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Mind, Brain, and Education: A Case Study of Student Perceptions of an Interdisciplinary Graduate Program

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Mind, Brain, and Education: A Case Study of Student Perceptions of an Interdisciplinary Graduate Program

A Dissertation Presented

By

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DEDICATION

This dissertation is dedicated to my husband, Jon Lees.
Jon's never-ending encouragement, support, sense of humor, and love through so many years in writing this dissertation, and in our lives together, are the sources of my happiness and inspiration.

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ABSTRACT

MIND, BRAIN, AND EDUCATION: A CASE STUDY OF STUDENT PERCEPTIONS OF AN INTERDISCIPLINARY GRADUATE PROGRAM

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Advances in developmental and neuroscience research, calls for educational reform, and an emphasis on interdisciplinarity have generated interest in how science might inform educational practice and policy, resulting in the emerging field of mind, brain, and education (MBE). A primary goal of the field is to connect the cognitive and developmental sciences, biology, and education to develop a scientific grounding for educational practice and policy. Interdisciplinary MBE graduate programs seek to train a new generation of interdisciplinary researchers and practitioners. The purpose of this case study is to investigate students' perceptions of their experiences developing interdisciplinary understanding in an MBE graduate program; how these perceptions vary based on student characteristics; and, to explore student perceptions of the potential and limitations of MBE to address educational problems. The findings suggest students gain interdisciplinary knowledge and skills in the program; are able to synthesize and produce integrative understandings to apply to problems in education; and, that the MBE program positively affects their appreciation for interdisciplinary research and their readiness to collaborate on interdisciplinary research. The results suggest students perceive the diversity of the knowledge, skills, and backgrounds of the cohort and participation in a

lab/research experience are among the most supportive aspects of their experience in interdisciplinary learning and understanding, as well as in their future interdisciplinary work. Students leave having thought critically about a wide variety of tensions, uncertainties, and power imbalances in the interdisciplinary work of MBE and feel prepared to participate in collaborative research and begin the slow, and significant, process of change to improve education. The study is unique in exploring student perceptions of an MBE program and contributes to the literature on students' development of interdisciplinary understanding and on educators' beliefs about the potential of MBE to influence educational practice and policy. The study offers insight to institutions and individuals interested in developing interdisciplinary programs to advance the field of MBE and address some of the complex issues facing education today.

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CHAPTER 1

INTRODUCTION

Introduction

Poor educational outcomes, changing demographics, and the need for citizens to participate in the global, knowledge-based economy have prompted a commitment from politicians and government agencies to education reform and evidence-based practice (Center for Educational Research and Innovation [CERI], 2007a; Committee on Science Engineering and Public Policy [COSEPUP], 2004; Duncan, 2009; Obama, 2009). At the same time, institutions of higher education, government, and international organizations realize that multiple perspectives are needed to address complex issues, leading to an increase in interdisciplinary programs in many fields, including education (COSEPUP, 2004; Klein, 1990). Advances in developmental and neuroscience research, and the corresponding media publicity, are driving educators and researchers to explore how science might improve teaching and learning (Goswami, 2008b). The emerging interdisciplinary field of mind, brain, and education (MBE) seeks to connect education with biology and the cognitive and developmental sciences to inform educational practice and policy (CERI, 2007b; Fischer, 2009). MBE programs in higher education aim to provide students with the knowledge and skills to participate in collaborative research, respond to the increased media publicity and commercial marketing of neuroscience information, and apply the results of scientific research to educational problems (Ansari, Coch, & DeSmedt, 2011; Fischer, Goswami & Geake, 2010).

Understanding students' perceptions of their intellectual development and of the potential of the emerging field of MBE is valuable to faculty and administration in higher education in guiding program development to meet the needs of students and to attract prospective students. Students are interested in interdisciplinary work and graduate programs offer training for these future interdisciplinary researchers (Borrego & Newswander, 2010); students' perceptions of their development, the program, and the future of the field influence their future and current engagement. This study uses a case-study mixed-methods design to investigate students' perceptions of their experiences in an MBE graduate program, their perceptions of the potential of MBE to address issues in education, and how these perceptions vary by student characteristics, including disciplinary background. A qualitative approach with semi-structured and open-ended interviews of administrators, faculty, current students, and alumni provides rich description and captures the context and complexity of the interdisciplinary program. The faculty's and administrators' descriptions of the goals and learning outcomes of the program provide a framework for student experiences and provide additional insight to students' experiences. Quantitative analysis of a survey of current students and alumni, as well as document and record review, provides additional insight into students' perceptions and program design.

Previous researchers have investigated the perceptions of educators about the role of neuroscience in education (Pickering & Howard-Jones, 2007; Zambo & Zambo, 2009), descriptive articles have been published about existing interdisciplinary programs connecting neuroscience and education (e.g., Blake & Gardner, 2007; Campbell, 2008; Coch, Michlovich, Ansari, & Baird, 2009; Schwartz & Gerlach, 2011), and studies have

investigated the development of interdisciplinary understanding in other fields (e.g., Gilkey & Earp, 2006; Graybill et al., 2006; Holley, 2009; Lattuca et al., 2011). This case study fills a gap in the literature by investigating the perceptions of students in a graduate program in the field of MBE. Students are drawn to interdisciplinary study, especially when the study is relevant to social issues (COSEPUP, 2004), and their perceptions influence their future professional engagement and offer a perspective on the functioning of programs to guide program evaluation and development and inform prospective students. (Golde & Dore, 2004; Graybill et al., 2006). This study may provide valuable information to MBE programs, as well as other interdisciplinary programs integrating sciences and social sciences, in considering how to best support students in developing interdisciplinary understanding. This study investigates both current student and alumni perceptions of interdisciplinary programs and the potential of the field of MBE.

Historical and Political Context

MBE programs developed as a way to improve education by preparing researchers and practitioners to approach educational problems from an interdisciplinary perspective with a strong science foundation. The social and political factors that have influenced the development of MBE programs include:

- pressure for educational reform and improvement;
- an increased emphasis on interdisciplinary studies to address complex problems; and,
- developments in neuroscience research and technology.

The following section details these three influences.

Pressure for Educational Reform and Improvement

Politicians, educators, and citizens in the United States raise concerns about complex educational issues, suggesting that educational reform and improvement should result in:

- improved outcomes for all learners (Obama, 2009);
- evidence-based practices and policies (Eisenhart & DeHaan, 2005); and,
- the inclusion of developmental psychology and other sciences in educator preparation programs (Comer, 2005).

Many students, particularly those in underrepresented groups, experience poor learning outcomes in the United States and are ill prepared to participate in the global workforce (National Center for Educational Statistics [NCES], 2010; World Bank, 2003). The growing achievement gap based on socioeconomic and minority status, increasing diversity in student populations, and the changing skills needed in a global economy suggest an urgency to reform and improve education (Duncan, 2009; NCES, 2010; Organization for Economic Cooperation and Development [OECD], 1999; US Census Bureau, 2011). Data from the National Center for Education Statistics reveal that 50% or more of children identifying in each of the three categories *American Indian*, *African American* and *Hispanic*, and 20% of *White* children, scored *below basic* (the lowest level) on the 4thGrade Reading 2009 National Assessment of Educational Progress (NCES, 2010). These outcomes remain poor as children progress through the educational system - the 2010 Schott Report indicates that the 2007-2008 high school graduation rate for Black males was 47%, compared with 78% for White males (Schott Foundation for Public Education, 2010).

As a result of the global economy, employment prospects are limited for students who are not able to engage in lifelong learning, or are not proficient in decision making, problem-solving, collaboration, communication, creativity, and metacognition, or are illiterate (Gardner, 2008a; OECD, 1999; World Bank, 2003). These data suggest that we need new priorities for education and significant reform (e.g., see Reimers, 2011), however the education system in the United States historically has been resistant to change. The reasons for this resistance include the attitudes and practices within institutions of higher learning, as well as economic, social and political forces that affect all levels of government and education (Comer, 2005; Duncan, 2009).

Education reform requires that educators understand the relationship among child development, the science of learning, and educational practice; this interdisciplinary training is currently missing from educator preparation (Ansari, Coch, & DeSmedt, 2011; Comer, 2005; COSEPUP, 2004; Darling-Hammond, 2005; Education Science Reform Act, 2002; Eisenhart & DeHaan, 2005; National Council for Accreditation of Teacher Education [NCATE], 2008, 2010). Many faculty and administrators in schools of education agree that additional coursework in child development is needed to adequately prepare educators. While ninety percent of educator preparation programs require at least one course in child and adolescent growth and development, a 2010 NCATE report (NCATE, 2010) found that half of the survey respondents, who were either deans or faculty members, felt that a single course is insufficient.

Comer (2005) suggests the reason that education programs fail to emphasize developmental science is that most educators believe that intelligence, and therefore school performance, is biologically determined, despite overwhelming evidence that both

intelligence and achievement can be improved through experience. Research in scientific disciplines reveals the role of genes in many educationally relevant developmental differences (Diamond, 2006) and confirms a complex relationship between genes and environment, yet educators have little training in genetics (Walker & Plomin, 2005). Teachers' beliefs [1] about the influence of genes on children's academic performance and learning abilities suggests science-based course work is critical (Comer, 2005; Walker & Plomin, 2005), and will require significant changes in the institutions training educational practitioners and researchers (Ansari, Coch & deSmedt, 2011; Comer, 2005; Duncan, 2009; Darling-Hammond, 2005; Eisenhart & DeHaan, 2005, Fischer, 2009; NCATE, 2010).

Increased Emphasis on Interdisciplinary Studies

Additional coursework in child development that includes material on genetics will provide educators with some of the knowledge and skills necessary to effectively inform practice and policy; in addition they must be able to synthesize knowledge from several disciplines to fully participate as collaborators and critical consumers of scientific knowledge (Geake, 2008; Goswami, 2008b; Stein, Connell & Gardner, 2011;). As Eisenhart and DeHaan (2005) note:

> Cutting-edge research in learning and education now ranges across the disciplinary boundaries that have heretofore separated the social and natural sciences. Thus it seems that an important aspect of preparing scientifically based education researchers is to train students who are familiar with, and are expected to contribute to, such interdisciplinary work.

The complexity of modern society, the problems therein, and the technologies being developed have all contributed to an increased role for interdisciplinary research

[1] Walker & Plomin (2005) report that teachers believe that genetics is at least as important as environment for many educationally relevant behaviors and traits; they found that 94% of teachers believe this to be true for both intelligence and learning difficulties, and 43% believe it to be true for behavioral problems.

(COSEPUP, 2004); government, industry, and academia recognize *interdisciplinary*[2] integration as critical in addressing today's complex problems (COSEPUP, 2004; Klein, 2010; National Institutes of Health [NIH], 2011). Interdisciplinary collaborative efforts of scientists result in contributions to understanding diverse issues such as climate change (e.g., Janes et al., 2010), cultural resource management (e.g., the National Park Service development of historic museum sites, Jenkins, 2001) and public health issues (e.g., Allan et al., 2004), and interdisciplinarity is an important aspect of higher education in the United States (COSEPUP, 2004; Newswander & Borrego, 2009; Stein, Connell, & Gardner, 2008). Institutions of higher education, organizations, and agencies develop interdisciplinary graduate programs to prepare students to bring multiple disciplinary perspectives to bear on complex problems. The United States government has funded several efforts that are currently aimed at preparing interdisciplinary professionals. The National Science Foundation (NSF) began an initiative in 1998, the Integrative Graduate Education and Research Traineeship (IGERT), to provide doctoral students with interdisciplinary training (IGERT, 2011). In 1985 NSF began sponsoring interdisciplinary centers within universities to partner with industry. Among the goals for these Engineering Research Centers (ERCs) is to provide graduates of engineering programs with skills and knowledge to successfully produce technological innovation and provide leadership in interdisciplinary teams (COSEPUP, 2004). Similarly, the National Institutes

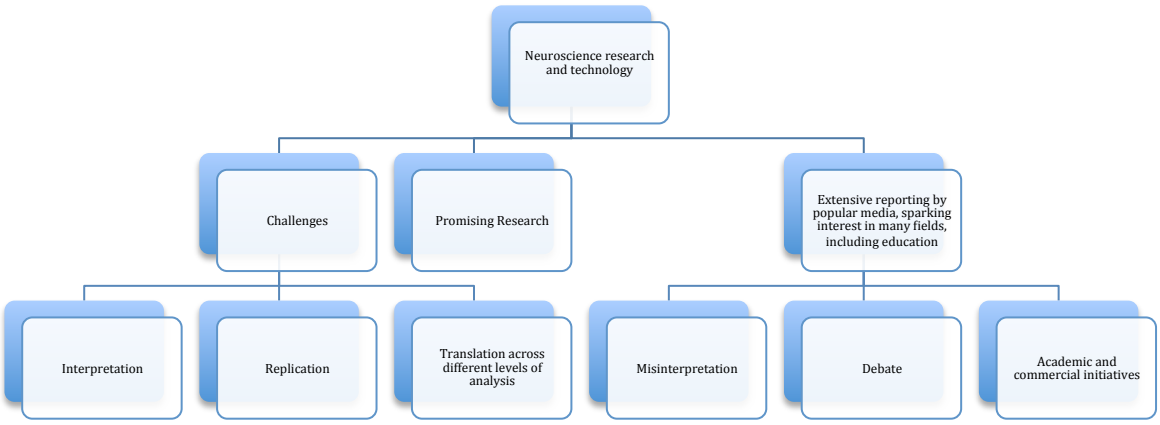
[2] The literature distinguishes between the terms multidisciplinary, transdisciplinary, and interdisciplinary, based on the degree of integration. For the purposes of this paper interdisciplinary will be used throughout and interdisciplinary understanding defined as: "the capacity to integrate knowledge and modes of thinking drawn from two or more disciplines to produce a cognitive advancement—for example explaining a phenomenon, solving a problem, creating a product, or raising a new question - in ways that would have been unlikely through single disciplinary means." (Boix-Mansilla, 2005, p.16)

of Health (NIH) Roadmap Initiative (NIH, 2011) and other initiatives support cross-disciplinary work in the health field (please see Misra et al., 2008 for an extensive list).

Challenges in interdisciplinary learning and programming include: tensions in content, methodology and standards; organizational challenges and factors affecting collaboration that are outside the control of individuals, (e.g., the administrative structure of the institution, the work environment, and attitudes of colleagues); and assessment of effective program characteristics, learning experiences, and learning outcomes (Howard-Jones, 2011; Klein, 2010). As the number of interdisciplinary programs increases, questions arise about how best to meet the challenges in interdisciplinary programming and foster interdisciplinary synthesis, as well as how to assess the quality of the program and the learning (Boix-Mansilla & Duraising, 2007; Klein, 2010; Newswander & Borrego, 2009; Stein et al., 2011). Yet, the literature on interdisciplinarity is limited, is exploratory and descriptive, lacking specific educational models and empirical research (L. Lattuca personal communication, July 6 & 7, 2011; Spelt et al., 2009). This study represents an initial effort to explore interdisciplinary understanding in the field of MBE.

Interest in interdisciplinary efforts in MBE and the potential of the field to influence educational practices and policies is fueled by the rapid increase in neuroscience research and technology and the resulting media reporting and commercial marketing of product and services. The following section details the challenges and promise of the scientific advances in relation to education (Figure 1). These factors affect educators' interest in how neuroscience may inform education and are considerations in preparing students for interdisciplinary work.

Figure 1. Impacts of Developments in Neuroscience and Technology



Developments in Neuroscience Research and Technology

The field of neuroscience is rapidly developing and offers promise, as well as challenges in the field of MBE (America Educational Researchers Association [AERA], 2011; CERI, 2007; Goswami, 2008a; International Mind, Brain, and Education Society [IMBES], 2011a). Advances in neuroimaging techniques and research at all levels, from molecular to behavioral, bring the role of neuroscience to public attention and engage scientists, as well as non-scientists, in investigating how neuroscience might inform educational practice and policy. (Katzir & Paré-Blagoev, 2006; Society for Neuroscience, 2008). Researchers successfully apply neuroscience methods and theories to understand teaching and learning and provide a biologically-based explanation for the effectiveness of teaching methods, child development, and individual and social behaviors. For example, recent studies explain and evaluate the effectiveness of interventions, explore the role of experience and genetics in development and learning, and detail the neural bases of cognitive processes. (Blair et al., 2007; Dehaene, 2009; Diamond & Amso, 2008). As McCandliss (2010) notes,

> The past several years have brought about a virtual explosion of cognitive neuroscience investigations into multiple neural systems that may modulate learning and brain plasticity (6). Attention (7), working memory, social cognition, anxiety (8), motivation, and reward (9) each represent functional domains that have been studied extensively in educational contexts as well as through neuroscience approaches. Combining these approaches via interdisciplinary work opens up opportunities to recast critical educational questions through the lens of developmental cognitive neuroscience. Considering how these neural systems change over the course of learning and development may prove useful for efforts to adapt educational approaches to the unique needs of children who arrive at the doorsteps of formal education exhibiting meaningful differences in the very neural systems on which educational practices must build. (p. 8050)

At the same time, the technology and research present challenges in interpreting images and research; in translating findings from molecular and cellular levels to the level of behavior and the complexity of classroom interactions; in critically assessing the interpretations made by the media and commercial enterprises; in replicating studies; and, in addressing the ethical issues that arise.

Many brain imaging techniques are available to researchers to reveal the underlying structure and activity of the cognitive processes related to learning, including the location, connections, and timing of processes (Campbell, 2008; Fischer, Rose & Rose, 2007; Hruby, 2011; McCandliss, 2011). Interpreting data from imaging studies is more complicated than many non-scientists understand and requires knowledge of the methods and their limitations.

Two of the methods most commonly used in research related to education are the spatial imaging of functional magnetic resonance imaging (*f*MRI) and the temporal imaging of electroencephelography (EEG) (IMBES, 2011a, Hruby & Goswami, 2011)[3]. The images resulting from these technologies do not directly measure cognitive processes in the brain - *f*MRI measures the oxygen level in the blood (BOLD), which is assumed to represent neural activity (Logothetis et al., 2001) and EEG measures electrical activity on the scalp, generated by neurons within the brain[4]. Rather than being "photographs of the brain in action," (Hruby, 2011, p. 318) most images are "statistical charts of subtracted correlations" (i.e., many participants are scanned in two different conditions, such as

[3] Each technique offers particular advantages and disadvantages related to the purpose of the investigation; technologies vary in, among other aspects, cost, invasiveness, conditions for use (e.g., the amount of movement tolerated, the mobility of the scanner), and temporal and spatial resolution.

[4] for a full discussion of *f*MRI see Kalbleisch, 2008; of EEG see Hruby & Hynd, 2006

reading words and reading numbers; the images from all participants in each condition are subtracted from one another and compiled into one image). (Baars & Gage, 2007; Immordino-Yang, 2011; Racine, Bar-Ilan, & Illes, 2005). Conclusions drawn from brain images depend on the design and methodology of the research (Immordino-Yang, 2011, Hruby & Hynd, 2006; Hruby & Goswami, 2011); for example, the quality of data can vary depending on factors such as ambient noise and movement (AERA, 2011; Kalbleisch, 2011). Conclusions are further limited by the fact that most studies are recent and have yet to be replicated and there are few meta-analyses (Hruby & Goswami, 2011).

The influence of media reporting further complicates interpretation of scientific findings and determination of their relevance to education. Media reports of studies involving brain images often present optimistic, rather than critical, views of studies with brain imaging (Racine et al., 2005), suggest causal relationships, and leap to statements of absolute truth rather than cautious interpretations. (Zhang, 2011). Readers may draw unwarranted conclusions from research material that includes neuroscientific information and their interpretation of the research may be inaccurate. (McCabe & Castel, 2008; Racine et al., 2005; Sylvan & Christodoulou, 2010; Weisberg, Keil, Goodstein, Rawson, & Gray, 2008). Weisberg and colleagues (Weisberg et al., 2008) completed a study, *The Seductive Allure of Neuroscience Explanations,* and write, "evidence presented in …a classroom, or a political debate, regardless of the scientific status or relevance of the [neuroscientific] evidence, could strongly sway opinion, beyond what the evidence can support." (p. 477). Additionally, many educators get information from sources that may be unreliable, such as television and websites (Pickering & Howard-Jones, 2007; Zambo & Zambo, 2009).

The technology used in interdisciplinary educational research presents ethical challenges as well. As imaging of the structure and function of the brain increases, educators will be faced with decisions regarding the extent to which brains should be recorded and imaged, for what purposes, and with whom the information should be shared (Gardner, 2007; Gardner, 2008; please also see Stein et al., 2011). As the field develops and educators and scientists move from describing phenomena to using the data to explain, draw conclusions, and make recommendations for practice, education professionals assume an increased responsibility to understand and apply the science (Stein et al., 2011).

Despite these challenges, scientific research with imaging has provided, and likely will continue to provide, data to confirm, refute, and extend findings from other branches of developmental psychology and education, as well as suggest new lines of inquiry (Blair et al., 2007; Dehaene, 2009; Diamond & Amso, 2007). In the last ten years, significant promising imaging research has been published relating to many educational topics, including reading (e.g., Ansari et al., 2011; Wolf et al., 2009) mathematics (e.g., Dehaene, 2009; Varma, McCandliss & Schwartz, 2008), individual differences (Rose, 2007), learning disorders (Fischer, Bernstein, & Immordino-Yang, 2007), attention (e.g., Posner, & Rothbart, 2007), emotion (e.g., Immordino-Yang & Damasio, 2008), the role of experience in social, emotional and intellectual development (Fusaro & Nelson, 2009), biomarkers of risk (e.g., Rappolt-Schlichtmann et al., 2009), teaching methods (e.g., Campbell et al., 2009), and developmental processes (e.g., Goswami & Szucs, 2011).

As research offers new insights into educational problems by connecting brain structure and function to complex educational behaviors, educators and researchers are

faced with challenges related to levels of analysis, i.e., dealing with phenomena that differ in scale and scope, e.g., interpreting molecular or imaging data on a behavioral level (Stein & Fischer, 2011). To resolve these issues, scientists and educators must develop theoretical models that tie the methods together and offer a comprehensive explanation for the phenomena (Stein &Fischer, 2011). Noble and colleagues' (Noble et al., 2006) investigation of the relationship between socioeconomic factors and reading acquisition is an example of promising work providing a theoretical framework for understanding individual differences in reading achievement. As noted previously, the discrepancy in reading achievement based on socioeconomic status is a significant issue in the United States. Noble et al. (2006) used *f*MRI to further understand the factors that contribute to the achievement gap, demonstrating the interrelatedness of social, cognitive, and neurobiological systems. They found that SES, as well as phonological skill, influences the activation of an area of the brain, the left fusiform gyrus (which has been previously been shown to be associated with reading skill). They suggest that this finding may lead to further research that will offer insight in how to effectively target the needs of children from low SES backgrounds.

Many educators, both pre-service and practicing, are interested in connecting science to their practice (CERI, 2005; Pickering & Howard-Jones, 2007; Zambo & Zambo, 2009), despite the lack of science-related coursework in educator preparation programs. Educators with less knowledge about science are those who are more certain about the potential of science to inform education (Hruby, 2011 citing Zambo 2008, 2010), suggesting that coursework in science becomes increasingly important.

The promise of neuroscience research to improve educational practice and policy is noted extensively in the literature[5] and academic meetings and conferences, such as the *Learning and the Brain*, the *International Mind, Brain, and Education Society,* the American Association of Educational Research special interest group *Brain, Neuroscience and Education*, the Annenberg Foundation (2011) free online course for educators, *Neuroscience and the Classroom: Making Connections*, and the Society for Neuroscience, engage thousands of educators from around the world each year (e.g., Society for Neuroscience, 2008). Scientists have initiated collaborative efforts as well, for example the S*f*N Neuroscience in Education Summit (Society for Neuroscience, 2009): *The Promise of Interdisciplinary Partnerships between Brain Sciences and Education* in 2009, but far fewer than educators (Bruer, 1997). Many of these efforts and collaborations are international, including the Organization for Economic Cooperation and Development (OECD, 2001) and the International Mind, Brain, and Education Society (IMBES, 2011b).

The current interest in translating neuroscience research and applying it to problems in education has caused some experts to debate the usefulness of this effort (Bruer, 2002; Varma et al., 2008). John Bruer, president of the James S. McDonnell Foundation, suggests that connecting neuroscience and education is "a bridge too far" (Bruer, 1997). Bruer contends that the proliferation of information to educators overestimates the contribution neuroscience can make to the field of education, oversimplifies the complexities of neuroscience, misinterprets research, and draws conclusions based on single, unreplicated studies. He suggests that these conclusions and

[5] for examples of literature aimed at educators, please see Shonkoff & Phillips, 2000; Byrnes, 2001; Posner & Rothbart, 2007; Fischer, Bernstein, & Immordino-Yang, 2007; Sousa, 2010; Tokuhama-Espinosa, 2010

communications are not only premature and misleading about the potential of science to inform education, but also may lead some to disregard existing educational research in favor of *brain-based* research, a "term associated with learning theories, principles, and products that posit a link to the brain's structure and function." (Sylvan & Christodoulou, 2010, p. 1).

The media, commercial enterprises, and consultants promote *brain-based* practices and products to educators (e.g., see Brain Gym®, 2011). Unfortunately, the connections with learning that many of these products and services promise have no scientific basis and result in misinterpretation and misapplication of science (Tokuhama-Espinosa, 2009). Many brain-based materials (e.g., Jensen, 2005) take information that is already known through behavioral studies and relate it to neuroscience, failing to offer new solutions to problems in education (Willingham, 2011).

Information that is inaccurate or oversimplified may result in *neuromyths*, which are defined as "misconception[s] generated by a misunderstanding, a misreading or misquoting of facts scientifically established (by brain research) to make a case for use of brain research, in education and other contexts" (CERI, 2007, p. 258). The OECD's *Center for Educational Research and Innovation* (CERI) details some of the main myths of brain science that relate to education (for a more detailed description of brain-based interpretations, please see (Bruer, 1999; CERI, 2007; Geake, 2008).

The risk of reductionism, oversimplification, and misapplication remains – it is tempting to find simple solutions to complex problems. Among the reasons for neuroscience in education to be misinterpreted and misapplied are the difficulty in understanding the methodologies and limitations of the research and the desire for

simple, definitive answers to educational issues (Ansari & Coch, 2006; CERI, 2007). Educators and scientists advise caution, emphasizing that the "relationship should be a reciprocal one in which educational practice and scientific research inform and learn from each other" (Fischer & Daley, 2007, p. 56). For an interdisciplinary effort to succeed educators must collaborate with scientists, and they must have the knowledge and skills to interpret and evaluate research connecting science and education, recognize the technological limitations, as well as the potential of the neuroscience research, and understand that science will not provide quick, easy answers to educational problems through direct application of research to practice (Bailey, Bruer, Symons, & Lichtman, 2001, Goswami, 2008b)

Scientists and educators suggest, "the era of brain-based pedagogy should be supplanted by a richer, interdisciplinary dialogue aimed at understanding and reshaping the study of learning" (Society for Neuroscience, 2009, p. 3). The new field will evolve, "fusing completely different disciplines resulting in a new discipline with its own conceptual structure, known to extend the borders of the original sciences and disciplines included in its formation" (CERI, 2007, p. 261). Koizumi suggests that this new field "could become one of the most important fields of the 21st Century" (Koizumi, 2004, p.440). Interdisciplinary training may offer educators the knowledge and skills necessary to understand the role of research design and methodology in imaging, the limitations of the technology, and to critically interpret claims made by the media and commercial enterprises and to foster meaningful collaboration resulting in useful knowledge for educational reform while offering scientists new avenues for innovative applied research.

Mind, Brain, and Education

Scientists and educators refer to this discipline most frequently as *educational neuroscience* (e.g., Atherton, 2005; AERA, 2011), or *mind, brain, and education* (e.g., Fischer, 2007, Tokuhama-Espinosa, 2009, IMBES, 2011a). Other terms, used less frequently, include *neuro-education (*e.g., Society for Neuroscience, 2009) and *brain science and education* (e.g., Koizumi, 2004). Educators continue to clarify a distinction between the terms *educational neuroscience* and *mind, brain and education.* Some suggest that each term represents different goals and engages professionals from different disciplines (J. Thomson, personal communication, November 17, 2010 & December 10, 2010). Fischer and colleagues (Fischer et al., 2010) suggest that educational neuroscience may be a field within the broader movement of MBE. While still a very new and rapidly growing discipline, MBE offers insight to maximize the effectiveness of teaching strategies and the potential of individual development. Graduate programs in MBE, such as those at the University of Texas Arlington (UTA) and the Harvard Graduate School of Education (HGSE), offer distinct courses in MBE and educational neuroscience (please see course listing for UTA and HGSE at http://www.uta.edu/coehp/mind-brain/Course%20Descriptions.pdf and http://www.gse.harvard.edu/academics/masters/mbe/curriculum/).

