significance of Study and Policy Implications

Policymakers have a strong interest in reforming math and science education because these subjects are seen as critical to economic competitiveness through their impact on innovation in scientific research and technology. Yet long-term trends in degree taking not only show a decline in student completion of natural science and engineering degrees compared to other countries, but point to the uneven participation in science and engineering in college across different demographic groups (Science and Engineering Indicators-2006). Pre-college education, as the National Science Board (2006) emphasizes, is the foundation for fostering leadership in science, technology, engineering, and mathematics (STEM). This proposed project intends to examine carefully the connection between students' pre-college foundational preparation in mathematics and science and their college participation in math and science related majors. As such, the proposed study will generate empirical evidence on what and how different factors influence students' persistence and participation in STEM. This information is useful for policy makers and other stakeholders (e.g., K-16 educators) as they attempt to strengthen the collaborative effort between K-12 and postsecondary institutions in designing intervention strategies to increase STEM participation in college and workforce. For instance, findings relevant to how soon one can predict whether a student would choose a STEM major or not down the road based on this student's timing of taking algebra 1 in middle or high school will be important signaling information. In addition, a nuanced investigation of different patterns of transition to college in STEM fields among various demographic groups is also helpful for policy conceptualization (e.g., avoid one-size-fits-all policy initiatives). Finally, differentiating among specific STEM fields (e.g., engineering vs. natural science) when examining patterns of participation and persistence among different demographic groups could also enhance our understanding and provide clues for further investigation.

Innovative Aspects of Study and Intended Audience

Conceptually, this proposed study borrows the concept of path dependence from studying phenomenon in political science, sociology, and economics and considers the timing (DesJardins et al., 2002) of taking algebra 1 in secondary schools as a critical juncture which could potentially set students off on different trajectories in terms of pathways into STEM majored fields in college. The proposed study integrates the concept of path dependence with Tinto's seminar work (1987) on college dropout for thinking about developing "early warning systems" that spot and track students who may opt out of STEM majored fields, since today's choices constrain tomorrow's options. This path-dependent feature is especially true for attracting more students into STEM majored fields in the sense that more advanced math and science studies depend or are built on a solid foundation in these subjects at lower levels.

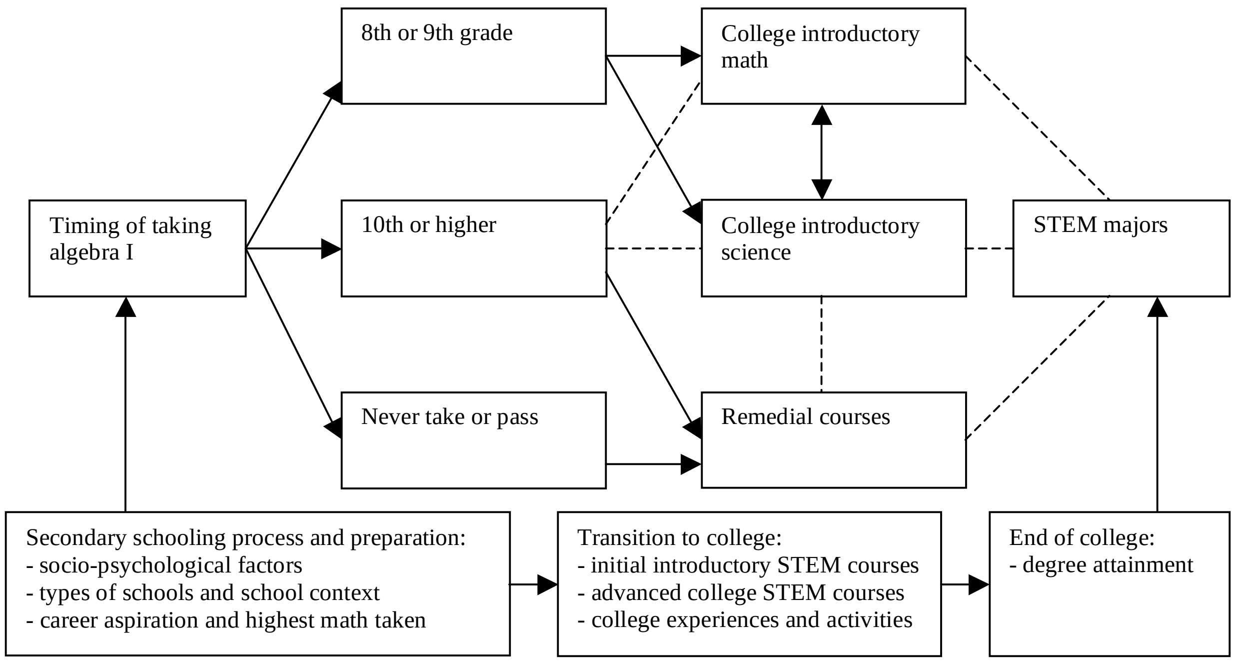
Methodologically, the proposed study takes advantages of the recent advance development in Hierarchical Linear Modeling framework. Specifically, the study uses hierarchical models for multinomial data to investigate how differential schooling process leads to different pathways into STEM majored fields. The synergy of the advanced methodological and conceptual framework is a unique feature of the proposed study.

