

This prior research statement was used for my application for NSF's Graduate Research Fellowship, which I won in 2011.

Introduction. My ongoing graduate research investigates the value of interactive computer visualizations by developing, assessing, and refining technology-enhanced science instruction. I collaborate with high school and middle school science teachers to facilitate the development and implementation of these novel visualizations. As my "Proposed Plan of Research" essay discusses, one central aim of this project is to understand how students can develop spatial thinking skills to strategically interpret computer visualizations.

My past research in physics, social psychology, and science education has given me the relevant skills to contribute to knowledge on computer visualizations and spatial thinking. These experiences have given me broad training in complex research methodologies that I can apply to improve science education.

Physics Intern – Astronomy REU (*Lowell Observatory, Summer 2007*). To explore my interest in research science, I obtained a competitive astronomy Research Experiences for Undergraduates (REU) internship at Lowell Observatory the summer after my freshman year in college. Dr. Georgi Mandushev and I determined distances to astronomical objects over 14,000 light years away based on photometric data of open clusters, collections of stars loosely bound by gravity. I constructed an open cluster's Color-Magnitude Diagram (CMD), a graphical representation that relates stars' observed colors to their total energy output. To help remove uninteresting background stars, I developed a computer algorithm that statistically removed stars from the CMD based on the number of stars expected from a nearby comparison field. In this project and subsequent physics projects, I learned computer programming skills such as using object-oriented languages to construct visualizations of data for analysis and presentation.

Research Associate – High-Energy Particle Physics (*Harvey Mudd College, Fall 2007 – Spring 2008*) During my sophomore year, I worked with Dr. Adam Edwards to search for a faint signal of an excited charm-strange baryon using SLAC National Accelerator Laboratory's massive database of electron-positron collisions. I improved our data's signal-to-noise ratio by testing various multivariate classifiers that were crafted to discriminate between "background-like" and "signal-like" events. To help comprehend massive amounts of data, I constructed many spatial-visual representations such as boosted decision trees and neural networks to help visualize the process of making particle identifications from petabytes of 3-D trajectory data.

Physics Intern – High-Energy Nuclear Physics REU (*SUNY - Stony Brook, High-Energy Nuclear Physics REU Intern, Summer 2008*) After my sophomore year, I obtained my second REU internship at SUNY - Stony Brook developing software for the installation of the innovative Hadron-Blind Detector (HBD) at Brookhaven National Laboratory (BNL). Dr. Thomas Hemmick and I developed a creative geometric event reconstruction algorithm, dubbed the "Hub and Spoke" clustering algorithm, to identify electron signals in 3-D space. I transformed our ideas about the geometric algorithm into tangible computer code and tested the algorithm's efficacy using realistic simulated gold-ion collision events.

My proudest moment in the project occurred during an hour-long international conference call when I presented my results to the group of about twenty-five research physicists involved in the HBD's original design. The physicists extensively questioned me how to apply and extend my study's results. The HBD is now installed at BNL's Relativistic Heavy Ion Collider, the second most powerful heavy-ion collider in the world. Dr. Hemmick tells me that the "Hub and Spoke" algorithm exhibits similar positive performance when applied to real data, as it did when applied to simulated data.

Physics Intern – Low-Temperature Physics Laboratory (*University of California – Irvine, Summer 2009*) To further expand my physics research experience, I obtained a paid

internship over Summer 2009 working in Dr. Peter Taborek's low-temperature physics laboratory at UC - Irvine. Dr. Taborek, two graduate students, and I collaborated to implement a miniature crystal tuning fork as a creative sensitive pressure gauge in millikelvin temperature ranges. Results of this project were presented at the 2010 American Physical Society conference.

Relevance of past physics research. These past four physics projects give me concrete understanding of some of the spatial thinking skills students need to succeed in research science. Two example skills include identifying spatial patterns and developing 3-D technical drawings. For instance, at the SUNY – Stony Brook REU, the inspiration for the electron identification algorithm came from a spatial understanding of how Cherenkov radiation deposits signal patterns at different locations on particle detector hardware. Also, the low-temperature physics internship at UC - Irvine had many spatially intensive challenges such as constructing complicated 3-D technical drawings in AutoCAD and using machine shop tools to construct experimental apparatuses based on those drawings. These physics projects demonstrate that spatial thinking is fundamental to success in research science, even if often neglected in the classroom.

Furthermore, these physics research experiences have helped me become an effective designer of computer visualizations. In addition to computer programming skills, I learned skills how to develop visualization tools that could communicate large amounts of data without overwhelming others. For instance, in the particle physics research at Harvey Mudd, I constantly battled the tension of including more information on a single display versus removing elements for simplification. I found that what made sense to me as a designer often did not make sense to others, such as my research advisor. These experiences taught me the value of an iterative design process of multiple cycles of design, evaluation, and refinement.

Project Representative – Applied Social Psychology Research (*Harvey Mudd College, Fall 2009 – Spring 2010*) A team of three undergraduates and I worked on a year-long controlled, randomized study to research whether lesbian, gay, bisexual, and transgender (LGBT) ally training programs can reliably reduce homophobic attitudes. As the group's project representative, I communicated with LGBT diversity training organizations to obtain the study's training materials and disseminate our study's results to relevant organizations. The project taught me skills in (1) applying psychological research methodologies and (2) collaborating with community organizations to communicate findings to a broad audience. These skills have been invaluable in pursuing science education research. I presented results at the 2010 Western Regional LGBTQIA and Claremont Graduate University Student Research Conferences.

Principal Investigator – Improving the 3-D Spatial Skills of Gifted STEM Majors (*Harvey Mudd College, Fall 2009 – Present*) My undergraduate thesis project investigated the hypothesis that 3-D spatial instruction can enhance students' skills to learn challenging spatial science concepts such as visualizing complex 3-D rotational motion. For this study, I wrote a successful \$5,000 grant proposal to the president of Harvey Mudd College and recruited 77 Harvey Mudd first-year students (over a third of the first-year class) as study participants. I learned and applied skills in science education research such as reviewing education literature, collaborating with college science professors, and analyzing student data.

I presented results at several national conferences including the American Association of Physics Teachers and American Psychological Association (APA) conferences. This research won two outstanding research awards and an abstract of this research will appear in *The General Psychologist*, the bi-annual newsletter for APA's Division 1 (Society for General Psychology) which reaches approximately 1,000 members. This project will continue to track students' grades, retention rates, and spatial skills until students' graduation.