Geake (2011) defines educational neuroscience as "cognitive neuroscience which investigates educationally inspired research questions" (p. 43). Thomson (J. Thomson, personal communication, November 17, 2010 & December 10, 2010) suggests that educational neuroscience focuses on neuroscientific research that is driven by neuroscientists and psychologists with questions related to basic research, which may

have educational implications, (for example, see Goswami, 2008b) whereas the MBE movement is led by educators with an intention for educational change by applying theory and research from multiple disciplines to educational issues. MBE practitioners seek to form alliances and work within the existing system and try to change it (J. Thomson, personal communication, November 17, 2010 & December 10, 2010).

The term MBE will be used in this study, referring to the international efforts to develop an interdisciplinary research base based in biology, the cognitive and developmental sciences, and education to focus on educational problems. The MBE movement began in 1999 with the first graduate-level program at Harvard Graduate School of Education (Blake & Gardner, 2007). The International Mind, Brain, and Education Society (IMBES) was formed in 2004 and a peer review journal was launched in 2007. The identified goals and objectives of IMBES are:

> The Society's principal goal is to foster dynamic relations between neuroscience, genetics, cognitive science, development, and education so that each field benefits from and influences work in the others, including questions asked, phenomena addressed, and methods employed.
> To that end our objectives are:
>
> - To improve the state of knowledge in and dialogue between education, biology, and the developmental and cognitive sciences.
> - To create and develop resources for scientists, practitioners, public policy makers, and the public.
> - To create and identify useful information, research directions, and promising educational practices. (IMBES, 2011b)

Rose (2007) suggests the current climate "requires educational researchers to move beyond their current role as passive recipients of interdisciplinary research and actively engage in the process" (p.5). Toward this end, several institutions of higher learning have developed graduate degree programs in the United States to provide

interdisciplinary training to educators and researchers connecting science and education. These include the programs described in Table 1 below; the schools were identified through conversations with the directors of these programs:

Table 1.

Graduate Programs Connecting Education and Sciences

School	Program	Degree	Department	History	Currently Enrolled
Johns Hopkins[6]	Neuro Education Initiative Mind, Brain, and Teaching	15-credit certificate	School of Education	1st cohort Summer 2009	2 cohorts per year, currently 16 online, 15 face-to-face
University of Texas Arlington[7]	Mind, Brain and Education	Two-year master's degree	College of Education and Health Professions Southwest Center for Mind, Brain, and Education	1st cohort Fall 2011	16 students
Columbia University Teachers College[8]	Neuroscience and Education	Master's of Science	Department of Biobehavioral Sciences	Uncertain – possibly 1982	41 (students do not necessarily enroll continuously)
Harvard University[9]	Mind, Brain, and Education	One-year master's degree	Graduate School of Education	1999	47

These programs share common goals, including a goal to develop educators and researchers who have experience with, and knowledge of, the theories, research, and

[6] M. Hardimann, personal communication, November 7, 2011
[7] M. Schwartz, personal communication, October 6, 2011
[8] K. Silva, personal communication, November 11, 2011
[9] J. Thomson, personal communication, October 11, 2011

methods of multiple disciplines in order to participate in collaborative research and connect it to practice.

The newest program, the University of Texas Arlington (UTA) College of Education and Health Profession's master's degree in MBE (operated through the Southwest Center of Mind, Brain, and Education at UTA), enrolled the first cohort of 16 students in the Fall 2011 semester. Marc Schwartz, director of the UTA program, notes that the program is the second MBE master's program in the country and that two related programs are based in other institutions (M. Schwartz, personal communication, October 6, 2011). The School of Education at Johns Hopkins University, in collaboration with other schools and institutes within the university, offers a 15-credit certificate program designed for educators through their Neuro-Education Initiative. The fourth cohort began the program in July 2011. The certificate may be combined with another certificate and a capstone experience to earn a master's degree (Johns Hopkins, 2011). Columbia University Teachers College offers a two-year Master's of Science in Neuroscience and Education (Columbia University Teachers College, 2011). Of the programs in the United States, the HGSE master's program in MBE enrolls the greatest number of students, approximately 50 students per year (J. Thomson, personal communication, October 9, 2011).

I selected the Harvard program as the most appropriate for investigating the perceptions of students because of the number of students graduated from the program, the length of time it has been operating, and the professional engagement of its faculty, students, administrators and alumni in the field of MBE. The 23 faculty listed on the website as part of the MBE program represent multiple disciplinary backgrounds and many are actively engaged in dialogue, program development, and publishing in MBE, as

well as interdisciplinary learning. Students may opt to earn a doctorate through one of the concentrations, for example through Human Development and Education, and therefore dissertations from students in the doctoral program are available (for example, please see Connell, 2006). The Harvard program served as a model for the University of Texas Arlington program (University of Texas Arlington [UTA], 2011) and a graduate of the Harvard program has been instrumental in developing the undergraduate teacher education program at Dartmouth, which uses an MBE approach and may be the only undergraduate institution in the country using this interdisciplinary approach (Dartmouth, 2011). The history, current professional engagement, and the influence of the HGSE program on the other programs in the country led me to select the Harvard MBE master's as the case for this study.

Purpose of this Study

The purpose of the study is to investigate the development of interdisciplinary understanding in MBE from student perspectives. Based on a framework of *pragmatic constructionism* in interdisciplinary learning, the study explores four aspects of students' perceptions: 1) their perception of the purpose for interdisciplinary work in MBE; 2) their understanding and use of disciplinary perspectives; 3) their perception of disciplinary integration; and, 3) their critical thinking. This study will also provide rich description of an interdisciplinary graduate program in MBE.

Conceptual Framework

The interdisciplinary field of MBE aims to improve educational practice by connecting insights from biology, psychology and education, i.e., it is *problem focused*. (Stein & Fischer, 2011). The HGSE MBE program seeks to develop interdisciplinary

understanding as it guides students in synthesizing information from the disciplines of neuroscience, psychology, and education, as well as other disciplines (Blake & Gardner, 2007; Fischer, 2009; Harvard Graduate School of Education, 2011). Boix Mansilla's concept of *pragmatic constructionism* in interdisciplinary learning offers a framework for understanding interdisciplinary learning in the context of practical application to educational problems (Figure 2). The theory is based on the work of philosophers Nelson Goodman and Catherine Elgin and proposes that the integration of knowledge in interdisciplinary learning is *constructionist* in that it aims to increase "broad, deep, and revisable" understanding (rather than *propositional knowledge*) and *pragmatic* in that it emphasizes the purpose of the knowledge (Boix Mansilla, 2010, p. 295). Boix Mansilla developed the theory from Elgin's concept of understanding as a *system of thought in reflective equilibrium*, i.e., knowledge is continually evaluated and analyzed in light of new information and alternatives, it is not absolute, but rather is reasonable in the face of the current evidence with the expectation the conclusions may be revised in the future (Boix Mansilla, 2010).

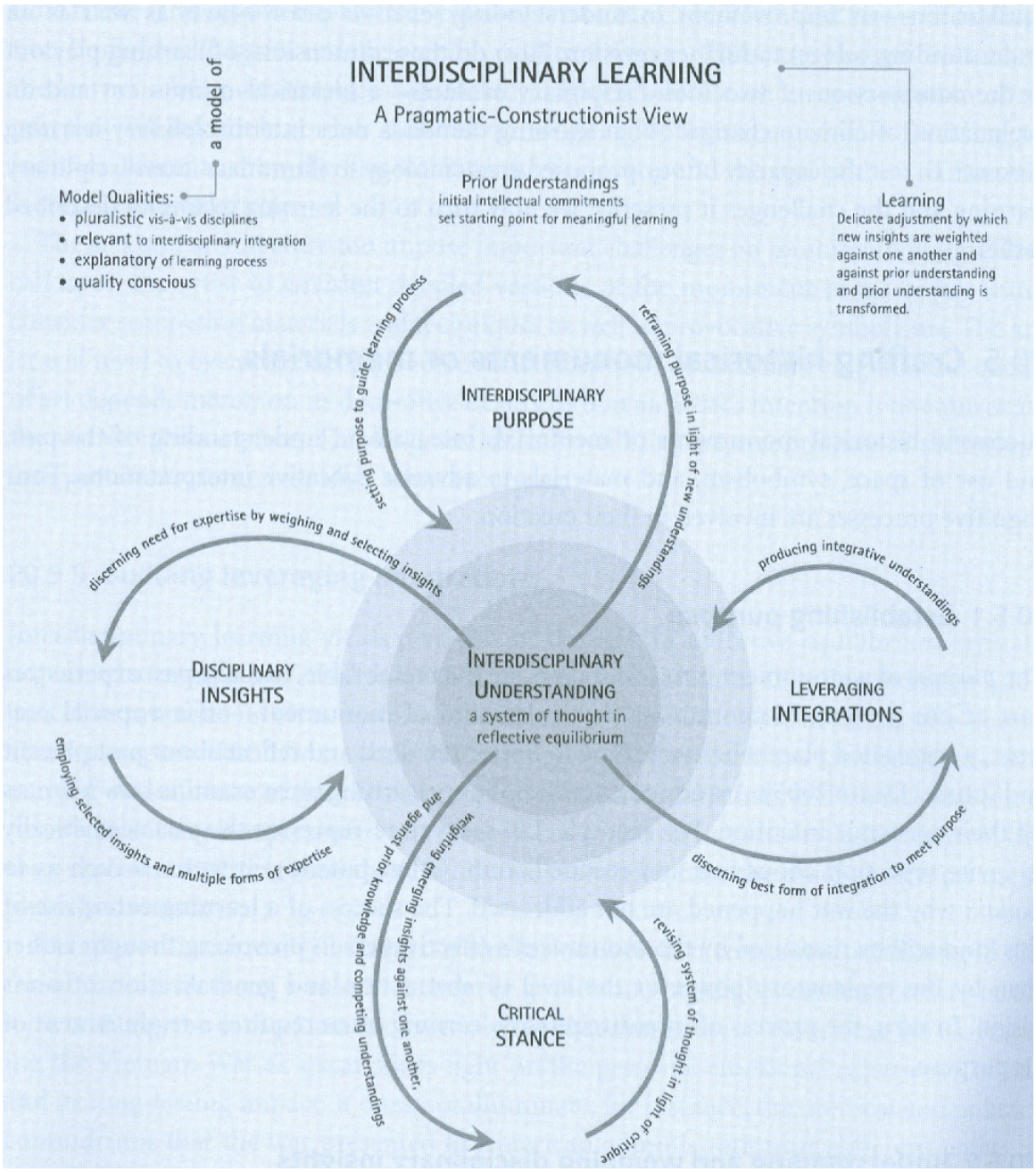
The pragmatic constructionist approach involves four interacting cognitive processes. These include:

1) Establishing a purpose or question that calls for an interdisciplinary approach. This purpose may change in light of new understandings. For example, in MBE this purpose may be to plan the timing of instruction, asking, "When is it best to introduce algebra to children?"
2) Understanding, considering, choosing, and using insights from multiple disciplines. These include "concepts, theories, findings, images, methods, techniques, tools,

assessments, applications, analogies, discourse, language, genres" (Boix Mansilla, 2010, p. 299). In MBE, this may be selecting the appropriate imaging technique to investigate an educational question.

3) Building interdisciplinary knowledge and aligning this synthesis with a specific problem. This might take a variety of forms, for example in MBE it might be a more complete explanation of a phenomenon, such as understanding why some children struggle to learn to read, or it may predict outcomes, such as identifying biomarkers for risk of reading difficulties.
4) Maintaining a *critical stance* by considering new insights and revising thinking in light of the above three processes, i.e., the purpose, the insights from individual disciplines, and those from the integration of those disciplines. A critical stance assumes the impermanence of knowledge, i.e., understandings can be criticized, altered, and discarded when new information is considered. For example, our findings today may be altered as new technologies lead to new understandings about brain structure and function.

Figure 2. Pragmatic Constructionist Framework[10],

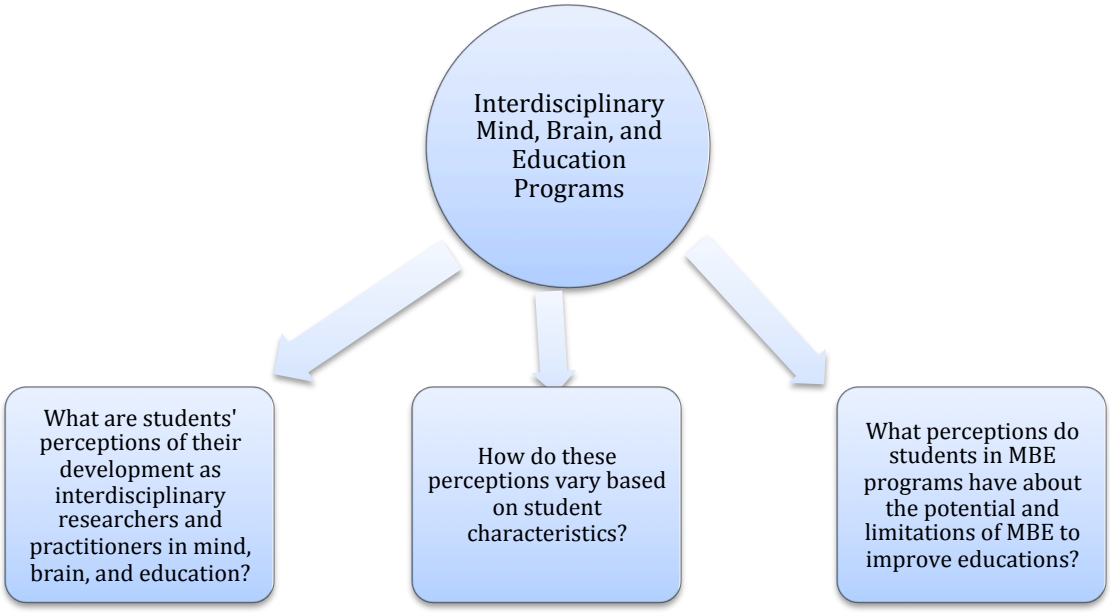


[10] Used with permission from V. Boix Mansilla. The graphic appeared as Figure 201.1, p. 299 in Boix Mansilla, V. (2010). Learning to synthesize: the development of interdisciplinary understanding. In R. Frodeman, J.T.Klein, C. Mitcham & J.B. Holbrook (Eds.) *The Oxford handbook of interdisciplinarity (pp. 288-306).* New York: Oxford University Press.

Pragmatic constructionism underscores the idea that interdisciplinary understanding and knowledge should be useful and applied to new problems, aligning with the goals of the emerging field of MBE to produce useable knowledge for education, and frames the disciplinary and interdisciplinary understanding necessary for the bi-directional collaboration among disciplinary experts to integrate current expertise and knowledge (IMBES, 2011b; Boix Mansilla, 2010). Boix Mansilla (2005) emphasizes the foundational role of disciplinary knowledge in building interdisciplinary understanding: "Prior knowledge sets the stage for the insights to come, by informing questions, affording hypotheses and providing an initial representation of a problem under study." (Boix Mansilla, 2010, p. 295). The framework is dynamic, recognizing the development of interdisciplinary understanding as being in *reflective equilibrium* and the possibility of modification in the face of reflection and new information (Boix Mansilla, 2010). As an emerging field utilizing rapidly changing technologies, knowledge in MBE will continue to be challenged and refined.

Research Questions

Figure 3. Research Questions



The following research questions (Figure 3) relate this framework to the interdisciplinary learning of students from different disciplinary backgrounds in an MBE program. The research questions explore learner perspectives on the purpose of an interdisciplinary approach to informing educational practice, the experiences offering opportunities to develop and integrate disciplinary knowledge and skills, and the usefulness of the learning for addressing educational issues. Based on this framework, this study will investigate the relationship between student characteristics and students' perceptions of the development of their interdisciplinary understandings.

The following questions are investigated:

- What are students' perceptions of their development as interdisciplinary researchers and practitioners in MBE? How do they perceive

        - the purpose for interdisciplinary study in MBE?
        - their understanding and use of disciplinary perspectives?
        - their understanding and use of disciplinary integration?
        - how their understandings may change in the future?
    - What perceptions do students in a graduate MBE program have about the potential and limitations of MBE to improve education?
    - How do these perceptions vary based on student characteristics?

These questions will be situated in an understanding of the structure and development of an MBE program and the career paths of students who complete an MBE program.

Contribution to the Field

Interdisciplinary programs affect society directly and indirectly by contributing new knowledge, developing new fields, adding value to traditional fields, creating new technologies, enriching the quality of the educational experience of students, and enhancing the reputation of institutions (COSEPUP, 2004). This study adds needed research to the scant literature on interdisciplinary programs, as noted by COSEPUP (2004):

> Continuing social science, humanities, and information-science-based studies of the complex social and intellectual processes that make for successful [interdisciplinary research] are needed to deepen the understanding of these processes and to enhance the prospects for the creation and management of successful programs in specific fields and local institutions. (p. 187)

Elucidation of the process of developing interdisciplinary understanding is valuable to institutions and funding organizations and contributes to an understanding of learning and teaching. This study contributes to the field of education by illuminating the perspectives of students who are engaged in interdisciplinary study at the graduate level

on the potential, as well as the limitations, of the field of MBE to inform educational practice and policy. The study provides insight to institutions and individuals interested in initiating similar programs by describing students' perspectives on the development of their ability to engage in collaborative work to provide useable knowledge for the field of education. An understanding of the relationships of student characteristics with perceptions of the development of interdisciplinary understanding is useful in guiding faculty and administrators in interdisciplinary program development. Student perspectives may guide those "developing, implementing and participating" in MBE programs (Graybill, 2006, p. 758) to influence the choices students make concerning professional engagement in interdisciplinary work, ultimately affecting the future of MBE.

Conclusion

The field of MBE is emerging with a rapid proliferation of research aimed at using multiple perspectives to address educational issues. Along with the academic efforts are commercial marketing and popular media reports relating science to education. Scientific research is unlikely to be directly applicable to classrooms and will require collaborative work between scientists and educator (Ansari et al., 2011). Interdisciplinary collaborations are challenging, especially between the sciences and humanities. Students' perceptions of their development, the program, and the future of the field influences their future and current engagement in interdisciplinary work. This study explores students' perspectives on a program designed to develop individuals who will have the interdisciplinary knowledge and skills to effectively transform education by integrating knowledge gleaned from neuroscience research and technology. This paper adds empirical study of student perspectives on interdisciplinary teaching and learning aimed

at integrating sciences and social sciences in the emerging field of MBE to the literature on interdisciplinary programs in higher education.

CHAPTER 2
LITERATURE REVIEW

The process of developing interdisciplinary understanding in MBE involves learning and using new and familiar ideas, conventions, and methods and applying these in new ways to create a common ground by merging the *languages* and concepts of multiple disciplines, while at the same time honoring one's disciplinary perspective (Boix Mansilla, Miller, & Gardner, 2000). The field of MBE is thus grounded in multiple disciplines, yet is qualitatively different from each of those disciplines and is continually evolving (Newell, 2001). Practitioners must recognize both the possibilities and the limitations of MBE to improve educational practice and policies.

Despite the great interest in interdisciplinary studies from industry, academia, and government, empirical literature on how to effectively foster interdisciplinary understanding and measure the outcomes of interdisciplinary educational programs is limited (Ivanitskaya et al., 2002; L. Lattuca personal communication, July 5, 2011; Nikitina, 2005; Spelt, 2009; Richter & Paretti, 2007). The lack of research on interdisciplinary learning and the process of integration are noted extensively, dating back to 1990:

- "There is much that we know, but there is also much to do in order to reach a fuller understanding of interdisiplinarity. [Among the five tasks] of utmost importance [is] conducting empirical studies of current interdisciplinary research, teaching, and practice in order to broaden the data base on which general observations are drawn and theories constructed." (Klein, 1990, p.195-196)

- "Social-science research has not yet fully elucidated the complex social and intellectual processes that make for successful [interdisciplinary research]. A deeper understanding of these processes will further enhance the prospects for creation and management of successful [interdisciplinary research] programs." (COSEPUP, 2004, p.190)

- "Because we know little about teaching and learning in interdisciplinary courses, a survey of the landscape is needed. Our questions about teaching are tied to questions about student learning. …What are the educational outcomes of interdisciplinary courses? Do learning outcomes vary by the type of interdisciplinary course…or program? How do these outcomes compare to those of students in discipline-based courses?" (Lattuca, Voight, & Fath, 2004, p.43-44)

- "[The literature] is limited in its ability to shed light on the substantive knowledge base of student understanding and the unique demands of disciplinary coordination." (Boix Mansilla & Duraising, 2007, p. 218).

- "Despite the proliferation of interdisciplinary graduate programs designed to fill this need, there is virtually no archival literature identifying learning outcomes, methods, or benchmarks for assessing interdisciplinary graduate programs and associated student learning…"(Borrego & Newswander, 2010, p.61-62)

- "…there is little serious research on interdisciplinary education… "(L. Lattuca, personal communication, July 5, 2011)

I began identifying studies relevant to interdisciplinary education aimed at integrating science and humanities by reviewing references cited in articles and books related to interdisciplinary research, teaching, and learning. I then conducted database searches of PsychInfo, ERIC, Web of Science, PubMed, and Engineering Village using *interdisciplinary education*, *interdisciplinary program*, and *interdisciplinary training*. I utilized the Engineering Village and PubMed databases because much of the interdisciplinary literature stems from the IGERT and health initiatives (described in chapter 1). From these studies I selected research in higher education at both the undergraduate and graduate levels in order to increase the number of available studies. The selected studies include students as participants and explore interdisciplinary integration of science and humanities.

In reviewing references, I found that Lisa Lattuca, professor of education and senior scientist at the Center for the Study of Higher Education at Pennsylvania State

University, and colleagues had published an article, *Does Interdisciplinarity Promote Learning? Theoretical Support and Researchable Questions* (Lattuca et al., 2004), which is particularly relevant to my proposed study, in which they articulate questions similar to those I had identified for my study. In noting the need for increased study of interdisciplinary education, they pose some of the important questions to investigate:

> What behavioral, cognitive, and affective outcomes do students report?...What types of students experience the greatest success in interdisciplinary courses? To what do students attribute their success or difficulty in interdisciplinary courses and programs? (p. 42-43)

I contacted Lattuca and through personal communication she generously shared her perspectives, the surveys she used in her work, and several studies, including her 2011 studies, David Knight's (2011) study, and Coso's (2010) study, as well as additional references.

This review includes studies of undergraduate and graduate programs in a range of disciplines, including sciences, social sciences, health sciences and engineering. The majority of the studies use mixed methods, incorporating surveys, focus groups, interviews, and reviews of student products and course evaluations. The review of the literature reveals several consistent findings and influenced my decision to collect and analyze data on the relationship between students' perception of the development of their interdisciplinary understanding and student characteristics, such as disciplinary affiliation, as is done in several of these studies. In review I found 18 studies, which I detail in two sections: 1) five studies that provide frameworks for describing the *Dimensions of Interdisciplinary Understanding*, and 2) thirteen empirical studies investigating the *Challenges and Effective Features of Interdisciplinary Programs* in higher education, as outlined in Tables 2 and 3 below.

Dimensions of Interdisciplinary Understanding

Boix Mansilla and colleagues' (2000) definition of interdisciplinary understanding, quoted below, aligns with the conceptual framework detailed in Chapter 1 and is cited in many of the studies in this review. The definition is relevant to MBE because it privileges useable knowledge over static knowledge (Perkins, 1998). Interdisciplinary understanding is defined as:

> the capacity to integrate knowledge and modes of thinking in two or more disciplines or established areas of expertise to produce a cognitive advancement…in ways that would have been impossible or unlikely through single disciplinary means (Boix Mansilla & Duraising, 2007, p. 219, citing Boix Mansilla et al., 2000),

The studies in this section pertain to the process of developing interdisciplinary understanding and how that understanding can be recognized. The researchers acknowledge that the process of developing interdisciplinary knowledge differs from that of developing disciplinary knowledge, as interdisciplinary knowledge is constructed both within and across boundaries (Boix Mansilla, 2006) and requires a learner to integrate concepts and methods and to apply the knowledge to complex problems. The literature suggests that the focus of interdisciplinary understanding differs depending on disciplinary background, with scientists focusing on the interpersonal aspects and those in the humanities focusing on the individual cognitive processes of synthesis. The learning outcomes for interdisciplinary work identified in these studies include disciplinary grounding, the ability to resolve conflicts involved in integrating disciplines, interpersonal communication, the ability to maintain a "broad systems perspective," and critical awareness.

Table 2 details the studies in this section.

Table 2.

References related to Dimensions of Interdisciplinary Understanding

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Boix Mansilla, V. (2006). Assessing expert interdisciplinary work at the frontier: an empirical exploration. *Research Evaluation,* 15 (1), 17-29.

Boix Mansilla, V. & Duraising, E. D. (2007). Targeted assessment of students' interdisciplinary Work: An Empirically Grounded Framework Proposed. *The Journal of Higher Education,* 78(2), 215-237.

Borrego & Newswander, (2010). Definitions of interdisciplinary research: Toward graduate-level interdisciplinary learning outcomes. *The Review of Higher Education, 34 (1), 61-84.*

Coso, A.E. (2010). Measuring undergraduate engineering students' interdisciplinary understanding. *Master's of Science in Systems Engineering Thesis, University of Virginia*.

Spelt, E. J. H., Biemans, H. J. A., Tobi, H., Luning, P A., & Mulder, M. (2009). Teaching and learning in interdisicplinary higher education: A systematic review. *Educational Psychology Review,* 21:365-378.

In an effort to provide insight to educational programs on fostering interdisciplinary understanding, Boix Mansilla (2006) interviews 50 researchers working at five interdisciplinary institutes, representing a wide range of disciplinary integrations to explore experts' perspectives on interdisciplinary research[11]:

1. Santa Fe Institute in New Mexico
2. MIT Media Lab in Cambridge, Massachusetts
3. The Research in Experimental Design group at XEROX-PARD (RED) in Palo Alto, California

[11] This research is also published by the Interdisciplinary Studies Project, Project Zero, Harvard Graduate School of Education by Boix Mansilla & Gardner (2003) as a paper, *Assessing Interdisciplinary Work at the Frontier: An Empirical Exploration of "Symptoms of Quality"* presented at an online seminar, *Rethinking Interdisciplinarity.*

4. The Center for the Integration of Medicine and Innovative Technologies in Cambridge, Massachusetts
5. The Center for Bioethics at the University of Pennsylvania

Analysis of the interviews, samples of the researchers' work, and the institutional documents suggest that quality interdisciplinary work may be identified by three characteristics, or *symptoms*: *consistency, balance,* and *effectiveness, i.e.:*

1. Consistency with multiple disciplinary antecedents
2. Balance in weaving together perspectives
3. Effectiveness in advancing understanding through the integration of disciplinary views (Boix Mansilla, 2006, p. 23)

Boix Mansilla (2006) writes that her findings suggest that the development of interdisciplinary understanding involves creating appropriate ongoing assessment measures, as well as developing new insights and methods. She notes that assessing interdisciplinary knowledge requires evaluative measures that are unique to each piece of work and reflect the purpose of the work, as described in Table 3.