Information generated from the proposed study is relevant for a variety of stakeholder groups, including policy makers who are concerned with the quality of workforce in STEM fields at various schooling levels (e.g., K-12, higher education) and administrative levels (e.g., state and federal government), K-16 educators and administrators who work directly with students from underrepresented groups (e.g., minority students), scholars whose research focuses on a wide variety of issues related to STEM education and labor market supplies (e.g., K-16 math and science education, transition from high school to college, STEM participation by different demographic groups, quality of K-12 math and science teaching force, etc.), curricular developers who are interested in designing intervention materials for struggling students, and the general public who is interested in STEM educational issues.

Dissemination Plan

Results from the proposed study will be disseminated through various channels and in various formats, including presentations at professional conferences such as the Association for Institutional Research (AIR) forum and the annual meeting of the American Educational Research Association (AERA); peer-reviewed publications in relevant journals such as Educational Evaluation and Policy Analysis (EEPA) and Research in Higher Education (RHE); and journals for practitioners and general public such as Phi Delta Kappan (PDK). A nice feature of interpreting logistic regression analysis is that results can be interpreted with everyday terms such as odds and likelihood, which makes it easy to communicate study findings to policy makers, practitioners, and the general public.

Appendix A. Conceptual and Analytical Model of Connecting High School Mathematics Course Taking and Pathways into Postsecondary STEM Fields



Appendix B. Variable List

Weights

Proper weights variables as appropriate for the sample and data variables used

Demographic characteristics

Gender
Race/ethnicity
Social economic status

Secondary course taking in math

Timing of taking algebra I (8th/9th vs. 10th or higher)
Highest math course taken by the end of high school

Affective factors

Educational aspiration
Attitude towards math and science
Career aspirations for STEM related fields

College course taking and degree attainment

Introductory math or science course taking during freshmen and sophomore years
Degree attainment and majors

College activities and experiences

Remediation
Career counseling
Extra curricular activities

Organizational and contextual factors

Types of secondary schools
School demographics
Teacher quality in math and science (e.g., certification in math and science)

Types of higher education institutions
Quality ratings of institutional STEM programs (supplemented if necessary)

5. References

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Sadler, P. and Tai, R. (2007). The two high-school pillars supporting college science. *Science*, 317, 457-458.

Smith, J. B. (1996). Does an extra year make any difference? The impact of early access to algebra on long-term gains in mathematics attainment. *Educational Evaluation and Policy Analysis*, 18, 141-153.

Tinto, V. 1987. *Leaving College: Rethinking the Causes and Cures of Student Attrition.* Chicago: University of Chicago Press.

U.S. Department of Education, National Center for Education Statistics (2003). *Postsecondary Attainment, Attendance, Curriculum, and Performance: Selected Results From the NELS:88/2000 Postsecondary Education Transcript Study (PETS), 2000*, NCES 2003–394, by Clifford Adelman, Bruce Daniel, and Ilona Berkovits. Project Officer: Jeffrey Owings. Washington, DC: 2003.

6. Biographical Sketch

I am currently an assistant professor in the Quantitative, Measurement, and Evaluation division at the Graduate School of Education of the University of California, Berkeley. I have a Ph.D. in Education with an emphasis on Social Research Methodology from the University of California, Los Angeles.

The successful completion of the proposed project requires a rigorous training in quantitative methods, first-hand experiences in quantitative research using large-scale data, especially good knowledge of and experiences in HLM, and training with weighted sample surveys. And I meet these requirements.

I have extensive training and experience with research and statistics. My training at UCLA's Social Research Methodology division and other social science departments (e.g., sociology, psychology, and applied linguistics) involved extensive coursework in various statistical methods, including multiple regression, analysis of variance, multivariate analysis, factor analysis, structural equation modeling, survey research method, categorical data analysis, and hierarchical linear modeling. In addition, I have extensive experience conducting advanced quantitative analysis using both national database (the Longitudinal Study of American Youth—LSAY) and large-scale datasets at the Los Angeles Unified School District (LAUSD) which is the second largest urban school district in the country.