Following this 2006 work, Boix Mansilla and Duraising (2007) find that faculty identify hallmarks of interdisciplinary understanding similar to those identified by researchers, described as *disciplinary grounding, advancement through integration* and *critical awareness*.[12] They interview 41 faculty and 28 students, conduct classroom

[12] The analysis revealed faculty members' identification of three essential aspects of students' interdisciplinary work, *disciplinary grounding (75%), advancement through integration (68%), and critical awareness (54%)*: "1) The degree to which student work is *grounded* in carefully selected and adequately employed disciplinary insights – that is, disciplinary theories, findings, examples, methods, validation criteria, genres, and forms of communication; 2) The degree to which disciplinary insights are clearly *integrated* so as to advance student understanding – that is, using integrative devices such as conceptual frameworks, graphic representations, models, metaphors, complex explanations, or solutions that result in more complex, effective, empirically grounded, or comprehensive accounts or products; and, 3) The degree to which the work exhibits a clear sense of purpose, reflectiveness, and self-critique – that is, framing problems in ways that invite interdisciplinary approaches and exhibiting awareness of distinct disciplinary

observations and review program documentation and 40 pieces of student work in four established, highly regarded undergraduate interdisciplinary programs representing a variety of disciplines and combinations:

1. BioEthics program at the University of Pennsylvania
2. Interpretation Theory at Swarthmore College
3. Human Biology at Stanford University
4. The Science-Humanities NEXA program at San Francisco State University

In addition, they review literature to determine criteria for assessing interdisciplinary understanding. They report that the previous literature describes *how* interdisciplinary work is assessed (e.g., ongoing assessment and feedback, use of rubrics and portfolios, etc.), but is lacking in insight on *what* represents quality interdisciplinary student work. In this study, the authors develop a dynamic framework for assessing interdisciplinary work in a broad range of disciplines that asks "not 'How much integration is enough?' But 'What is the cognitive and practical *purpose* of the work.' (Boix Mansilla & Duraising, 2007, p. 230). This framework focuses on the effect of the interdisciplinary study on student learning through analysis of the students' products and individual competencies, using defined student learning outcomes. Table 3 below, adapted from the study, details the framework, which they propose may be applied to a wide variety of interdisciplinary efforts.

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contributions, how the overall integration "works," and the limitations of the integration. "(p. 222)

Table 3.

Summary of Key Criteria and Guiding Assessment Questions[13]

Criteria	Guiding Questions
I. Disciplinary Grounding	Are the selected disciplines appropriate to inform the issue at hand? Are any key perspectives or disciplinary insights missing? Are the considered disciplinary theories, examples, findings, methods, and forms of communication accurately employed, or does the work exhibit misconceptions?
II. Advancement through integration	Where is there evidence of disciplinary integration (e.g., conceptual framework, graphic representation, mode, leading metaphor, complex explanation, or solution to a problem? Is there evidence that understanding has been enriched by the integration of different disciplinary insights?
III. Critical awareness	Does the work show a clear sense of purpose, framing the issue in ways that invite an interdisciplinary approach? Is there evidence of reflectiveness about the choices, opportunities, compromises, and limitations involved in interdisciplinary work and about the limitations of the work as a whole?

[13] Used with permission from the author. Originally appeared in Boix Mansilla, V. & Duraising, E. D. (2007). Targeted assessment of students' interdisciplinary Work: An Empirically Grounded Framework Proposed. *The Journal of Higher Education,* 78(2), 215, p. 233.

Boix Mansilla and Duraising's (2007) investigation is relevant to this proposed study because it aligns with the MBE perspective of interdisciplinarity as outcome-based. They offer an alternative to the traditional perspective of interdisciplinarity, which defines work based on the degree of integration (i.e., the distinction between multidisciplinary, interdisciplinarity and transdisciplinarity, described in chapter 1 of this paper) to focus on the relationship between the purpose of the integration and the degree of integration, evaluating the interdisciplinary work on the cognitive and practical purpose and how the integration furthers those purposes with critical awareness while remaining grounded in disciplines. They suggest that while disciplinary grounding is critical, mastery of all disciplines is not. They provide a framework for the skills involved in acquiring and integrating knowledge from multiple disciplines; their study provides the foundation for several of the studies in this review (e.g., Borrego & Newswander, 2010; Coso, 2010; Drezek et al., 2008; Spelt et al., 2009).

Borrego & Newswander (2010) investigate how science and engineering faculty define interdisciplinary work for the purpose of graduate education and seek to define learning outcomes for graduate interdisciplinary education. Borrego and Newswander (2010) add a dimension of "teamwork" to Boix Mansilla & Duraising's (2007) framework. They find that those in the sciences and humanities operationalize *integration* differently, with those in the sciences emphasizing teamwork and those in humanities emphasizing individual critical awareness. Consistent with studies in this review, Borrego & Newswander (2010) identify the learning outcome of interdisciplinary programs as performance-based synthesis of knowledge.

Borrego & Newswander (2010) review and analyze the learning outcomes described in 129 successful IGERT proposals from 1999-2006 and compare them to peer-reviewed literature from interdisciplinary studies in the humanities to investigate how the interdisciplinary literature from the humanities might contribute to describing learning outcomes for interdisciplinary graduate education. The interdisciplinary proposals represent a wide range of disciplines - from economic, behavioral, and social sciences to mathematical and physical sciences, as well as education and computer science. They find that the scientists operationalize interdisciplinarity as teamwork, and the humanities literature "does not focus on interpersonal interactions or processes" (p. 64), rather it "focuses on the individual intellectual processes of synthesizing perspectives, theories, and methods from multiple disciplines." (p. 64). They note the literature and proposals together inform "a deep definition of interdisciplinarity, which in turn fleshes out key learning outcomes." (p. 65). By comparing the proposals and the literature they articulate five categories related to interdisciplinary process and evaluation:

- Disciplinary Grounding
- Integration
- Communication and Translation Across Disciplinary Boundaries
- Critical Awareness
- Teamwork

The analysis is primarily qualitative, using a constant comparative method to code the data according to the five themes above. They find that both the IGERT proposals and the humanities literature emphasize the first three categories, while critical awareness is a focus in the humanities literature and teamwork is a focus in the scientists' proposals. They suggest that these differences may inform the groups, and each may benefit by expanding their perceptions.

Borrego and Newswander's (2010) findings suggest that further exploration of the relationship between students' disciplinary backgrounds and the way they operationalize interdisciplinarity (i.e., as individual integration or interpersonal teamwork) and investigation of the kinds of experiences offered to MBE students in terms of teamwork and developing critical awareness, disciplinary grounding, integration and communication, is warranted. MBE programs bring together students from science and humanities backgrounds and this study investigates how disciplinary affiliation is related to student perceptions of interdisciplinarity.

Several studies in this review investigate the relationship between disciplinary affiliation and interdisciplinary understanding (e.g., Knight, 2011; Lattuca et al., 2011). In investigating undergraduate engineering students' perceptions of interdisciplinarity in an interdisciplinary engineering program, Coso (2010) finds that disciplinary affiliation is not related to interdisciplinary perspectives in undergraduate students. She notes that the lack of correlation may be the result of small sample size. Her findings suggest that undergraduate engineering students in an interdisciplinary program recognize the components described by Boix Mansilla (i.e., purposefulness, disciplinary grounding, integration, and critical awareness); she also finds that engineering students value teamwork as a component of interdisciplinarity, similar to Newswander & Borrego (2010).

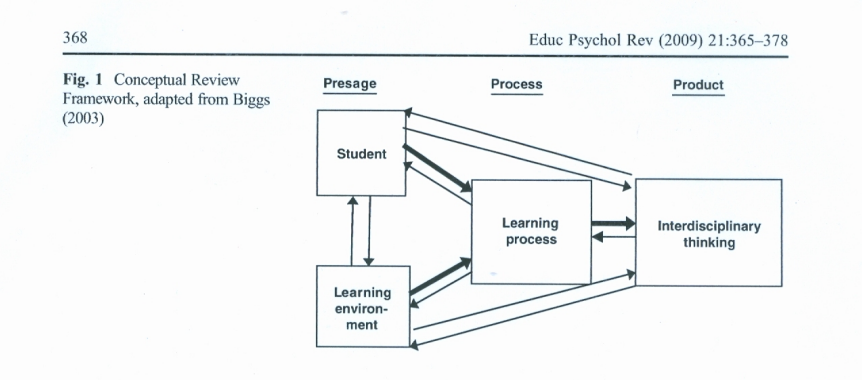
Coso (2010) focuses on the second year of undergraduate study, which is the first year of major coursework in the engineering program. She uses a four-phase mixed methods design, with more than 100 second-year students participating in at least one phase of the research. Although Coso's results do not indicate a difference based on

disciplinary affiliation, she finds that students' previous experience with team-based engineering projects affects their perceptions of interdisciplinarity, raising the question of the subskills and conditions underlying the development of interdisciplinary understanding.

Spelt et al. (2009) review and analyze the literature on interdisciplinary teaching and learning to identify the subskills and conditions necessary for developing interdisciplinary understanding in multiple disciplines. The study aligns with Boix Mansilla & Duraising (2007) in proposing a definition of interdisciplinary higher education based on student performance. Their work provides further insight into the current state of research on interdisciplinarity and reveals additional studies undiscovered in my database search. Their work provides a framework for reviewing studies that explore the challenges and effective characteristics of interdisciplinary programs.

Using Biggs' (2003, cited in Spelt et al., 2009) model of four interacting components (i.e., *student*, *learning environment*, *learning process*, and *learning outcomes;* please see Figure 4), and grounded in a performance perspective (i.e., Boix Mansilla's framework), Spelt et al. (2009) find that the majority of the studies (9) investigate the learning environment (curriculum, teacher, pedagogy, and assessment), while none investigate the personal characteristics or prior knowledge of students (despite the fact that none of the studies focuses primarily on student conditions (detailed in Table 4), Spelt et al. (2009) note they are able to discern eight possible conditions). Two studies explore the knowledge and skills of interdisciplinary thinking and two examine the learning process (pattern and learning activities).

Figure 4. Spelt et al (2009) Conceptual Review Framework[14]



Spelt et al. (2009) conduct a broad review of the scientific literature in interdisciplinary higher education, searching four scientific databases and conducting a critical analysis, and reveal the limited number of empirical studies and the explorative state of the research. Their search of four databases (Educational Resources Information Centre, the Science Citation Index Expanded the Social Sciences Citation Index, and the Arts & Humanities Citation Index) includes peer reviewed scientific research from 1992-2009 of teaching and learning in interdisciplinary higher education in three languages (English, German and Dutch). They develop a literature review form based on the framework to standardize their critical analysis. Of the 309 publications identified in the search, 14 met the criteria for inclusion[15] and they analyze 13 (2 publications report on

14 From Spelt, E. J. H., Biemans, H. J. A., Tobi, H., Luning, P A., & Mulder, M. (2009). Teaching and learning in interdisciplinary higher education: A systematic review. *Educational Psychology Review,* 21:365-378**,** adapted with permission from Biggs (2003).

[15] Inclusion criteria described as: " First, each publication should be relevant, meaning that the publication should examine teaching and learning in interdisciplinary higher education within the scope of the Conceptual Review Framework [see Figure 4]. Second, each publication should be peer reviewed. Third, publications written in English, German

the same results; of the 13, ten are empirical and three are theoretical; all are explorative). Three of these publications concern one project, nine are in the domain of education, and 11 were published between 2000 and 2009. The topics of the research include: potential frameworks (7 of the 13), best practices (4 of the 13), and essential conditions (2 of the 13). The studies, primarily conducted in the United States, include both graduate and undergraduate settings and span the sciences, social sciences, and humanities. They exclude "publications reporting on individual faculty experiences, courses, curricula, or projects without any scientific examination of teaching and learning [as well as] publications on institutional or organizational topics such as the implementation of interdisciplinary higher education." (p. 369).

Based on Biggs' theory, Spelt et al. (2009) identify the following subskills and conditions for interdisciplinary higher education (please see Table 4), which the authors suggest may provide the basis for empirical research in interdisciplinary education.

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and Dutch were included, as the authors could read and understand these languages. Finally, the time span of the literature search was limited to 1992-2009 to provide an overview of the most recent research in the field. Publications reporting on individual and faculty experiences, courses, curricula, or projects without any scientific examination of teaching and learning were excluded. Publications on institutional or organizational topics such as the implementation of interdisciplinary higher education fell outside the scope of this review." Spelt et al., (2009) p. 368 -369.

Table 4.

Potential Subskills and Conditions for Interdisciplinary Higher Education[16]

Interdisciplinary Thinking	Having Knowledge	Knowledge of disciplines Knowledge of disciplinary paradigms Knowledge of interdisciplinarity
	Having Skills	Higher order cognitive skills Communication skills
Student	Personal Characteristics	Curiosity Respect Openness Patience Diligence Self-regulation
	Prior Experiences	Social Educational
Learning Environment	Curriculum	Balance between disciplinarity and interdisciplinarity Disciplinary knowledge inside or outside courses on interdisciplinarity
	Teacher	Intellectual community focused on interdisciplinarity Expertise of teachers on interdisciplinarity Consensus on interdisciplinarity Team development Team teaching
	Pedagogy	Aimed at achieving interdisciplinarity Aimed at achieving active learning Aimed at achieving collaboration
	Assessment	Of students' intellectual maturation Of interdisciplinarity
Learning Process	Pattern	Phased with gradual advancement Linear Iterative Milestones with encountering questions
	Learning Activities	Aimed at achieving interdisciplinarity Aimed at achieving reflection

[16] From Spelt, E. J. H., Biemans, H. J. A., Tobi, H., Luning, P A., & Mulder, M. (2009). Teaching and learning in interdisciplinary higher education: A systematic review. *Educational Psychology Review,* 21:365-378, p. 372.

The studies in the Spelt et al. (2009) review fall into three broad topics noted above: frameworks, best practices, and essential conditions. I review four of the studies from this review in depth, representing each of the categories. These include: a) *Frameworks*: Lattuca et al. (2004) and Boix Mansilla & Duraising (2007); b) *Best Practices*: Graybill et al. (2006); and c) *Essential Conditions*: Gilkey & Earp (2006) and Misra et al. (2008). I selected these studies from the thirteen in Spelt et al.'s (2009) review because they represent graduate student perspectives (Graybill et al., 2006), explore effective characteristics of interdisciplinary programs (Gilkey & Earp, 2006 and Misra et al., 2008), and were previously identified as relevant to my study (Boix Mansilla & Duraising, 2007 and Lattuca et al., 2004).

The results of Spelt et al.'s study reveal considerable gaps in the literature on interdisciplinary teaching and learning, which my study begins to fill. Of the studies reviewed by Spelt and colleagues, one, Graybill et al. (2006), investigates the experiences of graduate students, suggesting that further investigation will contribute to the literature. The authors note the need for empirical research, a perspective echoed by Lattuca (L. Lattuca, personal communication, July 6, 2011). The methodologies of the ten empirical studies are similar to my study, i.e., surveys, interviews, observations, and document review. Spelt et al. (2009) informs my study by identifying the skills and conditions that students may perceive to be relevant to their interdisciplinary development and suggests that analyzing the data to explore the relationship between students' prior educational and professional experiences and interdisciplinary thinking may be illuminating.

In summary, the dimensions of interdisciplinary understanding include a basis in multiple disciplines, an ability to synthesize the disciplinary perspectives and ways of working, an awareness of how the knowledge may be applied to problems and the limitations of the interdisciplinary approach, and recognition of the collaborative and interpersonal skills involved. Learners' disciplinary backgrounds affect their perspectives on interdisciplinary work – scientists emphasize interpersonal interactions and those in humanities emphasize critical awareness and individual cognitive integration. The subskills necessary to develop interdisciplinary skills relate to individual student characteristics and prior experiences as well as the learning environment and the learning process. The studies in the following section describe research that explores interdisciplinary programs in higher education, illuminating some of the challenges and effective characteristics of interdisciplinary programs.

Interdisciplinary Programs: Challenges and Effective Characteristics

The goal of interdisciplinary programs is to develop the skills necessary to integrate multiple disciplines to cross boundaries (Spelt, 2009). Multiple challenges confront this endeavor. These include structural (e.g., academic schedules and the traditional disciplinary academic structure) and cultural (e.g., territoriality, perceived career risks, privileging of some disciplines over others, and faculty expertise and identification with a disciplinary community) challenges. In planning interdisciplinary programming, faculty and administrators have little research on the effects of interdisciplinary programs on student learning to guide them. The studies reviewed below (Table 5) use a variety of methodologies and investigate projects and programs in undergraduate and graduate higher education to explore the characteristics of effective

programs and the challenges of the education components. These studies reveal the importance of faculty perspectives on interdisciplinarity, of maintaining an overarching structure and making explicit connections among disciplines, of the social environment, of team projects with facilitated support, and of maintaining an identified interdisciplinary center or home.

Table 5.

References Investigating the Challenges and Effective Characteristics of Interdisciplinary Programs

Drezek, K.M., Olsen, D., & Borrego, M. (2008). Crossing disciplinary borders: A new approach to preparing students for interdisciplinary research. *38th ASEE/IEEE Frontiers in Education Conference*.

Gilkey, M.B., & Earp, J. L. (2006). Effective interdisciplinary training: Lessons from the University of North Carolina's student Health Action Coalition. *Academic Medicine,* 81(8), 749-758.

Graybill, J. K., Dooling, S., Shandas, V., Withey, J. Greve, A., & Simon, G. L. (2006). A rough guide to interdisciplinarity: Graduate student perspectives. *BioScience,* 56(9), 757-763.

Holley, K. (2009). The challenge of an interdisciplinary curriculum: A cultural analysis of a doctoral degree program in neuroscience. *Higher Education,* 58:241-255.

Knight, D. B (2011) Educating broad thinkers: A quantitative analysis of curricular and pedagogical techniques used to promote interdisciplinary skills. *American Society for Engineering Education Conference, June 26-29, 2011.*

Lattuca, L. R.., Voight, L. J., & Fath, K. Q. (2004). Does interdisciplinarity promote learning? Theoretical support and researchable questions. *The Review of Higher Education,* 28(1), p. 23-48.

Lattuca, L.R., Trautvetter, L.C., Codd, S.L., Knight, D.B., Cortes, C.M. (2011). Promoting interdisciplinary competence in the engineers of 2010: P360 – Promoting the engineer of 2020: Conditions and processes of effective education. *Annual Meeting of the American Society of Engineering Educators, Vancouver, Canada,* June 2011.

Lattuca, L.R., Trautvetter, L.C., Codd, S.L., Knight, D.B., Cortes, C.M. (2011). Promoting interdisciplinary competence in the engineers of 2010: P2P – Conditions and processes for educating the engineer of 2020. *Annual Meeting of the American Society of Engineering Educators, Vancouver, Canada,* June 2011.

Minnis, M. & John-Steiner, V. (2005) The challenge of integration in interdisciplinary education. *New Directions for Teaching and Learning,* No. 2 Summer, 45-61.

Misra, S., Harvey, R.H., Stokols, D., Pine, K.H., Fuqua, J., Shokair, S.M., & Whitely, J.M. (2009). Evaluating an interdisciplinary undergraduate training program in health promotion research. *American Journal of Preventive Medicine*, 36 (4), 358-365.

Newswander, L.K. & Borrego, M. (2009). Engagement in two interdisciplinary graduate programs. *Higher Education,* 58:551-562.

Pierrakos, O., Borrego, M., & Lo, J. (2007). Empirical evidence to support interdisciplinary projects in engineering design experiences. *Proceedings of the 2007 AaeE Conference*, Melbourne, Australia.

Richter, D.M & Paretti, M.C. (2009). Identifying barriers to and outcomes of interdisciplinarity in the engineering classroom. *European Journal of Engineering Education*: 34(1), p. 29-45.

In a three-year (2006-2009) project funded by the National Science Foundation, Lattuca and colleagues (Lattuca et al., 2011) conduct two studies, one qualitative and one quantitative, to fill the gap in the literature on undergraduate engineering education. Noting the emphasis on interdisciplinarity in the field of engineering, they focus on how curriculum and instruction affect students' interdisciplinary competence. They find that both curricula and co-curricular activities (e.g., internships, research, design competitions, field-related clubs) contribute to interdisciplinarity, with the contribution varying with the students' branch of engineering (e.g., mechanical engineering, civil engineering). They find interdisciplinary programs are effective in enhancing students' interdisciplinary skills and that making explicit connections among disciplinary concepts is the primary factor in students' development of interdisciplinary skills. A curricular focus on "broad and systems perspectives" is critical, irrespective of discipline.

One study, referred to as *Prototyping the Engineer of 2020: Conditions and Process of Effective Education* or *P360,* includes case studies of six undergraduate engineering schools and analyzes individual and group interviews of faculty, students, administrators and professional staff, observations of classes and events, archival records such as minutes of meetings, and artifacts such as websites and documents, with the aim of investigating programs with high-quality, innovative engineering programs. The other study, *Prototype to Production: Conditions and Processes for Educating the Engineer of 2020*, or *P2P*, involves a survey of students, faculty and program chairs in 31 four-year institutions to investigate the student experiences in engineering programs. The framework for the studies relates four control variables to student outcomes of interdisciplinary skills: 1) institutional characteristics (size and highest degree offered); 2) student characteristics (race,

ethnicity, gender, pre-college academics); 3) curriculum (emphasis on broad and systems perspectives); and 4) pedagogy (active/collaborative learning, student-centered teaching).

Participants (5,249 undergraduates, 1119 faculty, and 86 program chairs in 31 institutions) responded to three different surveys, in which the researchers use four scales to measure interdisciplinary learning outcomes. In personal communications (L. Lattuca personal communication, July 5, 2011 and July 6, 2011), Lattuca provided me with her survey and I adapted the four scales for this study (please see more detail in Chapter 3).

Based on the survey of engineering students, their findings reflect the concepts brought forward in the earlier section relating to scientists' emphasis on teamwork over critical reflection and support Borrego and Newswander's (2010) finding that interdisciplinarity in science and engineering is based in teamwork. Lattuca et al. (2011) report a moderately high correlation between interdisciplinary skills and teamwork skills, and the correlation is higher than that between interdisciplinary skills and reflective behavior.

Lattuca et al.'s (2011) findings suggest that students from all disciplinary backgrounds benefit from a *broad and systems perspective*. Curricula focusing on *broad and systems perspectives* (i.e., making explicit connections among disciplinary concepts, applying knowledge to problems, relating the concepts to practical contexts) contribute to interdisciplinary learning outcomes. While both the curricula and co-curricular activities predict interdisciplinary skills, the *broad systems perspective* of the curriculum (i.e., an emphasis on interdisciplinarity) is a significant predictor of interdisciplinary skills across disciplines (.34; $p<0.001$), and although curricula and co-curricula activities affect interdisciplinary learning, they do so differentially, depending on discipline.

Undergraduate engineering students' pre-college Critical Reading SAT scores predict interdisciplinary skills, also differentially based on subdiscipline. The SAT Critical Reading Score was significant ($p<0.001$) for many of the subdisciplines in predicting the self-reported interdisciplinary skills.

Influenced by Lattuca (2011), my study investigates students' perceptions of their interdisciplinary skills by the student characteristic of disciplinary affiliation.

Using the survey results from Lattuca et al. (2011), Knight (2011) analyzes the data to investigate the relative contributions of active/student-centered pedagogy and interdisciplinary content to interdisciplinary learning. He analyzes the influence of curriculum and pedagogy on interdisciplinary skills through multiple regression analysis, revealing that both curriculum and pedagogy predict interdisciplinary skills (curriculum emphasizing a *broad systems perspective* is the greatest predictor and *active/collaborative learning* is not a factor; *broad systems perspective* = 0.31, $p<0.001$; *student-centered teaching* = 0.09, $p<0.001$; and *active/collaborative learning* = 0) and vary with the subdiscipline. For example, active/collaborative learning was significant for biomedical/bioengineering (0.30, $p<0.01$) and civil engineering students (0.14, $p<0.05$) and not for any others.

Knight's (2011) study illuminates some of the factors affecting the development of interdisciplinary skills. In repeating Lattuca et al.'s (2011) finding that the SAT Critical Reading score positively predicts interdisciplinary skills for engineering as a field, as well as for certain subdisciplines of engineering, Knight suggests that the relationship between admission test scores and success in achieving interdisciplinary skills may guide both admission decisions and faculty in providing individual support for enrolled students. He

notes several limitations, including the operationalization of pedagogy because the activities students report on are not exclusively interdisciplinary, and because students, in self-reporting on the *program emphases* "may not recognize the broad rationale for certain pieces of curriculum" (Knight, 2011, p.8). He notes, however, that a forthcoming paper detailing the results of the survey of faculty and program chairs "showed consistencies with student-reported emphases (p. 8)." Evidence that student self-reporting correlates with faculty reports is seen in Pierrokos et al. (2007) as well, and suggests that the method may be useful.

Richter and Paretti (2009) find that engineering students' previous disciplinary experience challenge their perceptions of the value of interdisciplinarity and their ability to connect their discipline to other disciplines. Richter and Paretti (2009) use a case-study approach with surveys, observations, and interviews of undergraduate students in a sustainable engineering program to "identify the key challenges to success in interdisciplinary contexts" (p. 29). They focus on a three-credit interdisciplinary course and find two challenges in students' interdisciplinary understanding: making connections between other disciplines and their particular specialty (e.g., mechanical engineering), and identifying and valuing the contribution of multiple perspectives to complex problems. They use the concept "disciplinary egocentrism" to describe the cognitive challenges in interdisciplinarity and note that the idea includes two themes, *relatedness* and *perspective,* affecting students' relationship to both the subject and to collaborators. Relatedness refers to disciplinary connections students make with the interdisciplinary topic (synthesis and integration) and perspective refers to valuing multiple perspectives. They recommend classroom interventions that focus on dialogue among students of different disciplinary

backgrounds on the strengths and limitations of the methods and modes of thinking in their disciplines, the ways their discipline might contribute to solving a problem, and their own disciplinary biases.

Interdisciplinary team-based experiences are described in several of the studies in this review (e.g., Minnis & John Steiner, 2005, Pierrakos et al., 2007, others) and contribute to the understanding of the importance of such experiences in students' interdisciplinary learning. Pierrakos, Borrego & Lo (2007) use quantitative methods to provide empirical evidence of the learning outcomes of undergraduate engineering seniors' capstone design experiences. They compile 50 learning outcomes, linked to engineering accreditation criteria, and categorize them as either *technical* or *personal and professional*. One hundred and twenty-five mechanical engineering students participate in either an interdisciplinary team (biomedical engineering) or a disciplinary team (automotive) and respond to the survey of their experiences. A complementary survey administered to the faculty advisors is based on a five-point Likert scale and asks, "How helpful was your design/project experience this semester in enabling you to achieve the following skills." (p. 2). The skills include *technical* and *personal-and-professional* items such as "an ability to apply knowledge of mathematics, science, and engineering" and "an appreciation for the diversity of students, faculty, staff, colleagues, and customers." The results suggest that student learning outcomes relate to the interdisciplinary nature of their team experience, with interdisciplinary students valuing certain aspects, such as "formulating a range of solutions" (p. 7) more highly than did those in the disciplinary group, and are better able to understand the ethical issues and the relationship of their design solution in a broader social/global context.

Minnis and John-Steiner's (2005) case study of an interdisciplinary professional master's degree program in water resources highlights the importance of an interdisciplinary team-based project. They review three years (2001 – 2003) of student commentary on the program's core interdisciplinary courses, highlighting student expectations and issues facing faculty. The program is in many ways similar to the master's degree in MBE - the students are drawn to the program with interest in interdisciplinary work; the program focuses on applying academic work to real issues; and, the course structure includes core courses, electives, and experience-based work. They describe the program as both *multidisciplinary and interdisciplinary* with courses in particular disciplines, electives, and three required, core, team-taught, interdisciplinary courses. One of the core courses is a capstone course, a Field Project partially completed out of the country. The students have varied backgrounds, some in humanities and social sciences, with the majority in basic science or engineering. The case study analyzes course evaluations of the three core courses, excerpts from students' Field Project journals, and transcripts of a focus group about interdisciplinary education. They find that students perceive the Field Course, which offers groups of students a fieldwork experience in a subsistence-farming village in Honduras, to be central to interdisciplinary integration of theory-to-practice. They suggest the *collaboration*, *guided participation,* and *scaffolding* involved in the project may be primary factors in students' perceptions of the value of the course relative to the other interdisciplinary courses in the program. Their investigation also suggests that students value faculty making explicit connections among disciplines in interdisciplinary courses, aligning with Lattuca et al.'s (2011) conclusion that a *broad and systems perspective* is valuable to students from varied disciplinary backgrounds.

The importance of social interactions in the development of interdisciplinarity, referred to by Minnis & John Steiner (2005) as collaboration, guided participation and scaffolding, are brought forward in a variety of ways in the studies in this review. In a study of interdisciplinary programming in the health sciences field, Gilkey & Earp (2006) explore the social dynamics, program structure, and skills of students to ascertain the critical elements of effective interdisciplinary programming. Using a conceptual framework of *community capacity*, they conclude that the social environment is critical to effective interdisciplinary programming and includes participation, training in group skills, information sharing, networking, and reflection. They write, "Students must be engaged in collaboration through joint problem-solving, respectful communication and critical reflections." (p. 757).

The service program that Gilkey & Earp (2006) study includes four categories of volunteers: counseling services, community outreach, medical care, and interpretation. Two hundred eighty one undergraduate students complete a 52-item questionnaire, which the reasearchers based on a literature review with the intent to investigate student perceptions of the level of interdisciplinary training they achieve and their ability to work together. Using quantitative and qualitative analysis of the survey, the authors find that effective programs intentionally plan the social environment and train students on group skills.

Gilkey & Earp (2006) anticipate their work will inform interdisciplinary program developers and evaluators in meeting the challenges presented in interdisciplinary programming. The researchers note that their work is limited because they did not pilot test their survey or analyze the validity and reliability. My study addresses this limitation

by adapting validated survey items from Lattuca et al. (2011) and Misra (2008) in investigating student perceptions of their interdisciplinarity.

Holley (2009) also emphasizes the social nature of developing interdisciplinary understanding, as well as the importance of a framework and a structure for integrating multiple disciplines. She investigates student and faculty experiences in an interdisciplinary doctoral program in neuroscience at a *very high research activity* (Carnegie classification) university to explore the purpose, organization, and content of an interdisciplinary curriculum through the lens of cultural understanding. Holley's (2009) study is the only research of an interdisciplinary program in neuroscience that I found in my search. The goals of the neuroscience program are similar to those of the MBE program, i.e., to prepare students for collaborative work and to understand problems at multiple levels of analysis. Similar to the MBE program, the program enrolls students from a variety of backgrounds and requires a first-year core course.

Holley (2009) notes the interdisciplinary nature of neuroscience in academia in the United States and poses questions related to the challenges of an interdisciplinary curriculum and effective strategies for delivering the curriculum. Her methodology, a descriptive case study, is similar to that which I use. In interviewing 45 students, faculty and administrators, she identifies both the collaborative process and the intentional promotion of interdisciplinary integration as critical within an interdisciplinary program and suggests that an "interdisciplinary graduate curriculum not only requires overcoming disciplinary cultural fault lines that impede the integration of multiple cultures, but also understanding the inherent individual and institutional conflicts that accompany such efforts." (p. 254). Organizational features that support interdisciplinary curricula include:

the presence of a full-time faculty director dedicated to the program, funding resources from the institution, and a core group of dedicated faculty. Weaknesses include the lack of planning for integrative experiences and financial burdens on certain departments. The laboratory research experience is the most valuable experience for students, a finding similar to that of Misra et al. (2008). Holley also notes that faculty mentors in these experiences influence students' perceptions of interdisciplinary research and finds that it is important for faculty from multiple disciplines to collaboratively determine the essential elements of students' interdisciplinary experiences. Table 6 describes disciplinary and interdisciplinary curricula in graduate education, detailing the collaboration and intentional processes involved in interdisciplinary programs.

Table 6.

Comparison Between Disciplinary and Interdisciplinary Curricula in Graduate Education[17]

	Traditional Disciplinary Curriculum	Interdisciplinary Curriculum
Formal, written curriculum	Faculty with specialized training provide students with depth of knowledge in disciplinary field of inquiry	A range of faculty with diverse training provide students with breadth of integrated knowledge in interdisciplinary field of inquiry
Research	Students and faculty engage in research activity designed to further disciplinary understanding	Students and faculty engage in collaborative activities related to problems or topics that cut across disciplinary boundaries
Program Administration	Programs exhibit institutional autonomy and bounded jurisdiction	Programs require collaborative support for faculty and students from across the institution
Institution	The university is a system of disparate, bounded, and autonomous disciplines engaged in knowledge production	The university is a network of collaborative and dependent efforts toward knowledge production

Drezek, Olsen and Borrego (2008) also find that an intentional interdisciplinary program positively affects students' interdisciplinary understanding and develops abilities necessary for interdisciplinary research. They focus on graduate-level engineering education, comparing student perceptions in a disciplinary and an interdisciplinary program. The program, Virginia Tech's EIGER program, is funded by the IGERT program

[17] From Holley, K. (2009) with permission. The challenge of an interdisciplinary curriculum: A cultural analysis of a doctoral degree program in neuroscience. *Higher Education,* 58:241-255, p. 254

and designed to offer practical experience and academic work to develop team skills, teach interdisciplinary knowledge and skills, and model interdisciplinary research. The study is based on Boix Mansilla's work and describes a model for faculty to use in developing curricula. Using assessment data gathered over two academic years, 2005-2007, from student and faculty interviews, surveys, course evaluations of the core course on interdisciplinary research, and a review of course assignments, the study compares graduate students from an interdisciplinary program (n=14; 9 of them included in both years) to those from a traditional program (n=7). They propose a model to support faculty in developing interdisciplinary curricula at the graduate level and emphasize the need for explicit connections to be made. Aligning with previously described models, their model notes that students' development proceeds from recognizing disciplinary boundaries, to integration, and finally to meta-cognitive reflection.

Drezek et al. (2008) find that students perceive the interdisciplinary program to be effective in developing the interdisciplinary attitudes, behaviors and understanding that they need to effectively participate in interdisciplinary research; the small sample size limits the study and offers an opportunity to further explore the relationship between student perceptions and interdisciplinary understanding in a program with similar goals.

Misra et al. (2008) compare interdisciplinary and disciplinary undergraduate summer programs in health sciences and find that while the training program is effective in changing behaviors and attitudes related to interdisciplinarity, student products, such as research projects, show no greater integration than do the projects of students who do not participate in the interdisciplinary program. The authors suggest that it is possible that the non-interdisciplinary students have experienced interdisciplinary mentorship

previously, which may explain the similarity in the quality of the projects. Their finding stresses the importance of students' prior experiences, which I explore in my study. As with most of the literature I review for my study, the authors note the lack of literature and research on interdisciplinary learning and programming, use both quantitative and qualitative methodology, and find a positive relationship between interdisciplinary programming and learning outcomes.

In studying the Interdisciplinary Student Undergraduate Research Experience (ID-SURE) at the University of California Irvine, Misra et al. (2008) compare the ID-SURE program with two similar summer programs, which do not include training in interdisciplinary research strategies. They adapt *process* and *product* measures from Mitrany & Stokols (2005) to evaluate the interdisciplinary training program and administer questionnaires (N=101) and conduct interviews and focus groups (N=19). Process measures include self-reports on experiences and personal values, attitudes and behaviors. Product measures include external assessment of products, such as papers. The survey instruments measure interdisciplinary attitudes and behaviors and include six scales: Behavior Change Collaborative Activities Index (BCCAI; α=0.843), Interdisciplinary Perspectives Index (IPI; α=0.930), Team Project Participation Scale (TPPS; α=0.859), Laboratory Impressions Scale (LIS; α=0.859), Social Climate Scale (SCS; α=0.832), and the Interdisciplinary Scientific Appreciation Index (IDSAI; α=0.836). Through personal communication with Misra (8.30.11), I received copies of the scales used in the survey and adapted four of these for this project.

The ID-SURE program includes practical and academic components, including research experience, course work, and journal clubs. The research mentors are from both

the biological and social sciences. The researchers survey the mentors to assess their interdisciplinary perspective in their research and find the results correlate positively with the students' BCAAII and IPI, emphasizing the importance of faculty perspectives on students' interdisciplinarity. This finding of Misra et al. (2008) echoes that of Holley (2009) and provides further support for the inclusion of both faculty and student interviews in my study.

The importance of faculty engagement and perspective on interdisciplinarity is also evident at the graduate level. Newswander and Borrego (2009) investigate two IGERT doctoral interdisciplinary programs and suggest the challenges and successes in the interdisciplinary programs relate to cultural and organizational disciplinary affiliations. They use a framework of engagement theory, as described by Haworth and Conrad (1997), to explore high-quality programs in which students, faculty, and administrators are collaboratively engaged in the teaching and learning. They conduct interviews, focus groups, and observations of a weekly seminar and a core course. The programs differ in the number of years they have received funding, the origins of their identity as interdisciplinary, the course structures, and the allocation of physical office and laboratory space. The researchers frame the final data analysis using engagement theory and code the data to align with the categories of engagement theory (i.e., diverse and engaged participants, participatory cultures, interactive teaching and learning, and adequate resources). They find that students report positive interdisciplinary experiences when the program supports diversity, participation, connections, and interactive teaching and learning. The most engaged students and faculty are those housed in the interdisciplinary program that confers degrees and is a tenure *home* for faculty, as opposed to those housed

in traditional departments. The MBE program provides such a structure and I use a similar methodology of interviews and observations of courses to reveal student perceptions of the tensions involved in integration.

Graybill and colleagues (2006) describe some of the challenges facing doctoral students in interdisciplinary programs, detailing recommendations to overcome some of the challenges noted repeatedly in the literature, such as the tensions created by disciplinary bias, group processes, and institutional structures. The authors, current and former doctoral students in the Urban Ecology IGERT program at the University of Washington, provide perspectives on the benefits and challenges of their participation in a natural science-social science interdisciplinary program with the intent of guiding prospective students and faculty members designing programs. They offer six core recommendations to improve doctoral students' interdisciplinary experiences: 1) intentional facilitation of group processes; 2) opportunities for student ownership and agency, e.g., designing and facilitating seminars; 3) intellectual and financial institutional support for interdisciplinary work; 4) planning for academic progress; 5) flexibility to accommodate individual students' needs; and 6) "appreciate inquiry" and reflection to counter disciplinary bias (p. 762). They note that most interdisciplinary research focuses on the perspectives of faculty and researchers and suggest that student perspectives are critical as they affect the success of interdisciplinary programs and future career paths of students.

The Urban Ecology PhD program differs from the MBE master's program in that it involves two distinct academic departments (faculty, degree requirements, and peers), which suggests an additional opportunity to add to the literature by including data on

student perspectives in a program with an interdisciplinary home. The small number of participants (the six authors are the sole participants) and the lack of description of the methodology limit the Graybill et al. (2006) study. My study adds to the literature with participation of more students and a detailed methodology.

Summary

Interdisciplinary understanding involves developing competency in multiple disciplines; integrating the knowledge and ways of thinking; being aware of the purpose, advantages and limitations of the synthesis; recognizing the need for reflection and revision; and, using the understanding to address complex problems. Interdisciplinary activities involve interpersonal skills and reflection, and require skill in collaboration and group work. A variety of factors influence the effectiveness of programs in fostering interdisciplinary understanding and include the curricula and co-curricular activities of students, individual student characteristics, and characteristics of institutions. Student characteristics such as prior experiences with projects and disciplines are related to their interdisciplinary development. Disciplinary affiliation, whether as a result of students' prior experiences or as a result of institutional structures and cultures, appears to affect students' perception of their interdisciplinarity. Faculty are critical in mentoring and supporting interdisciplinarity; the many ways they contribute include: their own engagement and participation in interdisciplinary programs; the perspectives they share through mentoring in lab and research experiences; the team experiences they offer; the way they collaborate to develop courses; the training they provide on group skills; and, the way in which they intentionally make connections among disciplines. The structure and support of interdisciplinary work within an institution can challenge or enhance

interdisciplinary programming. The traditional academic structure for evaluating research and teaching, cultures of territoriality, and privileging of some disciplines over others challenge effective interdisciplinary programs. Programs are supported when they experience an identity, space, and dedicated administration; adequate allocation of funding; and operate within a social environment and culture that are supportive of interdisciplinary efforts.

My study builds from these studies, using quantitative and qualitative data to explore student perceptions of their experiences in an interdisciplinary program. The study adds the field of education to the research on interdisciplinary programs in health sciences, sciences, and engineering and offers insight to some of the questions raised in the last decades about students' perceptions and the development of their interdisciplinary understanding.

CHAPTER 3

METHODOLOGY

Research Approach

As a developing field, MBE programs offer students interdisciplinary study of many disciplines, including psychology, education, neuroscience, and biology, to prepare educators for collaborative work to improve education. This study uses a case study approach to explore how students perceive the phenomenon of developing interdisciplinary understanding. The literature review in Chapter 2 highlights the lack of research on interdisciplinary programs in higher education and led me to select the descriptive case study methodology because it is:

> useful…in presenting basic information about areas of education where little research has been conducted. Innovative programs and practices are often the focus of descriptive case studies in education. Such studies often form a database for future comparison and theory building." (Merriam, 1998, p. 38).

Yin (2003) writes that case study is an appropriate research design when investigating complex social phenomena; the literature review describes the complex social phenomena involved in developing interdisciplinary understanding. In choosing a single case to investigate, I again refer to Yin (2003), who notes that a rationale for a single case study is the *revelatory* case, which may be used "when an investigator has the opportunity to observe and analyze a phenomenon previously inaccessible to scientific investigation." I anticipate that the description of this revelatory case will be informative to other institutions and individuals interested in MBE.

In investigating the Harvard Graduate School of Education (HGSE) *Mind, Brain, and Education* (MBE) graduate program, this study investigates students' development as

interdisciplinary researchers and practitioners and explores the relationship between student characteristics, such as prior experiences, and their perceptions of interdisciplinarity. The study provides rich description of the program and offers insight into students' perceptions of the MBE program and provides data to guide future development of MBE programs.

The conceptual framework guiding the research is Boix Mansilla's (2010) pragmatic constructionism and structures the research questions below:

- What are students' perceptions of their development as interdisciplinary researchers and practitioners in MBE? How do they perceive
  - the purpose for interdisciplinary study in MBE?
  - their understanding and use of disciplinary perspectives?
  - their understanding and use of disciplinary integration?
  - how their understandings may change in the future?
- What perceptions do participants in a graduate MBE program have about the potential and limitations of MBE to improve education?
- How do these perceptions vary based on student characteristics?

The study design investigates the four components of Boix Mansilla's framework: *interdisciplinary purpose, disciplinary insights, leveraging integrations,* and *critical stance*, using an online survey with program alumni and current students, interviews with alumni and students, interviews with relevant program administrators and faculty, and reviews of program artifacts. I include both alumni and current students to gather data on the relationship between student characteristics, such as the length of time from their completing the programs, and their perception of their development as interdisciplinary

researchers and practitioners. The interviews with faculty/administrators inform the data collected with the student survey and interviews.

I selected the HGSE program because it offers an opportunity to study an established program, which has been enrolling approximately 45 students each year for more than five years and has an articulated interdisciplinary focus. Members of the faculty, students, and graduates are engaged in a variety of activities in the developing field of MBE, including developing online courses and summer institutes for educators and publishing in peer reviewed journals. The program has been used as a model for other programs (e.g., UTA, 2010) and students have gone on to establish programs at other institutions (e.g., Dartmouth, 2010). The number of students and the longevity of the program allow me to investigate the relationship between student characteristics such as time since graduation and perceptions of interdisciplinarity, to gather data from students with diverse prior experiences to investigate the role of prior experience in interdisicplinarity, and to gather data from students who have been in the field following the program on the potential of MBE to inform educational practice and policy.

Description of MBE Program

Physical Site

The Mind, Brain, and Education program is a master's degree program offered in the Harvard Graduate School of Education (HGSE) at Harvard University. Harvard University is located in Cambridge, MA, across the Charles River from downtown Boston, and has approximately 2100 faculty members and 21,000 students. The area includes many "world class educational institutions" (City of Boston, 2013), as well as medical and technology-related institutions.

HGSE offers a total of 13 one-year master's degrees and 2 doctoral degrees, with approximately 100 faculty and 900 students. Students in the MBE program have access to all classes at Harvard Schools, as well as at other institutions, including Massachusetts Institute of Technology (MIT).

Students and Faculty

The MBE program enrolls approximately 45 students each year; the majority of the students are female. The students are primarily full-time, although there are a limited number of part-time slots available. HGSE offers a need-based grant program and merit-based scholarships to "ensure greater access and promote the diversity that is vital to a place of learning" (Harvard Graduate School of Education, 2012). Financial aid may include grants, scholarships, fellowships, loans, or workstudy; more than 75% of HGSE students receive financial aid, with half of those receiving need-based grants.

The HGSE MBE website describes the student population as:

> The backgrounds of our students vary greatly. A minority of students in the program have a strong biology background. Some have backgrounds in psychology and education research, but many do not. Every year we have a few students with no training in the social sciences at all. Given the multiple fields that are intrinsic to MBE, we cannot expect anyone to know all of them. Students in the program usually have a background in education (teaching or research), cognitive science, brain science, child development, philosophy, or biology; many other fields and backgrounds are also represented. Approximately half of our students are, or plan to become, teachers (Harvard Graduate School of Education, 2013).

The MBE website lists 20 faculty members, ranging from visiting lecturers to named professorships. Of those, one is emeritus and one no longer links to the Harvard faculty directory. The majority of the faculty are affiliated with the Education department; several are also affiliated with other departments, including Psychology and Public Health. Thirteen of the 18 are tenure track positions and five are lecturers. Four of the lecturers

and seven of the tenure track earned their undergraduate or graduate degrees at Harvard. Faculty have a range of research interests, which includes five projects, which are described on the website (Harvard Graduate School of Education, 2014):

- The Dynamic Development Lab
    - Dr. Kurt Fischer leads an active group of collaborators in the lab who are trying to explain the order behind variations in people's behavior.
- Project Zero, the Mind/Brain/Behavior Initiative
    - A research group at the Harvard Graduate School of Education, has investigated the development of learning processes in children, adults, and organizations since 1967.
- Mind/Brain/Behavior Initiative
    - A university-wide initiative created in 1993 by former Harvard President Neil Rudenstine along with four other Interfaculty Initiatives.
- The Center for Applied Special Technologies
    - A nonprofit organization that works to expand learning opportunities for all individuals, especially those with disabilities, through the research and development of innovative, technology-based educational resources and strategies.
- The Science Education Department
    - The Science Education Department (SED) of the Harvard-Smithsonian Center for Astrophysics develops curricula and materials that reflect current scientific philosophy.

In 2000, Harvard announced they would be offering a concentration in MBE (Blake & Gardner, 2007); the first course was offered in 2002. I selected the Harvard interdisciplinary MBE program as the case for this study because it was intentionally developed by "senior scholars" (Blake & Gardner, 2007, p.64); the founders are involved in *The Interdisciplinary Studies Project* (Interdisciplinary Studies Project, 2003), a multi-year research project of Project Zero, Harvard Graduate School of Education; the core course, HT-100, was the first of it's kind when it was offered in 2002-2003 and faculty have had the benefit of nearly a decade of feedback and evaluation to revise the course; and, the

program began as a *concentration* in 1999-2000 and was first offered as a program in 2003-2004. It was modeled on an existing "promising interdisciplinary program [at Harvard University] in 'Mind, Brain, and Behavior' (Bake & Gardner, 2007, p.61). The diversity of the student body, as well as the diversity of the potential research experiences and opportunities for cross-disciplinary connections, the number of faculty associated with the program, and the number of students enrolled each year provide opportunity for rich exploration.

Curriculum and Co-curriculum

At the time of this study, students in the MBE program are required to take eight four-credit courses: the core course, HT-100 *Cognitive Development, Education, and the Brain*, two courses selected from the eight *foundational* MBE courses, two selected from *additional* MBE courses, and three electives (Appendix A).

HT-100

HT-100, *Cognitive Development, Education, and the Brain,* is currently a semester-long course. The course is also listed cross-listed as Psychology 1607a and enrollment is not restricted to MBE students. Doctoral students who have taken the course previously work as teaching fellows to teach and support students in the course. Teaching fellows typically teach for multiple years to develop expertise and greater understanding and synthesis of the material (Blake & Gardner, 2007). The course maintains an extensive website with video lectures and supplemental reading.

Foundational Courses

The MBE program offers six foundational courses taught by six different faculty members; five of these courses are at the HGSE and one is at the Harvard Faculty of Arts

and Sciences. “These courses are designed to provide foundational knowledge about mind, brain, and education, including a survey of key concepts, findings, and practices from the field” (Harvard Graduate School of Education, 2013b).

Additional MBE Courses

Students select the two additional MBE courses from 51 courses (Appendix A) organized in three didactic categories: Cognition and Neuroscience (21 courses), Learning and Assessment (17 courses), and Research Methods and Assessments (13 courses). These courses are primarily at the Graduate School of Education; three of the courses from the Cognition and Neuroscience category are at the Harvard Faculty of the Arts and Sciences. To fulfill the requirement for additional MBE courses, students may also select any course from the Mind, Brain, and Behavior course selection or from the foundational MBE courses.

Electives

Students may take the three elective courses at any of the other Harvard or MIT schools, as long as a total of four courses in their program are at HGSE.

Research Labs and other Resources

MBE students have access to the many resources and research labs across Harvard University (Blake & Gardner, 2007). Although the MBE program does not require a research experience or an internship, “many students do independent research with HGSE faculty, and [the MBE program] has relationships with several labs in the Harvard Faculty of Arts and Sciences and the Harvard Medical School” (Harvard Graduate School of Education, 2013).

Data Collection

Research suggests that in case study design, all methods of data collection are appropriate, and that quantitative and qualitative methods may complement one another (Merriam, 1998; LeCompte & Schensul, 1999; Yin, 2003). With some adaptation, the qualitative and quantitative methods listed below replicate those used by the researchers cited in the literature review; allow for insight and interpretation (Merriam, 1998); and, provide objective information about students enrolled in an MBE program. The data collection includes multiple sources of data to offer a comprehensive understanding of perceptions of MBE graduate students and to allow triangulation of the data to increase internal validity (Merriam, 1998, p. 204). The quantitative measures from the survey provide data to best answer certain of the research questions (Gall, Gall & Borg, 2007), confirming and validating demographic information, enrollment patterns, goals, and post-graduate professional engagement.

I collected data from students (Table 7) using the following methods. I provide details about the response rate in the Results chapter.

- Semi-structured interviews with current students and alumni
- Survey of alumni of the MBE program 2007-2011
- Survey of students currently enrolled in the MBE program in 2012 and 2013

Boix Mansilla's (2010) framework suggests that interdisciplinarity is a dynamic process and prior experiences are foundational; students continue to revise their knowledge, adjust their purpose, gain disciplinary insights, and further integrations as a result of new experiences and reflection. I interviewed and surveyed both current students and alumni in order to investigate the relationship between student perceptions of their interdisciplinarity and time for reflection, to investigate the relationship between students

perceptions of the potential of MBE to influence educational practice and policy and time and experiences post graduation.

To supplement the data from students, I also reviewed printed and web-based documents and artifacts and conducted semi structured interviews with faculty/administrators.

Table 7.

Student Participants

Participants	Student Interview Participants (n = 27)	Student Survey Participants (n=48)
Current Students – 2012	6	10
Current Students - 2013	10	9
Alumni 2007-2011	11	29

Student & Alumni Survey Development

I used *SurveyMonkey.com* to develop a 43-item survey with Likert-scale, closed-, and open-ended questions (Appendix E). Questions that did not require writing text included a *comment* box. The questions related to the research questions as depicted in Table 8.

Jenny Thomson, a faculty member in the MBE program at the time of this study and a member of my dissertation committee, referred me to three alumni and three current students to pilot the survey for clarity of the questions and the amount of time needed to complete the survey. I received constructive feedback from the pilot and made changes to the survey, including adding a *progress bar* to indicate the number of items remaining to

be completed, adding detail to the Likert scale so every rating was accompanied by a word, and adding detail to questions to clarify the intent of the question.

The survey includes the following sections:

- MBE Program Experiences
- Interdisciplinarity
- Social Climate of the MBE Program
- Employment
- Disciplinary Experiences Prior to the MBE Program
- Prior and Current Interdisciplinary Experiences
- Demographic Information

To investigate the research questions related to students' perceptions of the development of their interdisciplinarity, how these perceptions vary based on disciplinary affiliation; and, the potential of MBE to influence practice and policy, I developed a survey that includes scales adapted from two previous studies (Lattuca et al., 2011 and Misra et al., 2008), as well as original items.

Replicated Scales

I contacted two researchers, Shalini Misra (Misra et al., 2008; Appendix B) and Lisa Lattuca (Lattuca et al., 2011; Appendix C), and received permission to adapt scales from their surveys, which were used to investigate the outcomes of interdisciplinary programs in engineering and health promotion, respectively. I maintained the original Likert scale for each question and adapted questions as detailed below. I used these as measures of students' interdisciplinary understanding related to Boix Mansilla's pragmatic-constructionist framework and the research questions (Table 8).

Lattuca et al. (2011) developed the following scales to measure the outcome of students' interdisciplinary program:

- *Recognizing Disciplinary Perspectives*
- *Interdisciplinary Knowledge and Skills*
- *Reflective Behavior*
- *Teamwork Skills*

These scales are part of a larger project in which Lattuca and colleagues developed three surveys (one each for students, faculty, and program chairs) to explore the current state of undergraduate engineering curriculum. The four scales were designed to investigate the effect of interdisciplinary programs on students' interdisciplinarity. In developing the surveys, Lattuca et al. (2011) "follow[ed] a rigorous two-year process" (p. 8), which included literature review on the key survey topics, individual interviews with faculty, administration, and alumni at two institutions of higher learning, and focus groups interviews with students at those institutions. Faculty and students at one institution met in focus groups to review the final survey instruments to be sure they were appropriate and understandable. Lattuca writes that these questions may be adapted for other disciplines (L. Lattuca, personal communication, July 5, 2011). The Cronbach's alpha on these scales ranges from .69 to .86.

I adapted four scales from Misra et al. (2008) to gather data on the component *leveraging integrations* and students' perceptions of the social climate of the MBE program (Table 8), which has been shown in previous studies to relate to students' interdisciplinarity. These measures were developed by Shalini Misra, (doctoral candidate in the department of Planning, Policy and Design, School of Social Ecology, University of California, Irvine) in collaboration with Dr. Daniel Stokols (professor in the department of Planning, Policy and Design, School of Social Ecology, University of California, Irvine) and others (Misra et al., 2008) to evaluate students' interdisciplinary attitudes and behaviors at the beginning and end of a summer interdisciplinary program. The authors note that

their survey provides a reliable measure to use in evaluating collaborative interdisciplinary processes. The Cronbach's alpha on these scales ranges from .83 to .93. I adapted the following scales:

- *Interdisciplinary Perspectives Index*
- *Behavior Change Collaborative Activities Index*
- *Lab Impressions Scale*
  - *Social Climate Scale*
  - *Experiences Scale*

Table 8.

Research Focus and Adapted Scales

Boix Mansilla Framework Component	Lattuca et al. (2011) Scale	Misra et al. (2008) Scale
Disciplinary Insights	*Recognizing Disciplinary Perspectives*	
Leveraging Integrations	*Interdisciplinary Knowledge and Skills*	*Behavior Change Collaborative Activities Index*
	Teamwork Skills	*Interdisciplinary Perspectives Index*
Critical Stance	*Reflective Behavior*	

Recognizing Disciplinary Perspectives Scale

To investigate the *disciplinary insights* component of Boix Mansilla's (2010) framework, I replicated Lattuca et al.'s (2011) three-item *Recognizing Disciplinary Perspectives* scale (Appendix C), which has a Cronbach's alpha of .69.

Interdisciplinary Knowledge and Skills Scale

To investigate the *leveraging integrations* component of Boix Mansilla's (2010) framework, I adapted Lattuca et al.'s (2011) eight-item *Interdisciplinary Knowledge and Skills* scale (Appendix C; Cronbach's alpha = .80). I eliminated one question, "Not all engineering problems have purely technical solutions." I adapted the other seven

questions to align with the MBE program, e.g., I substituted *education* or *educational* for the word *engineering*, added examples of *other fields*, and replaced *humanities and social sciences* with *sciences and psychology.*

Reflective Behavior Scale

To investigate the *critical stance* component of Boix Mansilla's (2010) framework, I replicated Lattuca et al.'s two item *Reflective Behavior* scale (Appendix C), which has a Cronbach's alpha .73.

Teamwork Skills

I adapted Lattuca et al.'s (2011) five-item *Teamwork Skills* (Appendix C) scale to measure *leveraging integrations* by changing *multiple engineering fields* to *multiple fields* and changing *engineering* to *education.* The Cronbach's alpha of the original scale is .86.