My dissertation focused on gender differences in growth in mathematics between grades 7 and 10, how these differences varied across schools, and how the differences were related to individual, family, and school characteristics. My analysis involved a three-level hierarchical linear modeling technique that combined the longitudinal and cross-sectional features of the data. Thanks to a 9-month National Science Foundation (NSF)/American Educational Research

Association (AERA) grant, I was able to continue this work and publish an article in the *Mathematical Thinking and Learning* (2002). I also applied the same methodology to investigate students' mathematics growth in secondary school years and end of high school mathematics attainment and wrote a paper based on this analysis. The manuscript is currently under review for possible publication in *Teachers' College Record*. While working for LAUSD, two of my evaluation reports received awards from the AERA Division H's Publication Competition in the category of Instructional Program Evaluation (Honorable Mention – 2003, Academic English Mastery Program Evaluation Report; and Outstanding Publication – 2004, District Math Plan Evaluation Report). In these two reports, I utilized advanced statistical techniques (i.e., Hierarchical Linear Modeling and multinomial logistical regression).

Thanks to a generous AIR fellowship, I attended the 2007 National Summer Data Policy Institute, where I had the opportunities to learn about various NSF and NCES databases and about the critical importance of using proper weights variables. All these preparations will enable me to successfully carry out the proposed project if funded.

Being a successful applicant for the AIR Research Grant Program will greatly contribute to my scholarly development and career goals. As an assistant professor at University of California, Berkeley, my career goals are teaching and doing research. Applying for the AIR grant is an integral component of my academic job that consists of teaching, doing research, and publishing papers. With these career activities, I strongly believe that the opportunity to obtain an AIR research grant will help me in my career pursuits in using NCES and NSF data sets for basic, policy, and applied research. Last but not least, the AIR research grant will provide an apprenticeship opportunity for me to mentor doctoral students in honing their quantitative skills as institutional researchers by providing them an opportunity to work on this proposed project.

7. Budget and Budget Justification

Personnel	**annual rate**	**no. months**		**percentage**	**6/1/08 - 5/31/09**
PI, Newton	63,300			8%	5,275
				Total PI salary	**5,275**
Graduate Student Researcher					
1 Graduate Student Researcher (III)	$3,262	3	sum	50%	$4,893
	$3,360	1	acad	49%	$1,646
	$3,360	8	acad	49%	$13,171
				Total GSR III salary	**$19,710**
				TOTAL PERSONNEL SALARIES	**24,985**
Employee Benefits				**Rate**	
Summer Personnel, Prof. - PI				22.0%	1,161
				Total PI benefits	**1,161**
Graduate Student Researcher, ac. year				1.3%	193
Graduate Student Researcher, summer				3.0%	147
				Total GSR benefits	**339**
1 Fee Remission per semester (incl. Health insurance) - resident - 4 yrs				$4,789	9,578
				Total benefits	**9,578**
				TOTAL PERSONNEL AND BENEFITS	**36,063**
Travel					
Domestic conference travel for PI and 1 GSR					3,210
				TOTAL TRAVEL	**3,210**
Other Direct Costs (Supplies)					
miscellaneous research-related supplies					$727
				TOTAL OTHER DIRECT COSTS	**$727**
				TOTAL DIRECT COSTS	**$40,000**

7.2. Budget Justification

Personnel:

The budget requests salary for the Principal Investigator at the rate of 8%, totaling $5,275. The principal investigator will be responsible for supervising all aspects of the project, including data base cleaning and match merging, running statistical analyses, writing journal articles, preparing conference presentations.

One Graduate Student Researcher will work at 49% time during the nine months of the academic year and 50% during the three summer months. The graduate student researcher will work closely with the principal investigator on all aspects of the project. The GSR will gain substantial experience using large scale, longitudinal databases for institutional and policy research.

Requested salaries total $24,985 for both the PI and the GSR.

Two semesters of tuition/fee remission is requested for the GSR, according to University policy. The tuition/fee remission is calculated at $4,789 per semester.

Benefits:

Benefits for the PI and GSR are calculated at University-approved rates: 22% for the PI; 1.3% for the academic year and 3.0% for the summer, totalling $36,063.

Travel:

Funds totaling $3,210 are requested for domestic travel for the PI and the graduate student researcher who plan to travel to two conferences (i.e., AIR and AERA) to present findings of the study.

Other Direct Costs:

Funds are also requested for purchasing supplies related to the project such as paper, notebooks, postage, and reproduction costs for printing and dissemination of final reports.

Indirect Costs:

The Association for Institutional Research does not fund indirect costs.

8. Current and Pending Support

8.1 Current Support

none

8.2 Pending Support

none

9. Facilities, Equipment and Other Resources

The proposed project will be conducted at the Graduate School of Education, University of California, Berkeley (UCB). UC Berkeley will provide computer and statistical software support, and access to library resources. The Quantitative Measurement and Evaluation (QME) laboratory, where the work outlined in this proposal will be conducted, has the requisite advanced statistical computer software for the project and workspace for the Graduate Student Researcher.