Interdisciplinary Perspectives Index

To measure *leveraging integrations,* I adapted Misra et al.'s (2008) seven-item *Interdisciplinary Perspectives Index* (Appendix B), replacing *ID-SURE* with *MBE*. The original Cronbach's alpha is .93.

Behavior Change Collaborative Activities Index

I replicated four questions from Misra et al. (2008) nine-item *Behavior Change Collaborative Activities Index* (BCAII) and used them as measures of students' *leveraging integrations* (Appendix B). I adapted two of the remaining five and included them in original items on the survey and the remaining three were not relevant to the MBE students.

Lab Impressions: Social Climate Scale and Experiences Scale

The literature I reviewed for this study suggests that the social climate of a program, students' teamwork skills, and their experiences in a research lab are related to their interdisciplinarity. I adapted scales from Misra et al. (2008) to measure students' perception of these aspects of their development as interdisciplinary researchers and practitioners.

I adapted the *personal experiences* questions on the *Laboratory Impressions* scales (Appendix B) to further investigate the relationship between students' interdisciplinarity and their perceptions of the social climate of the MBE program. I used the same seven-point Likert scale and categories and changed the original question from "For each item below please place a check in the box that best represents your personal experiences as a member of a research lab or group you work in." to "During the MBE program I felt primarily:" The Cronbach's alpha of Misra et al.'s (2008) *Laboratory Impressions* scale is .86.

I adapted Misra et al.'s (2008) s*ocial climate* questions from the *Lab Impressions Scale* (Appendix B) to measure students' perceptions of the social climate of the MBE program. I changed the question from "For each item below, please place a check mark in the box that best describes the social climate of the research lab or group you work in" to "Please rate the climate of the MBE program." The original Cronbach's alpha is .83.

Original Survey Items

I created original items to measure students' perception of the potential of MBE to influence educational practice and policy; to gather demographic data; to investigate students' purposes for interdisciplinary work (*Purpose* in Boix Mansilla's (2010)

framework); their perception of the source of their affinity for interdisciplinary study; their prior and current experiences; their disciplinary affiliation, and their perceptions of the experiences that facilitated and challenged integration.

The survey investigates students' perceptions of the purpose of interdisciplinary work in MBE; their experience gaining disciplinary grounding; their experience integrating disciplines; their critical awareness; their perspectives on the social climate; perspectives on the program in general; and, their interdisciplinary behaviors and attitudes. The relationship of the survey questions, the constructs, and the original author is detailed in Table 9. The survey includes both open- and closed-questions. All questions have an option for *comment* and were analyzed using qualitative methodology; questions with an * yielded only qualitative data. I analyzed all the *comments* as qualitative data.

Table 9.

Survey Questions and Research Focus

Research Focus	Survey Questions	Source of question
Boix Mansilla (2010) Framework		
Purpose	#1*, 14*	Author-developed
Disciplinary Insights	#19	Lattuca et al. (2011)
Leveraging Integrations	#7, 20 #16, 17 #8*, 9*, 10*, #32	Misra et al. (2008) Lattuca et al. (2011) Author-developed Author-developed and includes 2 questions from Misra et al.'s (2008) BCCAI scale
Critical Stance	#18	Lattuca et al. (2011)
Potential of MBE	#6, 15*	Author-developed
Perceptions of Program		
Program Impressions	#2,3,4,5	Misra et al. (2008)
Research/Lab Experience	#11, 12	Author-developed
Social Climate	#21, 22, 23, 24, 25	Misra et al. (2008)
Student Characteristics		
Disciplinary Affiliation	#13, 28, 31	Author-developed
Source of Affinity for interdisciplinary work	#34	Author-developed
Interests and Activities	#33	Author-developed
Personal demographics related to MBE enrollment	#11, 37, 38, 39, 40, 41, 42, 43	Author-developed
Personal demographics	#35, 36,	Author-developed
Education and Employment	#26, 27*, 28, 29, 30*	Author-developed

Participants

Survey Participants

On March 24, 2012 I sent a link to a survey designed to determine who would be interested in receiving a link to the full survey, which takes about thirty minutes to complete, to the 320 alumni on the MBE 2007-2011 HGSE MBE alumni listserv (students elect to join the listserv and therefore the listserv may not include all alumni and current students) and the approximately 45 students in the MBE class of 2012. The MBE program maintains a listserv for alumni and a separate one for current students. Because I received the general listserv address, I am unable to determine how many students received the survey. I received 65 responses with 59 alumni and current students interested in receiving a link to the longer survey. I sent the link to the full survey on April 10, 2012 to those 59 students.

To increase the response rate, I sent the survey in the morning during the middle of the week (Hambleton, n.d.; Krathwohl & Smith, 2005; LeCompte & Shensul, 1999; Merriam, 1998; People Pulse, n.d.; personal communication M. Watts, Abacus Associates, 2/4/11). I requested that participants complete the survey within a two-week period and sent a reminder on the Friday before the April 23, 2012 due date. I sent reminder e-mails close to the deadline and then again after the deadline, extending the deadline, to solicit more responses. The MBE program coordinator also sent an email in 2012 requesting additional participation.

On March 22, 2013 I sent a link to the full survey to the students on the alumni and current student 2013 listservs with a deadline of March 31, 2013. I sent a reminder on April 4, 2013 extending the deadline to April 11, 2013, to increase the response rate.

A total of 55 people responded to the survey, with 83.6% of those (46 participants; 19 current students, 27 alumni) completing the survey.

Student Interview Participants – Current Students and Alumni

I conducted 27 semi-structured interviews with current students in the classes of 2012 and 2013 and alumni from the classes of 2007 – 2011 (please see Table 7 for details of the interviews and Appendix D for interview questions). The interviews ranged from 20 – 45 minutes in length; most interviews were approximately 30 minutes long. To solicit participants for the student interviews, I emailed all members of the HGSE alumni and current student listservs asking if they would be interested in participating in a face-to-face, telephone, or Skype interview. Of those students, 40 replied they would be interested and provided contact information. I also used the purposeful *snowball* sampling type (Merriam, 1998, p. 63), contacting individuals referred by other participants. The interview participants may have also completed the online survey – the survey was anonymous so I am unable to confirm the number of duplicate participants.

Because some of the participants lived outside of traveling distance, I conducted four of the interviews using Skype; all others were conducted face-to-face. I conducted most of the interviews on site at HGSE; I conducted four interviews by Skype, one at a conference, and one in an off-site public building. Participants met with me individually for the interviews with one exception, when two participants participated in an interview together due to a scheduling conflict.

I sent consent forms electronically to all participants and also provided hard copies to those I interviewed in person.

I recorded the interviews using two pieces of equipment for each interview, either an Olympus VN-480PC digital recorder, an iPhone 4S, or the *Garage Band* program on a Macintosh computer.

I transcribed three of the interviews myself and sent the remaining twenty-seven to *TransciptionHub.com* (www.transcriptionhub.com). I reviewed all *TranscriptionHub* documents while listening to the interview to ensure the accuracy of the transcription. I e-mailed all transcription to participants to *member check* for accuracy to increase the internal validity of the study (Merriam, 1998, p. 204). Nine of the student and alumni interview participants commented on the accuracy of the transcribed interview.

Faculty/Administrator Interview Participants

I selected three faculty/administrators to interview to provide background information to the student interviews and surveys; three participants in this category were appropriate given the size of the program and the nature of the data I intended to obtain from this sector. I selected the faculty/administrator participants based on the amount of time they had been with the program, the extent of their contact with students, and their association with the core course, HT-100. Faculty include an HT-100 teaching fellow who completed the MBE master's program and a professor who taught HT-100. The interviews with faculty/administrators ranged from 30 – 60 minutes long.

I transcribed one of the interviews myself and sent the remaining two to *TransciptionHub.com*. I reviewed all *TranscriptionHub* documents while listening to the interview to ensure the accuracy of the transcription. I e-mailed all transcription to participants to *member check* for accuracy to increase the internal validity of the study

(Merriam, 1998, p. 204). All three of the faculty/administrator interview participants commented on the transcribed interview.

Demographics

I include the demographics of the participants in the Results section.

Document and Artifacts Review

I reviewed the following records and artifacts:

- HGSE and MBE websites
- HT-100 Syllabus and website
- Course evaluations for HT-100 2007-2011
- HGSE Course catalogues 2007-2008 to 2012-2013

I reviewed the HGSE and MBE websites to gather information about the program for descriptive purposes and to place the interview and survey data in context.

The core MBE course, HT-100 *Cognitive Development, Education and the Brain*, maintains an extensive website, which includes the syllabus, videos and the PowerPoint slides of the lectures, supplementary reading and resources, and links to discussion boards, guest lectures, and podcasts. The director of the MBE program granted me permission to log into the HT-100 website with access to the same material as students access.

I initially intended to review the HT-100 website in detail, as the site provides students with information about the course as well as offers materials for students to access to fill in gaps in their knowledge and to facilitate integration of the material. When I began the review of the content of the HT-100 website I realized that the amount of content was beyond the scope of this study. I limited my review to the syllabus and a sampling of the initial course meeting and two additional video lectures to gain an

understanding of the course structure, intent, content, and teaching methods. The syllabus articulates the goals of the course and reveals how the assignments, activities, and assessments reveal how the course addresses students' need to gain disciplinary knowledge and synthesize. I used the videos as a sampling of the course content and approach to learning.

I read the program description in each of the course catalogues to gather data on how the program requirements changed over time.

Field Observations

I observed two events sponsored by the MBE program, one with prospective students, the *Admitted Students Open House,* and one with current students, an *MBE Faculty/Student Conversation Luncheon,* and recorded my observations in field notes. I attended the Open House to familiarize myself with the program and to observe students' purposes in applying to the program.

HGSE offers admitted Ed.M. students an open house in the spring that includes a variety of activities spread out over four days. The MBE students' program includes a meeting with program administrators and faculty and a meeting with alumni of the program. I was invited to attend and observed these two meetings in on April 1, 2011.

During the academic-year, the MBE program schedules regular *Conversation Lunches* for students and faculty. I learned of the event during an interview with a student and was able to observe one of the luncheon meetings that same day, November 19, 2012.

Security

All documents, records, recordings, notes, and surveys are stored in a locked cabinet, on a password protected computer and on the web in a password protected *Box*

file (Box, 2014). *Box* is a campus-based secure content-sharing site. I assigned pseudonyms to all interview participants; participants of the surveys are anonymous. I protected participants' identities in quoting and attributing responses of faculty and administrators, however, due to the small number of administrators and faculty in the MBE program, the confidentiality of their participation may not be maintained. I will destroy all transcripts and identifying records when the project and all data analysis has been completed.

Researcher Biases and Qualifications

My interest and experience in the field of Mind, Brain, and Education brings both challenges in terms of biases as well as unique qualifications. I have participated for many years in conferences and institutes sponsored and hosted by the Harvard Graduate School of Education. I am a member of the International Mind, Brain, and Education Society, the organization in which Kurt Fischer, the director of the MBE program, assumes a significant role. I have closely followed the work of Kurt Fischer and Howard Gardner throughout my career as an educator and administrator; Fischer and Gardner are founding and current faculty in the MBE program. I hold personal beliefs that MBE will play an important role in education reform and that educator preparation programs should include more child development and science coursework. The focus of my comprehensive exam papers was the field of mind, brain, and education and I recently collaborated with neuroscience, psychology, and education faculty at the institution where I work to co-sponsor a lecture series featuring researchers using interdisciplinary methods that have the potential to influence educational practice and policy.

In advance of beginning the study, I conducted an informal interview with the director of the HGSE MBE program who provided guidance and contact information for accessing records and communicated with a founding and current faculty member who gave me names of graduates to contact, with permission to let them know he suggested them to me. I was in ongoing communication with a faculty member who provided information and participated on my dissertation committee. During the course of my research I maintained a research journal to bring awareness to potential biases. I find my prior knowledge of the field of MBE allowed me to reflect more deeply and insightfully on the qualitative data, as I brought a deeper understanding to some of the issues and concepts students brought forward. My journal did not reveal any potential problems due to my biases.

CHAPTER 4

RESULTS

I separated the results of this study into two sections: *Quantitative Results* and *Qualitative Results*. The quantitative and qualitative methods provide differential data on the research questions. Each section is subdivided in sections relating to the following questions:

- How do students perceive the MBE program?
- Research Question #1: How do students perceive their development as interdisciplinary researchers and practitioners?
- Research Question #2: How do students perceive the potential and limitations of MBE to improve education?
- Research Question #3: How do students' perceptions vary by student characteristics?

The results described in the sections titled *Perceptions of the MBE Program* relate to students' general impressions of the program, the curriculum and co-curriculum, the learning outcomes and students' career and employment experiences. The quantitative section provides descriptive data on these aspects of the program and uses original and adapted scales to measure the social and intellectual climate; the enrollment in the core course and participation in and effect of a lab/research experience; the changes students perceive in their appreciation for, and readiness to, participate in interdisciplinary collaboration and their disciplinary affiliation; and, the focus of alumni employment and how closely it relates to MBE. The qualitative data provide insight into students' perceptions of their experiences in the program.

The results described in the quantitative section *Research Question #1: Students' Perceptions of Their Development as Interdisciplinary Practitioners and Researchers* relate to the four components of the framework (purpose, disciplinary insights, integration, and critical stance). The quantitative section reports the results of adapted scales to measure students' perceptions of their ability to recognize disciplinary perspectives, of their interdisciplinary skills and perspectives, and their engagement in reflective behavior. I investigated the *purpose* component using only qualitative data. The results in the qualitative section offer insight into students' ratings in the quantitative section.

The results described in the section *Research Question #2* relate to students' perceptions of the potential of MBE to improve education. The quantitative section includes descriptive statistics rating students' optimism about the potential of MBE to inform education and their ability to contribute to collaborative MBE efforts. The qualitative section clarifies students' perceptions of the potential of MBE.

The *Research Question #3: Student Characteristics* section provides data on the question of how students' perceptions vary by student characteristic. The quantitative section provides descriptive statistics on the source and extent of the influences on their interdisciplinary perspective and the range and frequency of their extracurricular interdisciplinary activities, as well as comparisons between the student characteristics of enrollment status as a current student or alumnus/alumna and participation in a lab or research experience with the findings related to other findings in the section. The qualitative section investigates students' perceptions of their affinity for interdisciplinary work.

Research Questions

The purpose of this study is to investigate students' perceptions of an interdisciplinary program in Mind, Brain, and Education. The primary research questions are:

- What are students' perceptions of their development as interdisciplinary researchers and practitioners in MBE? How do they perceive:
    - the purpose for interdisciplinary study in MBE?
    - their understanding and use of disciplinary perspectives?
    - their understanding and use of disciplinary integration?
    - how their understandings may change in the future?
- What perceptions do participants in a graduate MBE program have about the potential and limitations of MBE to improve education?
- How do these perceptions vary based on student characteristics?

Quantitative Results

Statistics and Data Analysis

I analyzed the quantitative data from the survey using descriptive statistics by the subgroups of alumni and current students and those who do and do not participate in a lab/research experience while enrolled in the program. The quantitative data include:

- The online survey of 2007-2012 alumni and current students 2012 and 2013
- Course catalogues 2007-2013

The following sections describe the demographics of the student participants; their general impressions of the program, the curriculum and co-curriculum, learning outcomes, and careers and employment; and data related to each of the research questions:

- What are students' perceptions of their development as interdisciplinary researchers and practitioners in MBE?
- What perceptions do participants in a graduate MBE program have about the potential and limitations of MBE to improve education?
- How do these perceptions vary based on student characteristics?

Demographics

Student Survey Participants

Of the 55 survey respondents, 48 students identify their enrollment status as a current student (40%; 19 respondents) or an alumnus (60%; 29 respondents). Of the 19 current students, 47% (9 students) are enrolled in the class of 2013 and 53% (10 students) are enrolled in the class of 2012. Table 10 details the graduation years of the alumni; Table 11 details the graduation years of the current students.

The majority of the respondents identify as "white" (93%; 41 respondents) and female (83%; 40 respondents), as seen in Table 12; the age of the 46 respondents when they completed the MBE program ranges from 22 to 57, (M = 29, SD = 8.34). Most respondents (67%; 31 respondents) have not, to date, pursued further education, while 33% (15 respondents) have enrolled or graduated from programs offering doctoral degrees in education, psychology, medicine, and human development.

Table 10.

Graduation Years of Alumni Survey Participants

Graduation Year	Number	Percentage
2012	4	14%
2011	10	34%
2010	5	17%
2009	4	14%
2008	2	7%
2007	4	14%
TOTAL	29	100%

Table 11.

Graduation Years of Current Student Survey Participants

Graduation Year	Number	Percentage
2013	9	47%
2012	10	53%
TOTAL	19	100%

Table 12.

Gender and Race of Survey Participants

Gender and Race	Current Students	Alumni	Total
Gender - Female	17 (89%)	23 (79%)	40
Race – White	17 (94%)	24 (92%)	41

Perceptions of the MBE Program

General Program Impressions

I adapted Misra et al.'s (2008) ten-item *Lab Impressions* scale to measure students' general impressions of the program. The original scale includes five items related to the social climate and five items related to students' personal experiences in their lab or research group. I adapted the scale to maintain the five original questions related to social climate and eliminated one item from the personal experiences section (Table 13). Participants use a seven-point Likert scale to rate the social climate of the program on five items: *discouraging to encouraging*, *competitive to cooperative*, *un-stimulating to stimulating*, *cold to warm*, and *socially fragmented to socially cohesive*. The personal experiences section of the adapted *Lab Impressions* scale asks students to rate their overall experience in the MBE program on a 7-point Likert scale ranging from: *socially alienated* to *socially integrated*, *intellectually isolated* to *intellectually integrated*, *frustrated* to *satisfied*, and *progress hindered* to *progress advanced.* Most students rate the social climate

and their personal experiences on all items to be *slightly, moderately,* or *very positive*. The ratings indicate more than half of the participants find the MBE program *moderately to very encouraging*, *cooperative*, *stimulating, warm*, *intellectually integrated,* and *progress advanced* (Figure 5). Students rate the social cohesion and social integration of the program the lowest. The ratings for *socially fragmented* to *socially cohesive* were the lowest and the ratings for *un-stimulating* to *stimulating* were the highest. (Table 13). Students find the social climate and their experiences in the MBE program to be positive; they find the social integration and cohesion of the program to be less positive than other aspects.

Table 13.

MBE Impressions: Seven-point Likert scale (adapted from Misra et al., 2008)

Items	Mean	Standard Deviation	Minimum	Maximum
Social Climate				
Discouraging to Encouraging	5.3	1.47	2	7
Competitive to Cooperative	5.72	1.71	1	7
Un-stimulating to Stimulating	6.3	1.05	3	7
Cold to Warm	5.64	1.21	2	7
Socially Fragmented to Socially Cohesive	4.78	1.72	1	7
Personal Experience				
Socially Alienated to Socially Integrated	4.94	1.80	1	7
Intellectually Isolated to Intellectually Integrated	5.45	1.44	2	7
Frustrated to Satisfied	5.24	1.72	1	7
Progress Hindered to Progress Advanced	6.09	0.99	2	7
Average	5.50	1.46	N/A	N/A

Note: Social Climate section *n* = 55; *Personal Experiences* section *n* = 50

Figure 5. MBE Impressions Scale (adapted from Misra et al., 2008): 7-point Likert scale

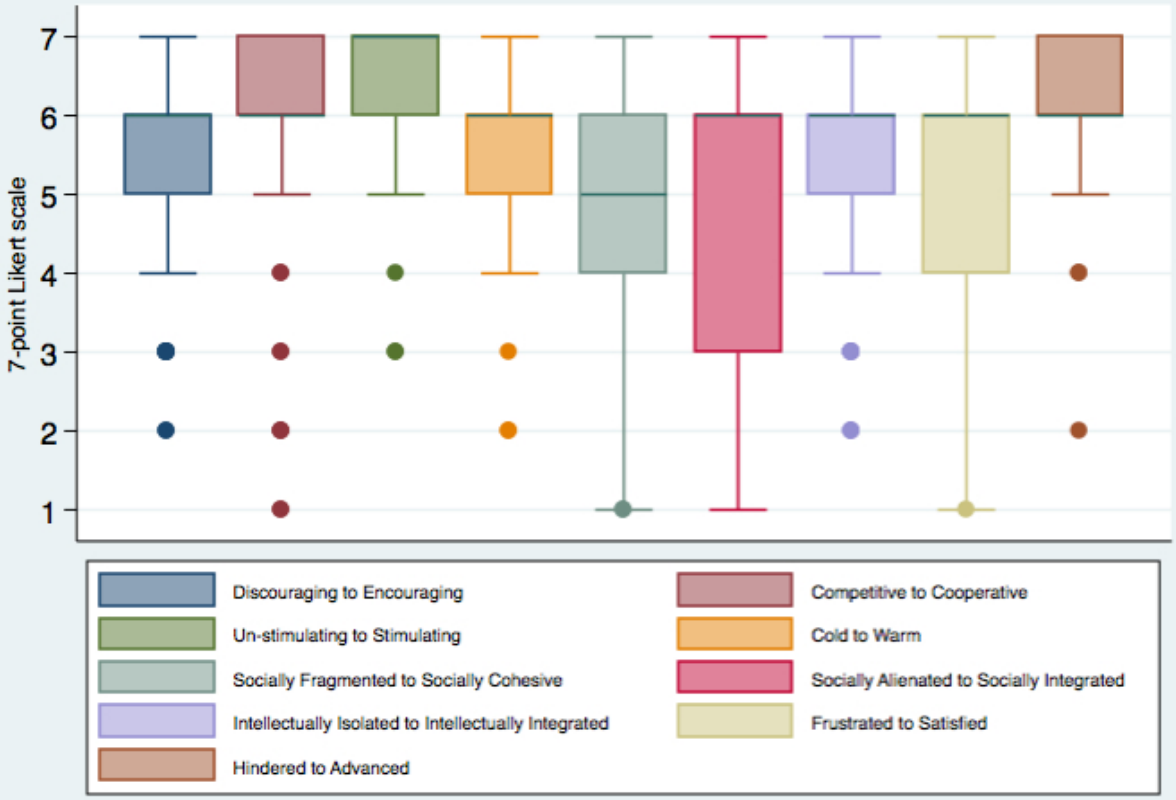


Figure 5. MBE Impressions Scale. Adapted from Misra et al. (2008). N varies between 50 and 55.

I analyzed the data using the subgroups of students who participate in a lab/research experience while in the program and those who do not. Students who participated in a research/lab experience rated four of the five items on the 7-point Likert scale of the *Social Climate Scale* (adapted from Misra et al., 2008) higher on most items than the students who did not have a research lab experience (Table 14). The average rating for students who participate in a lab/research experience is 5.76 and for those who do not, it is 5.15. The results suggest students who participate in a lab/research experience have more positive general impressions of the program (Table 14).

Table 14.

MBE Impressions: Students with and without a Lab/Research Experience

Items	Mean Rating Lab Experience	Mean Rating No Lab Experience
Social Climate		
Discouraging to Encouraging	5.42	5.18
Competitive to Cooperative	6.42	4.91
Un-stimulating to Stimulating	6.31	6.45
Cold to Warm	6.08	5.14
Socially Fragmented to Socially Cohesive	5.19	4.36
Personal Experience		
Socially Alienated to Socially Integrated	5.52	4.46
Intellectually Isolated to Intellectually Integrated	5.69	5.25
Frustrated to Satisfied	5.24	5.46
Progress Hindered to Progress Advanced	6.0	6.25
Average	5.76	5.15

Curriculum and Co-Curriculum

The following sections include data related to the core course, HT-100, and students' participation in an optional lab/research experience.

Core Course – HT-100

The core course, HT-100 - *Cognition, Development, Education, and the Brain,* is cross-listed at the Faculty of Arts and Sciences as Psychology 1607a. Neither HT-100, nor any of the other courses in the MBE program, includes only members of the MBE cohort. The course enrolls approximately 50 students; about 80% are MBE students (J. Thomson,

personal communication, April 12, 2014). The course has undergone a number of transformations since it was first offered in 2002-2003, including the number of faculty teaching the course and the length of the course, the semester in which it is offered. During the history of the course, it has been co-taught by three regular faculty members and by a single faculty member; teaching fellows have supported the regular faculty.

In this study, students experienced the course as either a yearlong course (classes of 2007, 2008, 2009, and 2010), a yearlong course in two parts (class of 2011), a semester-long course offered first semester (class of 2012), or a semester-long course offered second semester (class of 2013). The changes in the length and timing of the course reflect the administration's "commitment to revising…courses regularly to keep them responsive and up to date." (K. Fischer, personal communication, April 6, 2014). As a result of the change, the faculty "deal more selectively with the breadth of MBE topics" (K. Fischer, personal communication, April 6, 2014).

Approximately half the 49 participants enrolled in HT-100 as a full-year course (26 participants, 53%) and half as a semester course (23 participants, 47%). The majority of the alumni participants (25 participants, 86%) took HT-100 as a yearlong course; the overwhelming majority of the current student participants took HT-100 as a semester course (one part-time student took it as a year-long course).

As noted above, HT-100 was offered in the fall semester in 2012 and in the spring semester in 2013. Table 15 depicts the numbers and percentages of alumni and current students taking the class each semester. The students in the class of 2012 had completed the semester-long core course when they participated in the survey and students in the class of 2013 were currently enrolled in the class.

Table 15.

HT-100 Enrollment: Alumni and Current Student 2012 and 2013

Core Course HT-100	Alumni	Current Class of 2012	Current Class of 2013
Full-year	25 (86%)	1 (7%)	0 (0%)
Fall Semester	4 (14%)	14 (93%)	0 (0%)
Spring Semester	0 (0%)	0 (0%)	9 (100%)
TOTAL	29 (100%)	15 (100%)	9 (100%)

HT-100 aims to provide students with the core concepts, skills, and foundational domain knowledge in relevant fields (Appendix A). The purpose of the course is "to help [students] become …MBE professional[s]." Table 16 depicts the philosophy of the course as described in the syllabus. In the spring of 2013, the 25 class sessions included six classes with guest speakers and addressed a variety of questions and topics, including: "foundational assumptions" in MBE, "relevant disciplinary foundations," and "MBE in the education context."

Table 16.

HT-100 Course Core Concepts

Concepts	Skills	Domain Knowledge
1) Being question-driven 2) Taking a dynamic systems perspective by thinking about variability and people-in-context 3) Valuing a reciprocal relationship between research and practice	1) Interpreting scientific findings 2) Translating between practice and research 3) Integrating knowledge across different perspectives 4) Communicating to various audiences	The goal is to develop some foundational knowledge in relevant fields - it is not to develop expertise in several MBE-related content areas

Faculty encourage students to form study groups to support one another in the class and the course website offers privileged and copyrighted supplemental materials to enrolled students, including video lectures and written materials. Assessments include three essays, a capstone paper, and a final exam designed to help students synthesize the material.

Research/Lab Experience

The survey results indicate that approximately half of the 53 respondents (29 participants, 55%) participate in interdisciplinary employment, research lab, or internship experience. Approximately half of those participants (15 participants, 52%) rate the experience as *very positively* affecting their appreciation for interdisciplinary work and the overwhelming majority (25 participants, 87%) rate the experience as *slightly, moderately, or very positively* affecting their appreciation (M = 6.0, SD = 1.22). The ratings range from three to seven; no participant rated the experience as *very* or *moderately negatively*

affecting her appreciation of interdisciplinary work and one rated her experience *slightly negatively*. I compared the responses of those who identify as current students with those who identify as alumni students to determine if there were subgroup differences; alumni rate the experience more positively than do current students (Table 17, Figure 6).

Approximately half of the participants choose a lab/research experience while in the program; a substantial majority of those students find the optional experience of working in a lab/research environment positively affects their appreciation of interdisciplinary work; alumni find the experience more positive than current students and students who participate find the climate of the program more positive.

Table 17.

Effect of Lab/Research Experience on Appreciation for Interdisciplinary Work

Participants	Mean	Standard Deviation	Minimum	Maximum
All Students *N* = 29	6.0	1.22	3	7
Current Students *N* = 11	5.71	1.27	3	7
Alumni *N* = 14	6.18	1.25	4	7

Figure 6. Effect of Lab/Research Experience on Appreciation for Interdisciplinary Work

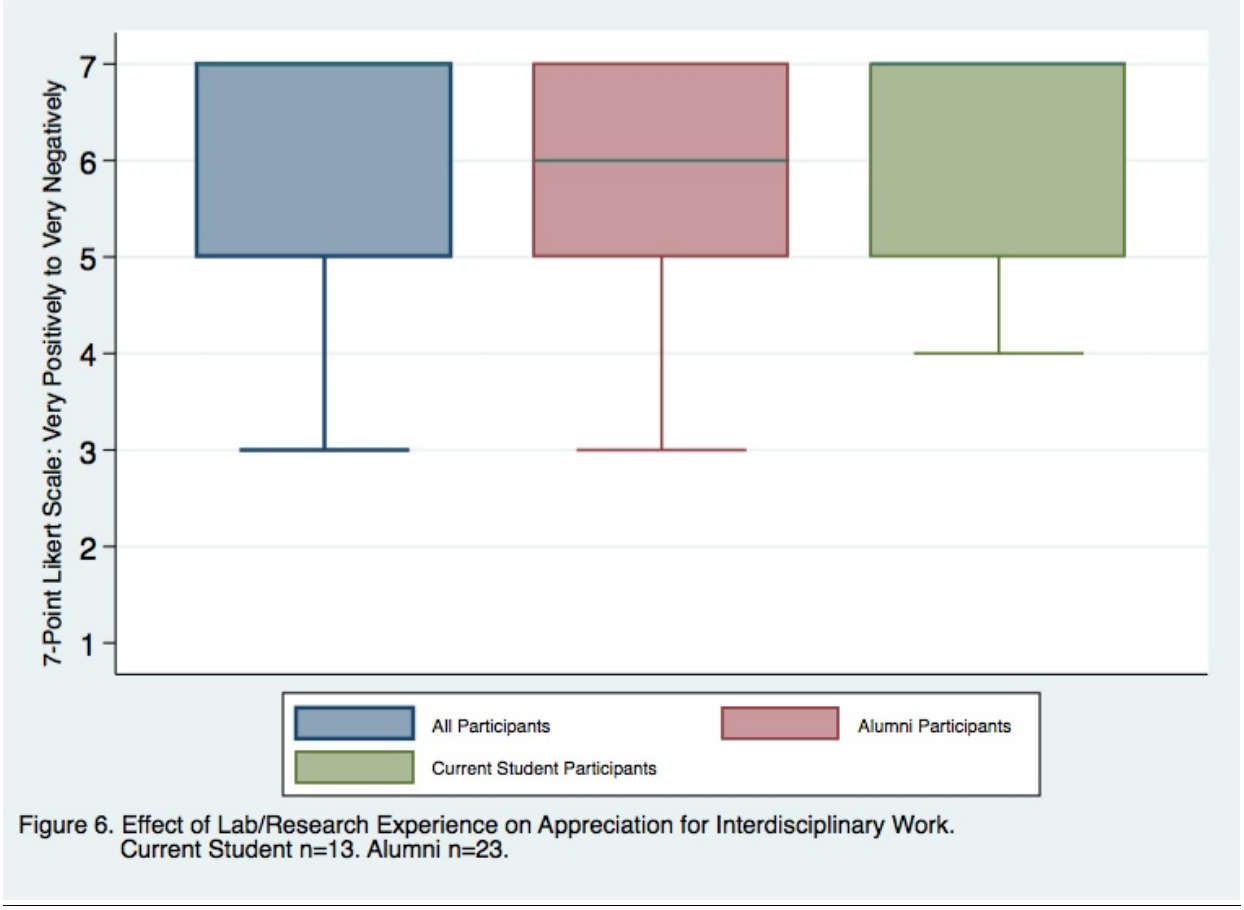


Figure 6. Effect of Lab/Research Experience on Appreciation for Interdisciplinary Work. Current Student n=13. Alumni n=23.

Learning Outcomes

I used two items from Misra et al.'s (2008) nine-item *Behavior Change Collaborative Activities Index* to measure students' perceptions of the effect of the program on their appreciation for interdisciplinary work and readiness to collaborate on interdisciplinary research and wrote an original item to measure students' perception of the change in their disciplinary affiliation as a result of the program.

Interdisciplinary Collaboration

The adapted *Behavior Change Collaborative Activities* Index (Misra et al., 2008) asks the 55 participants to rate, on a 7-point Likert scale, the increase or decrease in their appreciation for interdisciplinary research and their readiness to collaborate with researchers from other fields as a result of participating in the program. The scale ranges from *significantly decreased* to *significantly increased* (Table 18, Figure 7). Students find the MBE program positively affects their appreciation for interdisciplinary research and their readiness to collaborate on interdisciplinary research.

Table 18.

Behavior Change: Interdisciplinary Collaboration

Change in Interdisciplinary Appreciation and Readiness	Mean	Standard Deviation	Minimum	Maximum
Appreciation for interdisciplinary research collaboration	5.4	1.42	1	7
Readiness to collaborate with researchers from other fields	5.65	1.11	3	7

Figure 7. Behavior Change: Interdisciplinary Collaboration

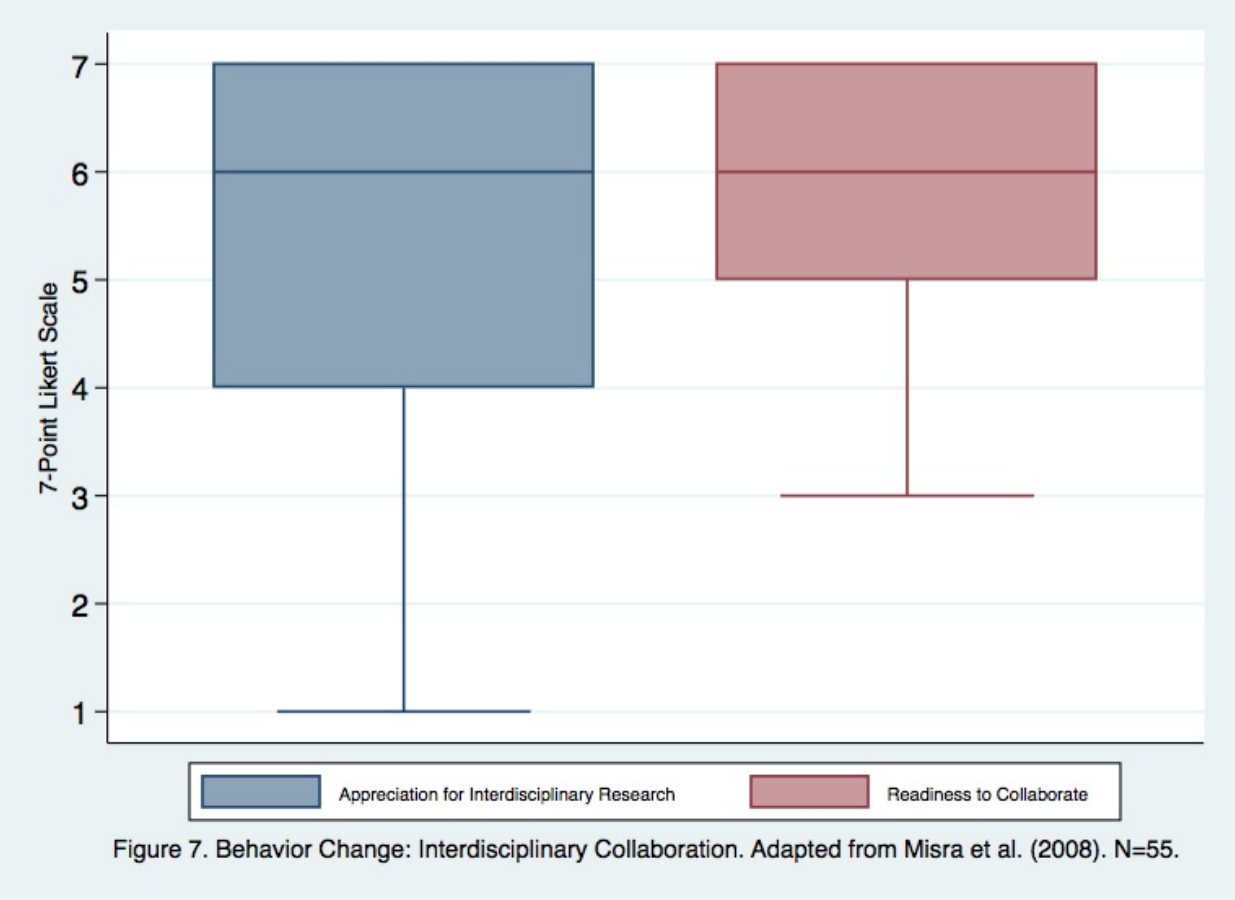


Figure 7. Behavior Change: Interdisciplinary Collaboration. Adapted from Misra et al. (2008). N=55.

Disciplinary Affiliation

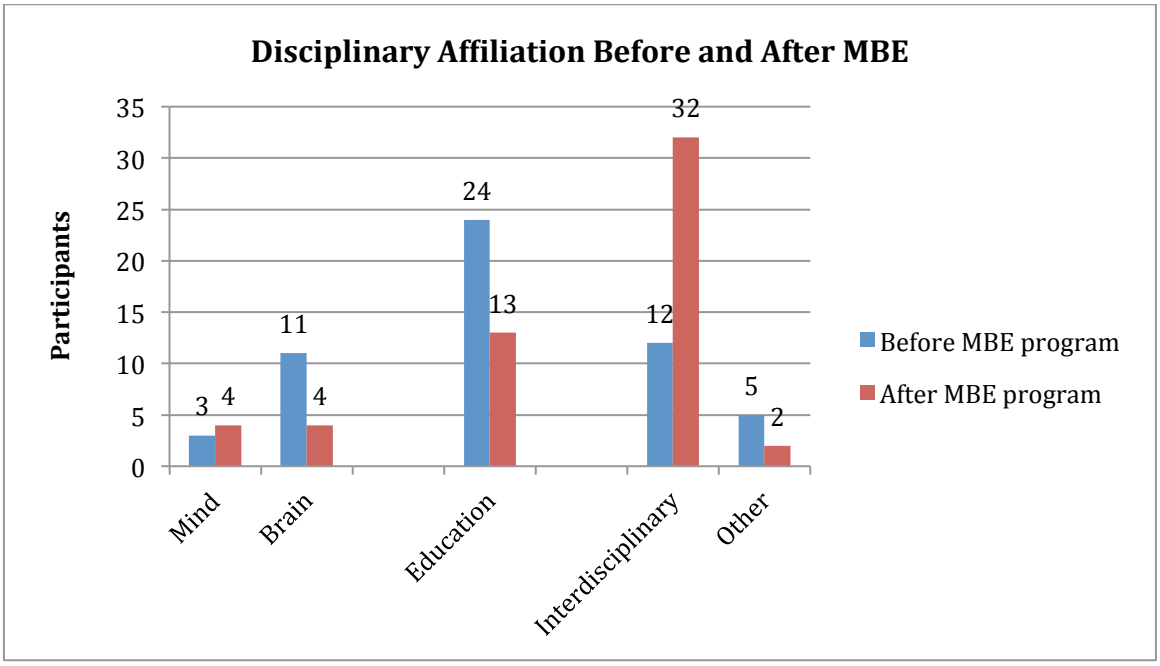
To investigate the effect of the program on students' disciplinary affiliation, I developed a survey question asking students to indicate their disciplinary affiliation before and after the MBE program. The response choices include: *mind, brain, education, interdisciplinary,* and *other.* The number of students reporting an *interdisciplinary* affiliation before and after the program nearly triples (Table 19). Approximately half of those who identify as affiliating with *education* before the program report they were *interdisciplinary* after the program (Table 19 and Figure 8).

Table 19.

Disciplinary Affiliation Before and After MBE

	Before MBE		After MBE	
Disciplinary Affiliation	Participants	Percentage	Participants	Percentage
Mind	3	5%	4	7%
Brain	11	20%	4	7%
Education	24	44%	13	24%
Interdisciplinary	12	22%	32	58%
Other	5	9%	2	4%
TOTAL	55	100%	55	100%

Figure 8. Disciplinary Affiliation Before and After MBE



I analyzed the data using the subgroups of students who participate in a lab/research experience while in the program and those who do not. A total of 53 participants identified their disciplinary affiliation before and after the program and also reported whether or not they had participated in a lab/research experience. The results suggest students who participate in a lab/research experience are more likely to identify as having an interdisciplinary affiliation (Table 20). The number of students who participated in a lab or research experience while in the program who identified as *interdisciplinary* before the program is the same; after the program the number tripled for those who had a lab/research experience and doubled for those who did not. (Table 20).

Students in the MBE program perceive their disciplinary affiliation shifts as a result of the program, from an affiliation with a particular discipline such as *mind*, *brain*, or *education*, to identifying as interdisciplinary; students who participate in a lab/research experience identify as *interdisciplinary* more frequently than do those without the experience.

Table 20.

Interdisciplinary Affiliation Before and After MBE: Students with and without a Lab/Research Experience

	With Lab/Research Experience		Without Lab/Research Experience	
Identify as *Interdisciplinary*	Number *N = 29*	Percentage	Number *N= 24*	Percentage
Before MBE	6	11%	6	11%
After MBE	19	36%	12	23%

Careers and Employment

Of the 34 survey alumni respondents all but two are employed, and both of those report being enrolled in graduate programs. Twenty-nine participants rate on a three-point Likert scale how closely their current employment is related to MBE. The scale ratings are: *not related, somewhat related, and directly related.* As shown in Table 21 and Figure 9, the employment of alumni range from *not related* to *directly related*; the majority of the alumni are either *directly* or *somewhat* related to MBE (M = 2.21, SD = .73).

Two-thirds of the alumni respondents describe the focus of their current employment as *interdisciplinary* (Table 22, Figure 10). Due to the design of the survey, respondents may have selected multiple categories. For example, a survey respondent "doing cognitive neuroscience research with an educational focus" may have selected both *interdisciplinary* and *brain.* I reviewed the individual responses and if a participant

responded *interdisciplinary* and also selected another category, I considered the response *interdisciplinary*. If a participant selected multiple options, I also considered the response *interdisciplinary*. A substantial majority of alumni are currently employed, are working in contexts related to MBE, and identify the focus of their work as interdisciplinary.

Table 21

Alumni: Current Employment Related to MBE

Employment related to MBE	Number Alumni Participants	Percentage Alumni Participants
Not related	5	17%
Somewhat related	13	45%
Directly related	11	38%
Total	29	100%

Figure 9. Alumni: Current Employment Related to MBE

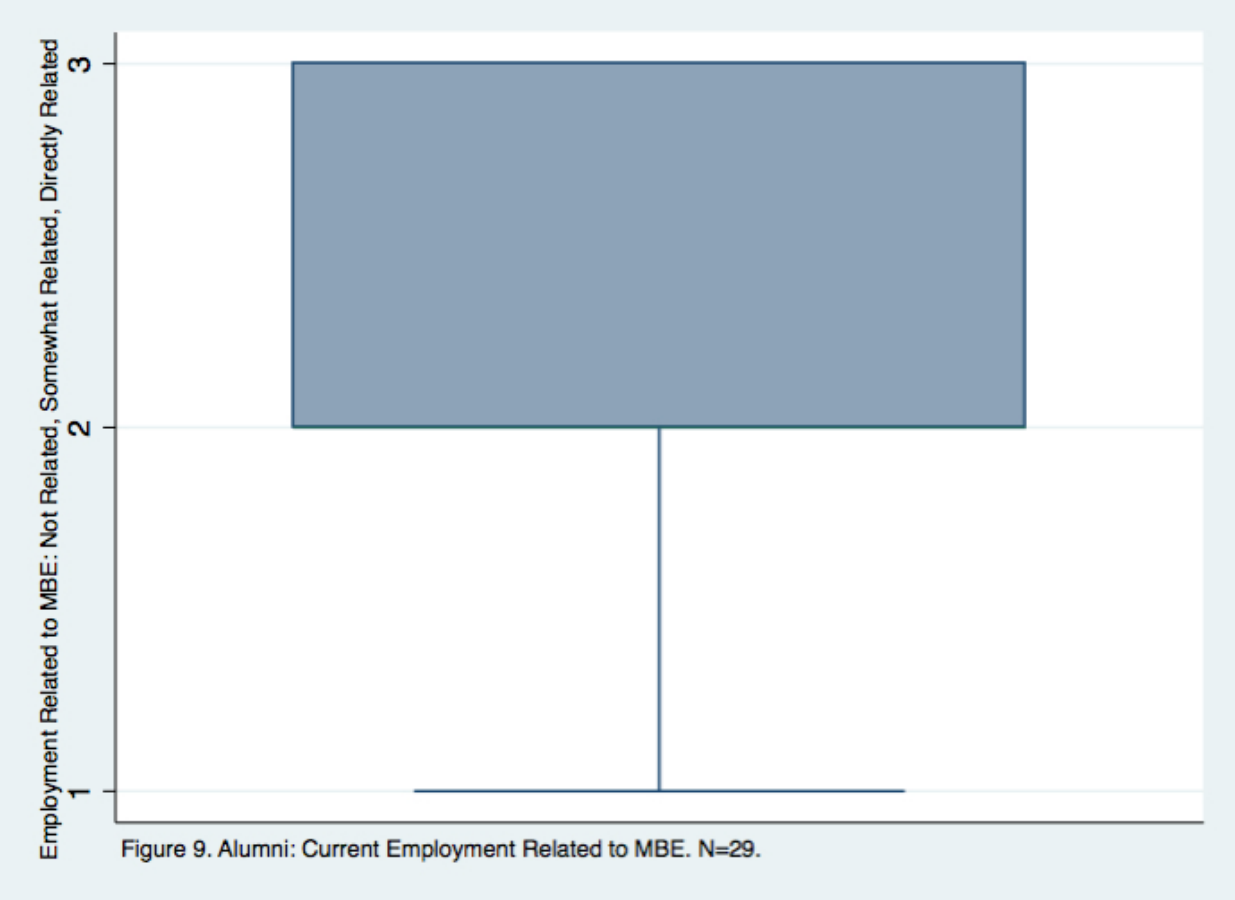


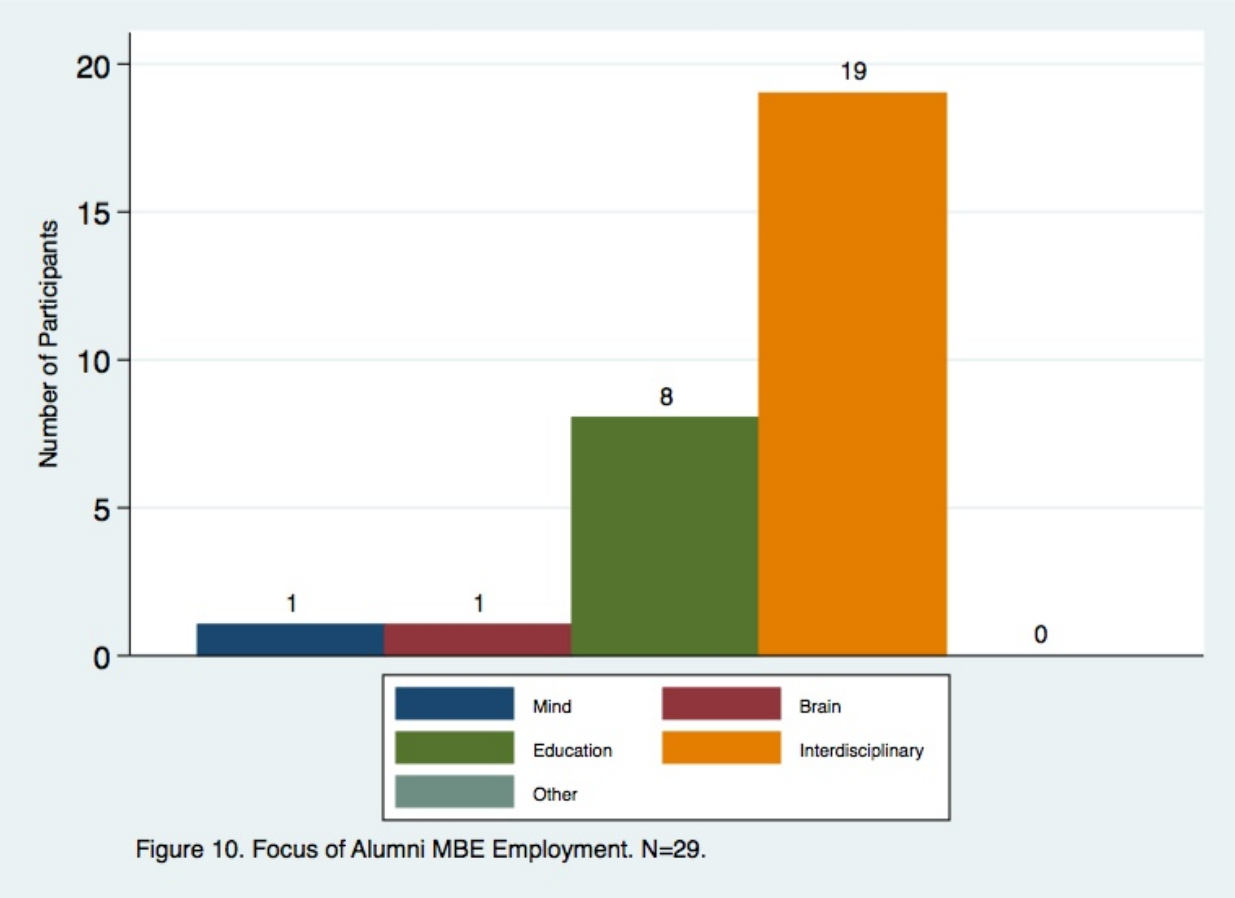
Table 22.

Focus of Alumni Employment

	Number of Alumni Participants	Percentage Alumni Participants
Mind	1	3%
Brain	1	3%
Education	8	28%
Interdisciplinary	19	66%
Other	0	0%

Total	29	100%

Figure 10. Focus of Alumni MBE Employment



Research Question #1: Development as Interdisciplinary Practitioners and Researchers

Boix Mansilla's (2010) suggests that interdisciplinary understanding involves "constructing a system of thought in reflective equilibrium," and comprises four cognitive processes: *establishing purpose*, *weighing disciplinary insights*, *building leveraging integrations*, and *maintaining a critical stance*. I adapted scales from Lattuca et al. (2011)

and Misra et al. (2008) to measure student perceptions of the components of *weighing disciplinary insights*, *building leveraging interactions* and *maintaining a critical stance*.

Weighing Disciplinary Insights

In the process of interdisciplinary learning, students "understand disciplinary contributions and weigh their role in informing the whole." (Boix Mansilla, 2010, p. 300). I use Lattuca et al.'s (2011) three-item *Recognizing Disciplinary Perspectives Scale* (Appendix C) to measure the component *weighing disciplinary insights* (Boix Mansilla, 2010). The scores on the five-point Likert scale range from 1 – 5 (*strongly disagree* to *strongly agree*), with the mean of the 50 responses ranging from 3.52 to 4.04 and the standard deviation ranging from .71 to .86. The average score is 3.85. Students find they are able to weigh disciplinary insights as they recognize the evidence from multiple disciplines, consider the differences and values of distinct knowledge bases, and use them in thinking about specific problems.

Building Leveraging Integrations

In *building leveraging integrations* students "produce integrative understandings" and "discern the best form of integration to meet the purpose" (Boix Mansilla, 2010, p. 299). I adapted Lattuca et al.'s (2011) *Interdisciplinary Knowledge and Skills* scale (Appendix C) and Misra et al.'s (2008) *Interdisciplinary Perspectives Index* (Appendix B) as measures of the process of *building leveraging integrations*.

I adapted Lattuca et al.'s *Interdisciplinary Skills* scale by omitting one item that I was unable to adapt from engineering to education. The original item reads: *Not all engineering problems have purely technical solutions.* The 51 participants rate their agreement with the items on a five-point Likert scale ranging from *strongly disagree* to

strongly agree. The means, standard deviations, and range of the ratings are shown in Table 23. The average rating is 4.46. Students find they gain interdisciplinary knowledge and skills in the program and are able to synthesize and produce integrative understandings to apply to problems in education.

Table 23.

Interdisciplinary Skills (Adapted from Lattuca et al., 2011)

Item	Mean	Standard Deviation	Minimum	Maximum
I value reading about topics outside of education (psychology, neuroscience, biology, politics, history, etc.)	4.74	.44	4	5
I enjoy thinking about how different fields approach the same problem in different ways.	4.61	.60	3	5
In solving educational problems I often seek information from experts in other academic fields.	4.10	.90	2	5
Given knowledge and ideas from different fields, I can figure out what is appropriate for solving a problem.	4.18	.59	3	5
I see connections between ideas in education and ideas in the sciences and psychology.	4.75	.48	3	5
I can take ideas from outside education and synthesize them in ways that help me better understand or explain a problem.	4.51	.64	3	5
I can use what I have learned in one field in another setting or to solve an educational problem.	4.31	.73	3	5
Average	4.46	.63	N/A	N/A

I adapted Misra et al.'s (2008) *Interdisciplinary Perspectives Index* by changing one item from *Overall, I believe that a high level of good will exists among the research associates at UCI affiliated with my research* to *Overall, I believe there is a high level of support within HGSE for MBE research.* The 49 participants rate their agreement or disagreement on a five-point Likert scale from *strongly disagree* to *strongly agree.* The means, standard deviations, and range of the ratings are shown in Table 24. The average rating is 3.63. Item #2 on the scale is reverse-scored. Students value interdisciplinary work and maintain an interdisciplinary perspective in thinking about their work in education.

Table 24.

Interdisciplinary Perspectives Scale (Adapted from Misra et al., 2008)

Interdisciplinary Perspective	Mean	Standard Deviation	Minimum	Maximum
In my own research, I typically use multiple research methods drawn from more than one discipline rather than rely exclusively on a single disciplinary approach.	3.24	1.92	0	5
I prefer to conduct research independently rather than as part of a group.	2.64	1.30	0	5
I would describe myself as someone who strongly values interdisciplinary collaboration.	4.33	.689	3	5
Generally speaking, I believe that the benefits of interdisciplinary research outweigh the inconveniences of such work.	4.18	.86	0	5
I am optimistic that interdisciplinary collaboration among MBE collaborators will lead to valuable scientific outcomes that would not have occurred without that collaboration.	4.04	1.15	0	5
Overall, I believe there is a high level of support within HGSE for MBE research.	3.24	1.27	0	5
Overall, MBE members as a group are open-minded about considering research perspectives from fields other than their own.	3.82	1.20	0	5
Average	3.64	1.20	N/A	N/A

Maintaining a Critical Stance

Maintaining a critical stance involves "revising a system of thought in light of critique" and "weighing emerging insights against one another, and against prior knowledge and against competing understandings." I used the *Reflective Behavior* scale (Appendix C) from Lattuca et al. (2011) as a quantitative measure of the *maintaining a critical stance* component of Boix Mansilla's (20) framework. Participants rate two items on a five-point Likert scale ranging from *strongly disagree* to *strongly agree.* The items read: *I frequently stop to think about where I might be going wrong or right with a problem solution* and *I often step back and reflect on what I am thinking to determine whether I might be missing something.* The scores range from 1 – 5, with the mean of the 50 responses ranging from 4.12 to 4.32 and the standard deviation ranging from .89 to .96. The average score is 4.22. Students find they maintain a critical stance and are reflective in thinking about the integrations they propose in addressing educational problems.

Research Question #2: The Potential of MBE

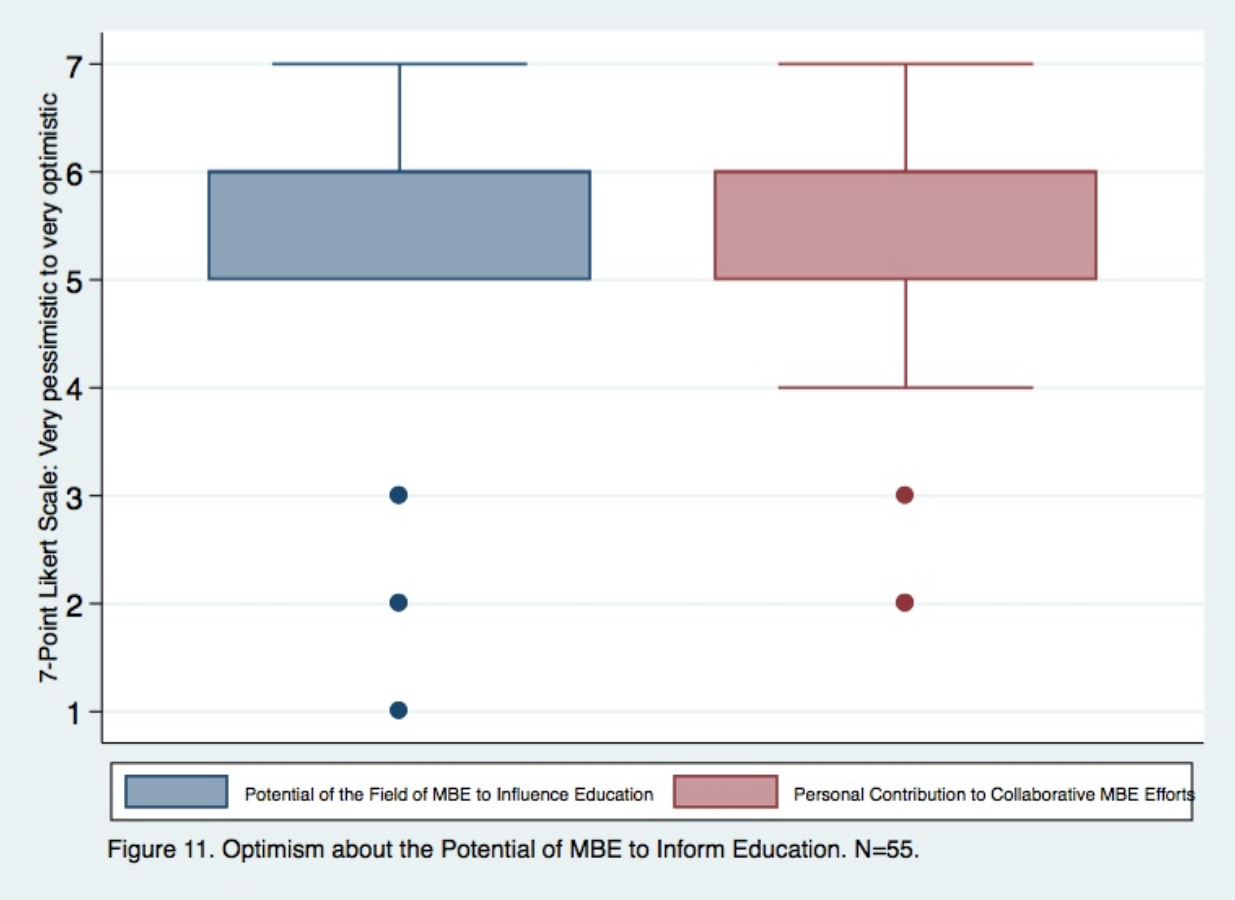
I designed two items to measure students' perceptions of the potential of MBE. Using a seven-point Likert scale ranging from *very pessimistic* to *very optimistic*, 55 participants rate the potential of MBE to inform education and how they may personally contribute to collaborative efforts to inform education (Table 25, Figure 11). The mean rating of both questions is similar: 5.34 (*SD* = 1.55) and 5.33 (*SD* = 1.36). Students are optimistic about the potential of MBE to inform education and about the contributions they may make to collaborative efforts.

Table 25.

Optimism about Potential of MBE to Inform Education

	Mean	Standard Deviation	Minimum	Maximum
Potential of field of MBE to inform education	5.34	1.55	1	7
Personally may contribute to collaborate efforts to inform education	5.33	1.36	2	7

Figure 11. Optimism about the Potential of MBE to Inform Education



I analyzed the responses to students' optimism about the potential of the field of MBE and their personal contribution to collaborative efforts by the subgroups of current students and alumni. Alumni rate the potential of MBE to inform education and the potential for their personal contribution to collaborative MBE efforts slightly higher than do current students (Table 26), suggesting alumni are more optimistic about the potential of MBE and their contribution to collaborative efforts than are current students.

Table 26.

The Potential of MBE: Comparison of Current Students and Alumni

Potential of MBE	Mean Rating Current Students	Mean Rating Alumni
Potential of field of MBE to inform education	5.15	5.69
Personally may contribute to collaborate efforts to inform education	5.35	5.48

Research Question #3: Student Characteristics

Teamwork Skills

I used Lattuca et al.'s (2011) five-item *Teamwork Skills* scale (Appendix C) to measure students' perception of their skills in working on interdisciplinary teams. The items ask participants to rate their agreement (ranging from *strongly disagree* to *strongly agree* on a five-point Likert scale). The ratings range from 3.80 to 4.0; the average rating is 3.90. Students find they work well in teams of people with diverse skills and backgrounds to accomplish group goals by applying knowledge from multiple disciplines.

Social and Intellectual Interdisciplinary Activities

I investigate students' prior and current interdisciplinary activities. Of the 55 survey respondents, 30 (55%) report having had prior interdisciplinary experiences, either in undergraduate or graduate school, employment, or a volunteer or internship experience.

I developed items to measure students' perception of the extent to which their interest in interdisciplinary activities extends to their social and intellectual activities

outside of the program and to what experiences they attribute their interest in interdisciplinary work. The following tables and figures depict the results of these items:

- *Sources and Extent of Interdisciplinary Perspective* (Table 27, Figure X*)*
- *Range of Interdisciplinary Activities* (Table 28, Figure X)
- *Frequency of Current Interdisciplinary Activities* (Table 29, Figure X)

Sources and Extent of Interdisciplinary Perspective

I developed items to measure students' perceptions of the extent to which their interdisciplinary perspective is evident in other areas of their lives and the extent to which family, community, and educational experiences contributed to their interdisciplinary approach (Table 27, Figure X). Fifty students use a five-point Likert scale to rate their agreement with the items from *strongly disagree* to *strongly agree.* As shown in Table 27 and Figure 12, most participants agree they have an interdisciplinary worldview that is evident in other aspects of their lives, which has been influenced to a great extent by educational experiences.

Table 27.

Sources and Extent of Interdisciplinary Perspective: Five-Point Likert Scale

	Mean	Standard Deviation	Minimum	Maximum
I consider myself to have an "interdisciplinary worldview."	4.32	.74	2	5
The interdisciplinary perspective I bring to my work in MBE is evident in other areas of my life.	4.2	.78	2	5
Family experiences influenced my interest in an interdisciplinary approach to problems.	3.78	1.15	1	5
Community experiences influenced my interest in an interdisciplinary approach to problems.	3.66	1.14	1	5
Educational experiences influenced my interest in an interdisciplinary approach to problems.	4.38	.72	2	5

Figure 12. Sources and Extent of Interdisciplinary Perspective

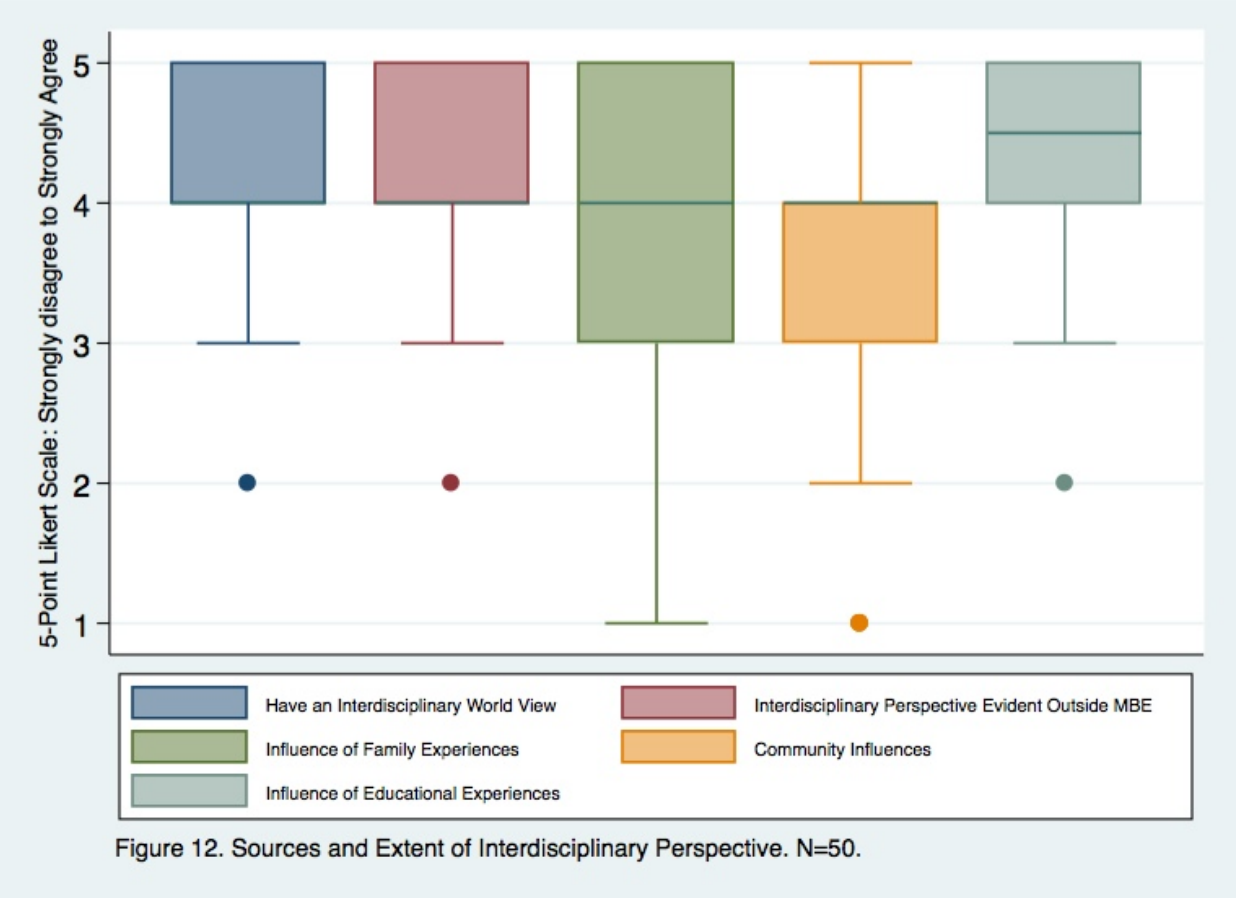


Figure 12. Sources and Extent of Interdisciplinary Perspective. N=50.

Range of Interdisciplinary Activities

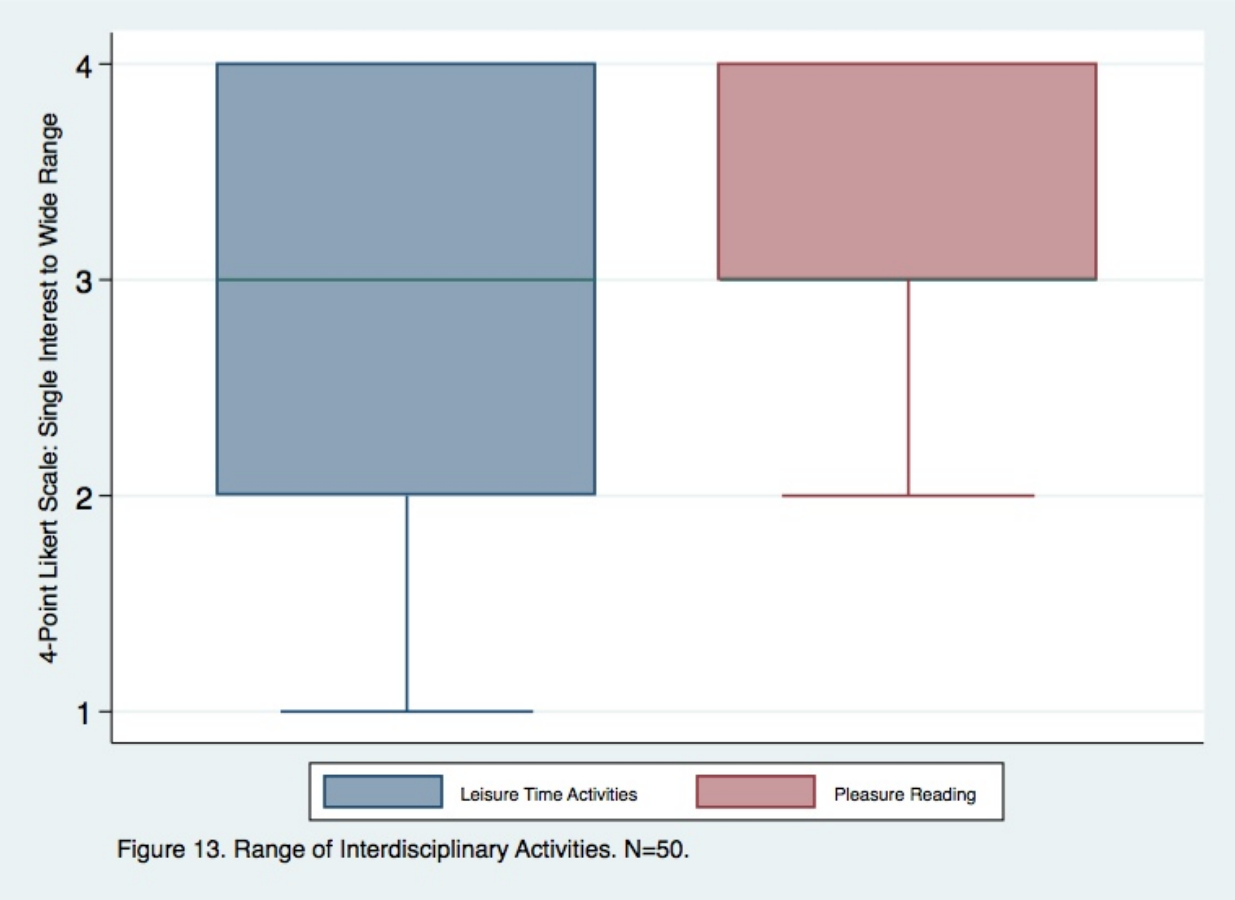
I measured students' perceptions of the range of their interdisciplinary activities outside of their academic work by creating two survey questions using a four-point Likert scale ranging from *single focused interest, a few interests, many interests,* and *a wide range of interests*. The results shown in Table 28 and Figure 13 suggest most students participate in leisure activities and read for pleasure in areas outside their discipline.

Table 28.

Range of Interdisciplinary Activities

	Participants	Mean	Standard Deviation	Minimum	Maximum
Leisure time activities, e.g., music, dance, drama, museums, sports, book clubs, etc.	50	3.02	.89	1	4
Pleasure reading, e.g., newspaper articles, journals, magazines, books, websites, etc.	49	3.26	.81	2	4

Figure 13. Range of Interdisciplinary Activities



Frequency of Interdisciplinary Activities

I measured the frequency of participants' engagement in reading, professional, and social activities outside of their disciplines. The 50 participants rate the frequency of their activity on a four-point Likert scale ranging from *never*, *infrequently*, *occasionally* to *frequently*. The means, standard deviations, and range are depicted in Table 29 and Figure 14. Students participate in interdisciplinary activities and more frequently read and engage in social activities outside of their discipline than they do in professional activities.

Table 29.

Frequency of Current Interdisciplinary Activities: Four-Point Likert Scale

	Mean	Standard Deviation	Minimum	Maximum
Read professional material outside of your primary discipline	3.52	.58	2	4
Participate in professional activities outside of your discipline	2.96	.88	1	4
Engage socially with people whose professional interest is in a different field	3.52	.79	1	4

Figure 14. Frequency of Current Interdisciplinary Activities: Four-Point Likert Scale

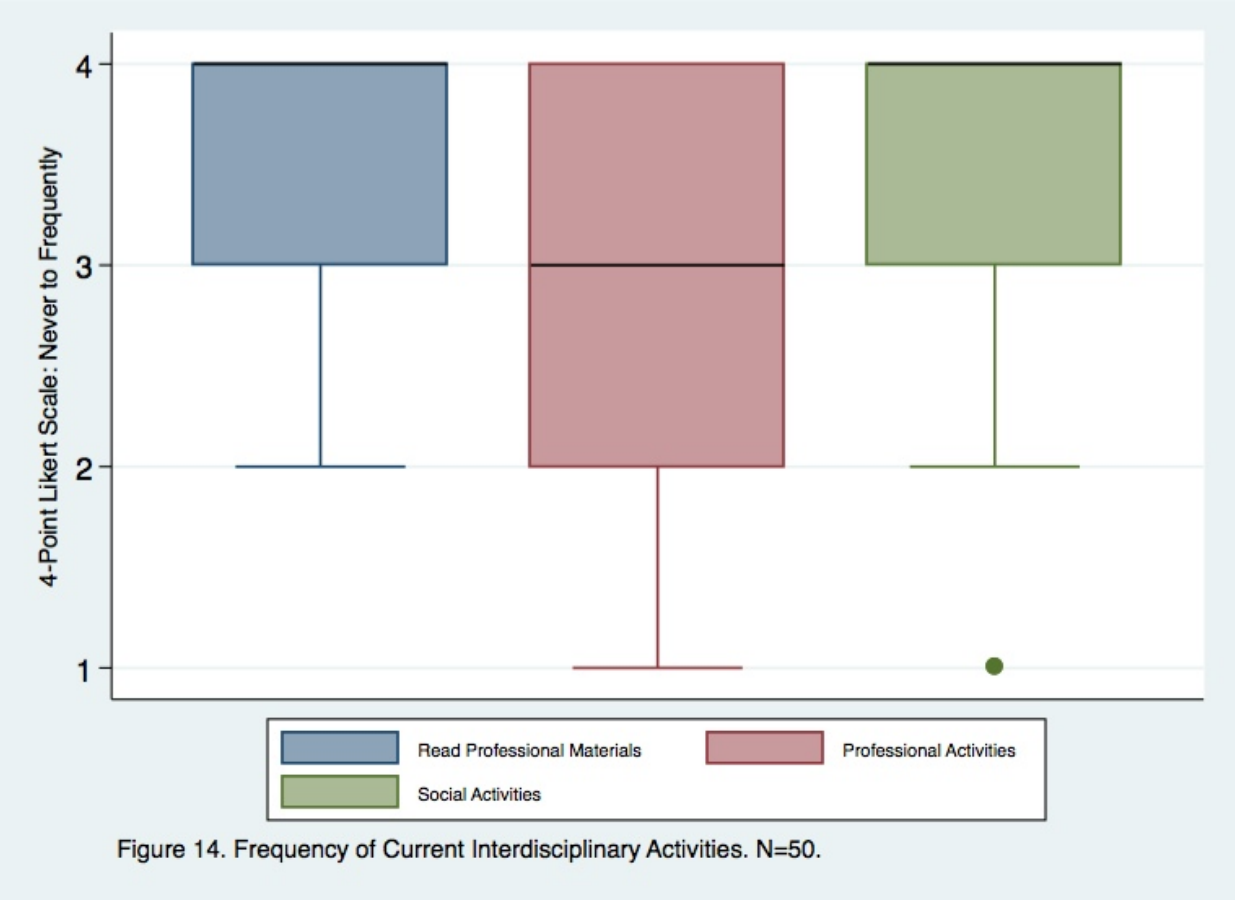


Figure 14. Frequency of Current Interdisciplinary Activities. N=50.

Qualitative Results

I begin the *Qualitative Results* section of this chapter with general information about the participants and the data and a description of the process I used in analyzing the data. I then present the results of coding the data using a grounded theory approach. Seven concepts emerged from the analysis: *tension, uncertainty, time, diversity, risk, power,* and *transformation.* I describe each of these concepts in relation to students' perceptions of the MBE program, the development of their interdisciplinary understanding, the potential of MBE to influence education, and to student characteristics. Finally, I provide a

rich description of the program and relate the data to each of the following research questions:

- Research Question #1: How do students perceive their development as interdisciplinary researchers and practitioners?
- Research Question #2: How do students perceive the potential and limitations of MBE to improve education?
- Research Question #3: How do students' perceptions vary by student characteristics?

Demographics

Student Interview Participants

The MBE program enrolls more female than male students; I was unable to obtain specific information about the ratio of males to females. Of the 27 student interview participants, 59% are current students (16 current students; 12 female, 4 male) and 41% are alumni (11 alumni; 9 female, 2 male). The graduation years of the alumni are depicted in Table 30 and those of the current students in Table 31.

Table 30.

Graduation Years of Alumni Interview Participants

Graduation Year	Interview Participants
2012	0
2011	5
2010	3
2009	1
2008	1
2007	1
TOTAL	11

Table 31.

Graduation years of current student interview participants

Graduation Year	Current Students
2013	10
2012	6
TOTAL	16

Faculty/Administrator Interview Participants

The three interviews with faculty/administrators provided information about the MBE program structure and goals and added a perspective to gain insight into student perceptions. I interviewed three administrators/faculty members who have extensive

contact with students either through the core course, HT-100, or through frequent administrative contact.

Data Analysis

I analyzed qualitative data from the following sources:

- Open-ended questions and comments from the online survey of 2007 – 2012 alumni and current students 2012 and 2013
- Transcripts of interviews with students
  - Alumni in the classes of 2007- 2011
  - Current students in the classes of 2012 and 2013
- Transcripts of interviews with faculty/administration
- HT-100 website and syllabus
- HT-100 course evaluations 2007-2011
- Field notes from observation of an *Admitted Students Open House* (April 1, 2011)
- Field notes from observation of *MBE faculty/student Conversation Luncheon* (November 19, 2012)

I emailed the interview transcripts to all participants to review for accuracy to increase the internal validity of the qualitative data.

Open Coding

Yin (2003) describes the need for a general strategy and analytic technique in high-quality case-study research. I began the analysis process by open coding the data, reviewing the material three times, coding and revising codes each time. In open coding, one "opens up the text" (Strauss & Corbin, 1998, p.102), approaches the data with an open mind to reveal "thoughts, ideas, and meaning therein" (Strauss & Corbin, 1998, p.102), identifies and labels *concepts* and compares them for similarities and differences. I grouped the concepts into *categories*, which I then defined by their *properties*, i.e.,

characteristics, and their *dimensions*, i.e., the range of variation of the general properties of a category. I initially identified many categories, then revised the categories and supported all categories, properties, and dimensions with evidence from the data, confirming that I had at least three pieces of evidence to support my claims.

The process of identifying, comparing, and categorizing is dynamic. I reflected on the meaning during the coding process and recorded notes, in the form of *memos*, to guide my reflection and future thinking. My memos included ideas I had about the categories, my interpretations, the relationship among the categories, alternative ideas, questions to explore and think about, and thoughts about the developing theory. The memos were useful both to clarify my thinking and as a reference as I continued analyzing the data. In coding and writing memos, I based my analysis on the research questions and on the theoretical framework of pragmatic constructionism while at the same time remaining open to emerging theory.

I identified four concepts from Boix Mansilla's (2010) framework (i.e., *purpose, disciplinary insights, integrations,* and *critical stance)* before beginning coding. Additional categories revealed themselves through the open-coding process, which I analyzed using the *grounded theory* approach to further explore students' perception of their experience in an interdisciplinary graduate program.

Grounded Theory

Grounded theory methodology, first described by sociologists Glaser and Strauss in 1967 (Glaser & Strauss, 1967), presents hypotheses about the relationship among concepts and is *grounded* in data and in *real-world* situations. It differs from other theory in that grounded theory is derived from the data, rather than being proposed in advance

and then supported by data (bottom up, or inductive, rather than top down or deductive), and is substantive in that it stems from, and is relevant to, practical situations (Merriam, 1998). Grounded theory is based on both "critical and creative thinking" in that analysis is grounded in the data (i.e., is a rigorous process) and relies on "the ability of the researcher to aptly name categories, ask stimulating questions, make comparisons, and extract an innovative, integrated, realistic scheme from masses of unorganized raw data." (Strauss & Corbin, 1998, p.13). Grounded theory is derived from a *constant comparative* analysis of contextual data and involves discovering and comparing the meaning behind actions and events, identifying concepts, creating categories and their properties and dimensions, and revealing patterns and the relationship among these patterns. Yin (2003) writes that pattern matching "compares an empirically-based pattern with a predicted one…If the patterns coincide, the results can help a case study to strengthen its *internal validity.*" (p. 116). I continued the process until I found it to be *saturated* or *theoretically complete.* Throughout the process I reflected on assumptions I was making and on my own biases and how they affected my interpretation.

Axial Coding

After open coding I began to "reassemble the data" (Strauss & Corbin, 1998, p. 124) to develop an explanation, or story, to describe the phenomena. I began by looking at the relationships among the categories and subcategories and relating them across their properties and dimensions. Through this axial-coding process I developed a more concise model and relate the categories.

Selective Coding

In the final step of my data analysis I began the selective coding process of identifying a core category and telling the story of how the other categories relate to this category, i.e., developing, refining, and integrating the theory. To identify the core category, I took each of the seven final categories *tension, uncertainty, time, diversity, risk, power,* and *transformation* and inserted them into the *core* spot and looked at how it related to each of the others. Through this process, I determined that the core category was *tension*. This category fulfills the criteria outlined by Strauss & Corbin (1998) for a core category, i.e., I can easily relate it to all the other categories, it appears frequently in the data, and it explains both the main findings and the variations on those findings.

Concepts

The seven concepts *tension, uncertainty, time, diversity, risk, power,* and *transformation* emerged from the grounded theory coding process. In the following sections I summarize the evidence for these concepts and then discuss the data relevant to each research question.

Tension

The concept *tension* relates to the incompatibilities, conflicts, and dichotomies students perceive in interdisciplinary learning. The challenge and stimulation of intellectually and emotionally balancing and managing these tensions is evident through the findings related to each of the research questions. The concept tension emerges from all of the data sources. The following sections describe how tension is reflected in the research questions.

Perceptions of the Program

Students perceive tension in how the diversity of the cohort affects their experience. They find the diversity of the cohort is an intellectual, social, and emotional support, and at the same time, presents challenges in collaboration because of differing knowledge, cultures, and perceptions of the individuals. While the cohort is diverse in the skills, knowledge, backgrounds, and goals each member brings, the students in the cohort also share many commonalities, including values, a passion for change, and ways of thinking about problems and solutions that are innovative and outside the traditional structure and system.

Tension is reflected in students' perceptions of the flexibility of the program. They perceive the open, individual curricular pathway and flexible coursework supports their goals and needs and at the same time find it challenges the sense of cohort cohesion that they find critical to their learning.

The length of the program also contributes to tension: an extended, longer program would provide more time for students to gain knowledge, reflect, and synthesize, while a shorter program is less of a financial commitment and requires students to take less time off from paid professional work to study in a graduate program.

Developing Interdisciplinary Understanding

In developing interdisciplinary understanding, students confront a tension between the traditional educational structure and culture, which supports and values the depth of disciplinary learning, and the structure and culture of interdisciplinary work, which supports and values breadth and collaboration. They struggle emotionally and intellectually with the degree to which they need to master the knowledge and methods in

multiple disciplines to collaborate as well as to individually synthesize and draw conclusions. Students' prior experiences, and the broader educational and social systems, reflect a structure that supports disciplinary learning and hierarchies, resulting in distrust, territorialism, and value of individual over collaborative work, which presents a tension between the interdisciplinary perspective of valuing collaborative work and equally valuing all contributions.

Gaining interdisciplinary understanding is both an individual and a social process, requiring skills that may be at opposite ends of a spectrum, for example, to listen and to persuade, to persevere to master existing disciplinary knowledge and to be open to new ideas and knowledge emerging from integration. Students must maintain a degree of certainty about their own synthesis and contribution, and also be open to considering others' ideas and possibly revising their thinking.

Potential of MBE

Students' perceive the tension between the "ivory tower" of academia and the "real world" of practice and struggle with how theoretical MBE might be translated and applied in classrooms. They perceive differences in the goals of researchers and practitioners and in the level of comfort each has with uncertainty; many practitioners are looking for concrete answers and solutions while the culture of researchers is more cautious and measured. Students find they must balance the tension between clear, timely communication with collaborators and avoiding the pitfalls of reducing disciplinary knowledge too extensively.

Similarly, the tension between the current educational and social landscapes and the ideas and ways of working in interdisciplinary MBE is evident to students. The culture

values the *right answer* and quick solutions to problems, while MBE suggests multiple answers and a slow process of change. Students perceive the potential for change with MBE will involve systemic change in teacher education, school structures, and social values, while they perceive the current system to be entrenched and resistant to change with cultures and structures reflecting values of individual work over collaboration and static knowledge over revisable knowledge.

Tensions exist within the field of education, as well; some educators believe science will make an important contribution to educators and others believe the difference in the level of analysis is too great to be useful.

Students' optimism and excitement about the potential of MBE is juxtaposed with caution and concern about the time needed to make change and the urgent need for change. Similarly, students' caution and desire for responsible actions conflicts with misinterpretation, misapplication, and sensationalizing by individuals and commercial organizations.

Student Characteristics

Interdisciplinary learning is emotionally and intellectually demanding; students experience a wide range of intellection and emotional tensions in the process. Students are excited and frustrated, stimulated and intimidated, appropriately challenged and overwhelmed, passionate and responsible, optimistic and cautious, comfortable and scared, engaged and frustrated. They must be flexible and perseverative, analytic and imaginative, reflective and collaborative, linear and divergent.

Uncertainty

Managing the tensions, conflicts, and incompatibilities in interdisciplinary work requires a wide range of emotional and intellectual skill. Among the skills needed is the ability to self-regulate and manage the *uncertainty* involved in the process. *Uncertainty* emerged as a theme within many of the research questions, as detailed below.

Perceptions of the Program

The individualized pathway and flexible curriculum represent the concept of *uncertainty*. Students choose their own courses rather than having a set curriculum and they also can choose co-curricular activities such as internships, which creates an uncertain path during the program. Students also face an uncertain career path at the end of the program. They begin the program with a question or purpose to address a social problem; they do not have a traditional, established career path to address that question.

Developing Interdisciplinary Understanding

Uncertainty is inherent in the process of developing interdisciplinary understanding. Boix Mansilla's (2010) model is dynamic and necessarily involves uncertainty as students continually reframe their purpose, gain and weigh disciplinary insights, integrate, reflect, and revise. Rather than one right answer, synthesis may result in multiple solutions, with no clear best solution or application.

Students experience uncertainty when engaging in the process of collaboration. What skills and goals do their collaborators bring to the process? Have they, and the others, accurately and appropriately shared their knowledge? Do have adequate time to collaborate, synthesize, and reflect? Do they have a *voice at the table?* Are their contributions valued?

Potential of MBE

The field of MBE is a new field and as such is being shaped and defined by the students. Their work is entrepreneurial, with all the uncertainty associated with innovative ventures, involving uncertainty such as: Will there be a financially rewarding career in the field? Will the culture be accepting of and value the ideas students bring forward? Will students' ideas be useful and effective in addressing the questions and issues they hope to address? Will the field grow and offer a community of colleagues for future endeavors? Will the ideas be thoughtfully and ethically interpreted and applied?

Time

The amount of time and the pressures of time emerge in coding the qualitative data.

Perceptions of the Program

Students report feeling that the length of program is too short to feel fully prepared for interdisciplinary collaboration; on the other hand, they also suggest that if it were longer, the time required would be a barrier for many and prevent them from enrolling in the program. They find that developing relationships with cohort members and faculty takes time, which can be influenced by the time commitments needed to manage the workload, the length of the program, and the timing of the core course.

Developing Interdisciplinary Understanding

Students perceive that the individual and social processes involved in gaining interdisciplinary understanding take time – time to gain knowledge in multiple disciplines, time to synthesize, and time to reflect and be critical. As a social process, collaboration

requires time to listen and understand all perspectives as well as time to scaffold one another in disciplinary learning.

Potential of MBE

Time relates to students' perception of the potential of MBE in the time they anticipate it will take to effect meaningful change in organizational and cultural perceptions and structures.

Student Characteristics

Students suggest the time they have spent in their lives participating in diverse interests and activities and considering multiple perspectives influences their affinity for interdisciplinary work. The ability to effectively manage time is a necessary skill in the MBE program.

Diversity

Perceptions of the Program

The concept of diversity relates to the diversity of the knowledge and experiences of the cohort as a group; of each individual student's knowledge and experiences; of the curricular and co-curricular offerings and pathways within the program; and, of the goals and purposes of individual students. The outcomes of students' experience in the program vary, with students demonstrating different levels of understanding and satisfaction.

Developing Interdisciplinary Understanding

Students find the diversity of the cohort is critical to both disciplinary learning and integration. They perceive that they need diverse skills and knowledge to develop interdisciplinary understanding and they recognize the various purposes students bring to their study. They find a wide range of methods, knowledge bases, and perspectives of the

multiple disciplines involved in MBE. They recognize the wide range of questions addressed by interdisciplinary work and the many solutions arising from synthesis.

Potential of MBE

The concept of diversity relates to students' perception of the potential of MBE to influence educational practice and policy as the methods and perspectives of multiple disciplines reflect a range of levels of analysis. Students consider if, and how, knowledge from the microscopic level of neuroscience can be usefully integrated with the individual and group behavioral level of education. Similarly, the contexts of the disciplinary knowledge vary – from the lab of the neuroscientist to the school of the educator.

Diversity emerges as a concept in students' perception of the variety of resources they are able to access once they graduate from the program and seek to make change. The diversity of the cohort members, as well as the faculty, offers students connections in their efforts outside of the MBE program.

Student Characteristics

In relation to student characteristics, diversity is represented in the range of interests and activities students experienced during their lifetime. They find these experiences influence their interest in interdisciplinary work.

Risk

Perceptions of the Program

Students perceive risk in their experiences in the program from the beginning, embarking on a program of study in a developing field with no clear path to professional career options. They perceive risk in the choices they make in planning their coursework to prepare them to address the questions they bring to their study.

Developing Interdisciplinary Understanding

In the process of developing interdisciplinary understanding, risk emerges in relation to students' status within a collaborative group and in the processes of integrating disciplinary knowledge with limited mastery of the disciplines. Students perceive they are vulnerable and may be viewed by others as inadequately prepared, have little credibility, and are of a lower status when they work collaboratively because of a lack of depth of knowledge. The risk of making erroneous connections, drawing inappropriate conclusions and making invalid assumptions concerns students in the individual cognitive processes of developing interdisciplinary understanding.

Potential of MBE

Creating new and entrepreneurial solutions to societal issues involves risk from individual students' and the program's perspectives in regard to students misinterpreting and misapplying knowledge. The risk that commercial ventures and the media may sensationalize and misinterpret findings concerns students. Individually, students take a risk to seek solutions outside of the established culture.

The concept of risk is also evident in the risk to the fields of education and neuroscience, as well as to the students. The field of neuroscience is rapidly growing - neuroscientists are creating databases built from multiple studies and neuroscience is currently portrayed by the media, and perceived by the public, to have the potential to offer causal explanations for a wide variety of human behaviors. As the field continually evolves and compiles data from multiple studies, it may be that initial theories and the findings from limited studies associated with learning and development are found to be invalid, putting the field at risk for reduced prestige and relevance.

The field of education faces similar risk as research-based databases develop, as there is risk to the field in interpreting, synthesizing, and applying findings from a field that is undergoing rapid change. The field is also exposed to risk, as there is the potential for the accumulating evidence to reveal limitations or errors in current practices and policies, further reducing confidence and status of the field of education. Sally (alumna) implies the potential risk for the field of education in maintaining the status quo in face of findings that contradict current practices: "You can't *not* know what you know. And once you know what happens to brains, and you are aware of what is needed to change people's lives, and you've read the research, [there is an obligation to make change]."

Student Characteristics

The ability to tolerate risk and work outside their comfort zone is a characteristic that supports students in the process of gaining interdisciplinary understanding.

Power

Perceptions of the Program

The concept of power is reflected in students' perception that the knowledge, skills, connections, and confidence they gain in the program empowers them personally and professionally. They perceive power imbalances within the institution and in collaborative groups in disciplinary hierarchies, privileges and territorialism and in the relationship and privileging of research over practice.

Developing Interdisciplinary Understanding

Power surfaces in relation to students' purpose in interdisciplinary MBE study. They perceive an imbalance of power in the educational system with some learners unable

to access equal opportunities. Disciplinary hierarchies and territorialism arise in weighing disciplinary insights and in the social processes involved in synthesis.

Potential of MBE

The field of MBE has the power to create significant change in educational practice and policy; at the same time, that power must be carefully and ethically applied. Interdisciplinary study offers the power to create something greater than any one discipline can do alone. Education as a field has the power to positively affect the lives of individuals and in the larger society. Educator preparation programs have the power to support change by altering teachers' self-perception and providing the skills and knowledge to collaborate. The imbalance of power is reflected in the relationship between educators and scientists and between educators and policy makers. The responsibility of communicating and using the knowledge gained in the MBE program represents power.

Student Characteristics

Students find their prior experiences are powerful and influence their interest in interdisciplinary study and activities.

Transformation

Perceptions of the Program

Students reported that the program transformed them personally. Their world is transformed when they find the program and feel it is what they have been seeking. The relationships they develop with cohort members transform their thinking, as do the coursework, the connections they develop with faculty members, and their participation in lab/research experiences. They think more critically, read material that may not have previously, and consider new issues.

Developing Interdisciplinary Understanding

Interdisciplinary work inherently involves transformation, as one creates new understanding and continually revises. Students perceive the process to be stimulating and challenging.

Potential of MBE

The concept of transformation arises in considering student perceptions of the potential of MBE to influence education as related to the need for innovative solutions and the magnitude of the change that is needed. MBE's potential is dependent on changing both educators' perceptions of themselves and society's perception of educators in terms of their status and their responsibility as collaborative researchers and must also involve changing school structures and educator preparation programs to support teachers in new roles.

Student Characteristics

During the course of the program students change from identifying with a discipline, such as psychology or education, and identify as having an *interdisciplinary* affiliation. At the same time, students find their interdisciplinary perspective has been evident for most of their lives.

Grounded Theory Summary

The theory may be summarized as: *Under the pressure of time and amidst diversity and shifting influences of power, students experience risk and uncertainty as they struggle with the tensions inherent in interdisciplinary study in MBE; through the process they perceive that they are personally transformed and inspired to participate in collaborative efforts to transform educational practice and policy*.

The following sections detail the results of the qualitative data analysis.

Perceptions of the MBE Program

This section offers a rich description of students' general perceptions of the MBE program and includes subsections titled *Prospective Students, Current Student Cohort, Social Climate, Curriculum and Co-Curriculum, Learning Outcomes, and Careers and Employment*.

Prospective Students

> I'm always amazed by the passion that this program attracts. The MBE [students] are so passionate and so emotional. This is a program that they've been looking for their whole lives, their eyes well up when they start talking about it because they feel like they've been in environments where they've tried to stress the importance of taking neuroscience and biology into account when you're working with people and they don't feel like they are very supported in their environments. So when they come here they feel like they've found their home and they've found their people and found people who want to talk about these things. (Lynn, faculty/administrator)

In searching for graduate programs many students immediately, and enthusiastically, recognize the MBE program as matching their interest in pursuing interdisciplinary work as a way to address a complex problem or question they have identified from prior experiences. Sally's (alumna) reaction to finding the MBE program, "This has my name written all over it!" is common to many of the participants. Many students enroll in the program having independently read interdisciplinary material in mind, brain, and education and enter the program highly motivated with a passion for applying their learning to practical problems and a desire to effect change related to social justice or equity. They express pivotal events, which fuel their passion and desire to change the current system. Examples of such events include having a child who was misdiagnosed with a learning disability; a personal difficulty in their own education; a

premature sibling who struggled with school; and, experiences teaching in which they felt they were unsuccessful in providing all students with appropriate educational experiences.

Current Student Cohort

> [When] I got here I knew this was the right place to be, just the people, that's what made [me] feel it was a fit. (Carl, current student)

The student body includes individuals from a variety of countries, and of a range of ages, who arrive with diverse experiences and education, often having pursued double or triple majors in diverse disciplines during their undergraduate education and having worked in a range of settings and fields. The program enrolls a student cohort with a variety of interests and goals. Jon (faculty/administrator) describes this diversity:

> [The cohort] is very international, usually we have at least three or four continents represented…plus multiple languages and cultures. It's diverse in that people have very different goals, most years we have two or three medical students who are doing the degree, we usually have several people from the business world like bankers, and we always have a bunch of teachers, and they range all the way from a kindergarten teacher focusing on art to a high school math teacher – a very wide range of kinds of teachers. We usually end up with maybe 40% teachers, 40% students who think they want to go for further study after the master's degree, and 20% people who are business people or medical students.

Students share commonalities, as well as differences. They find a sense of intellectual compatibility and shared interest in problem-focused work. Participants describe the intelligence, passion, and like-mindedness of the students, and appreciate their passion and purposeful dedication. As Krissy (current student) says, the students are "so excited and engaged and wanting to make things happen." Lynn, (faculty/administrator) describes the characteristics of MBE students saying:

> I think that the strength of the program is that you've really gathered these very passionate, very smart people who have been thinking about these things for a long

time and have done a lot of reading on their own and finally have a place where they can have productive conversations about it with like-minded people.

The primary structure supporting the cohesion of the cohort is the core course, HT-100. The students and administration also plan social events, such as a boat cruise and field trips, guest speakers and events, happy hours and potlucks, and Facebook connections, as cohort community-building structures (M. Kiesling, personal communication, April 19, 2014). The program coordinator also plays a significant role in the cohort through her personal connections and email communications (J. Thomson, personal communication, April 12, 2014). The faculty/administration planned a new initiative for the 2012-2013 academic-year and offered *Faculty/Student Conversation Luncheons*, which met approximately three times each semester. The purpose of the luncheons is to provide an informal forum for students interact with faculty about the field of MBE and also serves the purpose of connecting students within the cohort during the year HT-100 was offered in the spring, rather than the fall. (J.Thomson, personal communication, September 16, 2013).

Social Climate

The cohort provides a supportive social network for the majority of students, which they perceive to be a primary strength of the program. A survey respondent comments: "My cohort was amazing. For me it was far and away the best part of the experience. Many remain close friends to this day, while others form an amazing professional network." Emily (alumna) describes how relationships with her cohort colleagues bridges her academic and social lives: "My engagement with my peers and being able to talk with them, discuss with them, read with them and continue the

relationships outside of school - I think that's something that has been invaluable." Marcy (alumna) notes the importance of her relationships after graduating from the program:

> I think what almost is more valuable [than the courses] are the friendships and professional relationships I made with people who are teachers or school psychologists and engaging in dialogue with them. I do keep in contact with them still and getting their perspective on various issues is almost more informative.

One survey respondent reports finding the cohort less inclusive of all perspectives, saying: "I actually have a lot to offer in this area, but was never given the chance to share with my cohort." Students also describe challenges to integrating into the community of the cohort. As Molly (current student) says, "to create a community in a one-year program is pretty much impossible." Challenges include the academic workload and individual circumstances, such as personal responsibilities (e.g., family, part-time jobs), and geographic location when commuting to the program.

Curriculum and Co-Curriculum

> I thoroughly enjoyed my intellectual interactions within the program, in classes and study groups, as well as outside the program in research labs, lectures and other events in the greater HGSE/Harvard community. I felt respected and acknowledged by my professors and classmates in class discussions, and I enjoyed receiving feedback on my work from TFs and professors. (Survey Respondent)

Coursework, Faculty, and Administration

The faculty/administration participants describe the program as an open pathway, with flexibility and opportunities for students to take courses and plan experiences that meet their diverse individual needs and goals. Students perceive both the challenge and the benefit to the varied courses they complete to fulfill the master's degree requirements: "I think the flexibility is really helpful because we are so different we're able to do what is interesting for us." (Elizabeth, current student) and at the same time students raise the question of whether there is a "safety net for those who may struggle with making

choices" (Raquel, current student). In general, students find that the courses work well together, make sense as a whole and feel positively about many different courses individually.

The flexibility affects the opportunities for students to interact as a cohort. Gary (current student) says:

> We only have a single prescribed class that we have to take in this program and then the rest is 'choose two out of this list, choose three out of that list,' that sort of thing. Only one of our foundational courses is being offered this semester so at this moment very few of us have any classes together besides maybe Todd Rose's Educational Neuroscience class.

Students perceive a tension between pathways leading to careers in research and those leading to teaching. Some students find the program is biased towards the research pathway. As Sarah (current student) reports:

> There is a divide, like if you want to stay in academia and do research you have to kind of then decide that you are going to maybe take statistics classes or enroll in psych courses, and if you decide that you want to be more of a practitioner, you are going to maybe take more classes about trauma, developmental disorders, teaching. [The divide] is just reflecting the fact that the real world still works in a really kind of specialized way and it's hard to say, 'I am going to be a teacher and publish neuroscience research.' I don't think most people are able to do that.

A number of students describe the program as emphasizing theory and research over practice and find it challenging to consider how they will translate the research to practice. As Karin (current student) says, "my goal was to get a more broad background from the three perspectives [research, policy, practice] of the science of how we develop and learn but feel like it's been pretty limited to the researcher perspective."

Students perceive they need more examples, modeling, and opportunities for discussion to begin translating research to practice. As Elizabeth (current student) says, "What I haven't found here is how to translate the research and the findings to practical

application…A lot of the translation piece is put on us as the students and I would have liked a little more guidance as far as…classroom practices. Bella (current student) suggests "some class that shows you practical applications of MBE, and how did that turn out - why it did work, why it didn't." Carl (current student) suggests "models of teachers who came through MBE and then made a change in their schools." Other students propose structures they believe would be helpful. Lori (alumna) suggests that connections among the assignments in different courses and to the "realities of educational experiences" would facilitate synthesize and an understanding of the practical applications of their study. Karin (current student) notes that such connections are critical in a developing field and should be "built in as part of the [MBE] program." She suggests the program include "a seminar that has the whole group coming together to figure out how they're going to use what they've learned to inform practice and policy when they leave."

Several students recommend that such engagement continue after graduation. Molly (current student) describes students' initiatives in using technology to support an ongoing community, saying, "it's really cool to start to develop a community, and there are efforts to try to keep something going online." Lori (alumna) echoes Molly's perspective and seeks "ways to continue the conversation and stay in touch professionally, think about what each of us is doing, or would like to do, or have a debate about x, y, or z that comes up in the media or current events."

Students struggle with a tension between depth and breadth in their coursework. A survey participant writes: "[The] main challenge in an interdisciplinary approach is going to always be a width-versus-depth problem and making sure the connections you're making across sectors aren't just superficial." Sally (alumna) echoes the sentiment in

saying, "I found a lot of the course work at times frustrating because I had to be superficial to get a lot of information packed in." Students describe the curriculum as "challenging, " "rigorous," and "overwhelming." They use a variety of metaphors to describe their experiences in the MBE program. Lori (alumna) says, " I remember being very excited about feeling like my brain was on fire all the time, trying to think of all of this at once…just trying to think of all these different spinning wheels all at once." Rita (alumna) notes "the common phrase that was used while I was there was *drinking out of a fire hydrant* – we had this big onslaught of information pouring in from all sides." A minority of students find the coursework less satisfactory and less challenging. Lisa (current student) says, "During a lot of the courses it feels like neuro trivia and I don't think that's the most valuable use of people's time if this is going to be their only exposure to neuroscience before they go back to education."

Students describe experiencing a wide range of strong emotions during the program, such as "awesome", "exciting," "overwhelming," "frustrating," "thrilling," "intimidating," and "scary," and attribute these emotions to the workload, the intellectual stimulation, the process of learning new vocabulary, concepts and integrating and applying their knowledge, and the uncertainty of their plans for the future.

The faculty and administration value and facilitate students sharing their knowledge, dialoguing, and getting to know one another to support them in their academic work. Structures for supporting interactions among members of the cohort are formal and informal, virtual and actual, social and academic, and initiated by students and by the program. Participants talk about a variety of ways in which they connect, including study groups, project work, social events, online networks, and meetings. The physical space of

HGSE offers opportunities for interaction and collaboration, as it is limited to a few buildings, which are within close proximity to one another and includes spaces for students to gather formally and informally.

Students perceive the faculty, teaching fellows, and program coordinator as important aspects of the program in providing academic and personal support. They refer to a dozen faculty/administrators individually by name, using descriptors such as "awesome" and "incredible." Students identify the faculty as accessible and supportive, appreciate that they model MBE, and recognize them as a life-long resource. Carl (current student) finds "the access to the people here is unparalleled – it's really, really, excellent and everybody I've met is super willing to help you out and meet with you and speak with you." Students value the opportunities they have to be mentored and work directly with faculty members. Rita (alumna) says, " I think collaborating with those people was an incredibly valuable experience." Sally (alumna) describes the access to prominent people in the field, saying: "It's like you are in the operating theater and you are going right into the heart of things."

The program coordinator is a main point of contact for students, from the time of application through graduation, and plays a critical, and appreciated, role in their experience in the MBE program. The program coordinator communicates policies, provides emotional support, shares information and resources on courses and career-related opportunities, and facilitates cohort cohesion. Students refer to the multiple roles of the program coordinator and perceive the coordinator supports them socially, academically, and in planning for their future; Lois (current student) says "she is just incredible."

The interviews and open-ended questions on the survey suggest that a minority of students do not feel supported by the faculty, believe they were not known to faculty who were central to the program, and experienced courses that did not meet their needs or expectations. Marcy (alumna) says: "being a one-year program, [faculty] don't really get to know [their] students and…you don't really develop like a supervisor relationship. So I think [the relationship with faculty] is lacking compared to a research master's program, for example."

Students express a range of strong reactions, positive and negative, to the course and describe HT-100 as "overwhelming" and "inspiring." They note the extensive workload and challenge of the course, remarking "Oy vey," "Uggh," and "slogged through it," and also recognize the course as "critical" and "amazing." Rita (alumna) says:

> I think the best part of [HT-100] for me was honestly the cohort of people and the academic fervor, which a lot of the people there had, so I could have long debates and conversations and in-depth analyses of any number of different things and I honestly think that's what I learned most from.

The core course serves a variety of functions for students, including developing relationships that supported their learning. Susan (alumna) says:

> I do think [the year-long HT-100 course] was hugely valuable because by second semester we knew each other and we knew what sorts of things people were likely to say and you could go to class with this idea, 'Oh, I bet so-and-so would have an interesting perspective on this' or 'Oh, I would really love to hear so-and-so's perspective because she worked in this field.

Emily (alumna) echoes the importance of interaction within the core course, as she says, "I was really impressed with the delving into questions of child development or questions of practice and actually working with my peers, through these difficult questions, and growing our knowledge base together."

In contrast, taking HT-100 as a second semester course had a negative impact on some students' sense of cohesion. Lois (current student) describes the effect of taking HT-100 in the second semester: "The required course isn't until the spring and so I'm feeling a little disconnected from my cohort. I've met a lot of people…but there is not a Mind, Brain, and Education cohort."

Students' perceptions of the core course reveal the role the course plays in their consideration of the pragmatic applications of their interdisciplinary work. Some students find the exchange among diverse cohort members valuable in considering practical application. Lori (alumna) says, "you would hear these really cool ideas from the science-background people. 'Oh, yeah, wouldn't it be cool, why don't we do this in education.' They might just have a kind of skewed view of what was developmentally appropriate at different ages." Others question whether the course supports students in applying their knowledge to practice. As an alumni survey respondent writes, "At the time of my attendance, several peers had a similar frustration with the core course, which is why I'm only slightly optimistic about the field's potential. One would imagine the core course to be the place to inspire and equip students to help MBE inform the field of education. I don't recall any MBE student citing HT-100 as their favorite or most influential course at HGSE. I think one of the biggest frustrations, or disappointments, was the how removed the field still seemed from education. It's an interdisciplinary cohort but many students were educators in some respect and I think they probably had the most difficulty with the course. It was difficult to find relevance and applicability in a lot of the content."

The findings of this study suggest students' perceptions of the core course vary widely. Comments on course evaluations in response to a question asking what advice

they would give to students considering the course range from “Do NOT take this course unless it is required” to “It is a course that will challenge you and expand your thinking.” While some students report the course has little value, as the survey respondent who says, “SOOO happy I didn't have to take that class for a year. Such a waste of time,” others find their participation in the course results in changes in their skills, knowledge, and ways of thinking. Many students find the guest lectures, readings, and assignments effective and appreciate the depth and breadth of the knowledge of the faculty. Students suggest a variety of ways to increase the effectiveness of the course, e.g., more support in filling gaps in their knowledge with foundational material and scaffolding in understanding the readings; more explicit connections between the readings and the lectures; a more explicit framework with connections made among the disciplines; more small group discussions; and, a smaller class size. Lisa (current student) suggests the course might improve the way it “meet[s] the individual needs of students who need additional training and tools to independently synthesize.” Steven (current student) notes, “I would have done much better if I had had an introductory preparation such as a general introductory course to psychology. In the first semester I had to deal with quite a few ideas and concepts and technical terms that I was not familiar with, so I even lacked the language to either understand the problem or to express myself properly and I had to acquire that, [which] delayed my progress.”

Some students perceive the style of lectures contradicts the philosophy of MBE. (Sarah, current student) says, “It’s a very one-way transmission of information from the professor in the lecture” and Emily (alumna) says, “It felt like the delivery model was still

very traditional…I thought, 'Wow there are so many ways that we were talking about innovation and yet I didn't see innovation in the actual mode of instruction at the school.'"

Research/Lab Experience

> I think one of the most important pieces for me was that I did internships both semesters so I really stayed in practice and in the field…I think it brings greater depth to the program because you're being asked to take all these theories that you're learning about and apply them and reflect on them in a practical way. Some of my greatest insights this year have come from being asked to do written reflections on my internship experiences. (Missy, current student)

Harvard University and the city of Boston offer many opportunities for students to engage in an internship or lab experience. Students are encouraged, but not required, to seek a placement. Examples of students' research/lab placements include both interdisciplinary and disciplinary experiences. Students participated in studies using imaging techniques such as EEC and *f*MRI to investigate language development, the effects of reading and math interventions, and correlates of socioeconomic disparities, among others. Students also participated in technology-based communications and interventions, data analysis, and many other experiences in lab and research sites that include educational institutions, private companies, local hospitals, local universities, other schools and departments within Harvard, and centers affiliated with HGSE.

Many students discuss the importance of their lab experience, in particular when it is connected to their academic coursework. Gary (current student) says of his research experience "there is just no way to quantify that value." Students especially appreciate the connection to individual faculty members. A survey participant writes of seeing a positive model of interdisciplinary collaboration in his/her lab experience: "Here I saw people actually using their different expertises to work together and create something greater than what any one person could have produced alone." Students may expand their

resources and experiences beyond HGSE by planning lab/research placements in the broader university and community, which supports students with diverse interests and goals. Marcy (alumna) says, "I think I benefited the most from the connections I made through the labs outside of the Education School because of my career goals."

Several students said they would have appreciated more support in planning a lab experience – they found placements not always satisfying or easy to arrange and perceive the experience adds value to the program. Some describe their lab or research experiences, saying, "it wasn't a good match" and "[it is] not easy to get [a lab/research experience]," and "[it should] be an integral part of the program."

Broader Community

Students perceive their experience within the MBE program as inseparable from the larger context of the university and culture. Harvard University and the Boston area offer a wide range of co-curricular activities for students. Emily (alumna) notes, "…just immersed in such an academic culture of Harvard and being exposed to so many different opportunities, so many people and minds – going to lectures, being able to visit an *f*MRI imaging lab – those types of things energized me intellectually."

Learning Outcomes

> I think I felt a little helpless before I came here – just kind of stuck in the system and I'm just a teacher. Now I feel empowered. (Elizabeth, current student)

The individual courses and interactions with the faculty members in the HGSE were life-changing for many students. Elizabeth (current student) describes one course, saying, "it totally changed my world." Sally (alumna) describes the program as "changing her life dramatically" and her coursework, in which she "thought about issues and read papers that have shaped [her] thinking tremendously." Students feel personally transformed and

empowered. They attribute their empowerment to having access to resources - personal internal knowledge and confidence as well as external networks.

Students find that interdisciplinary study improves their ability to be a critical thinker and that critical thinking continues after graduation. Melissa (alumna) says, "The best thing that I got out of MBE is knowing how to be a really smart consumer of a lot of different kinds of information – a smart consumer and a smart and responsible steward of certain kinds of information from each of those disciplines." (alumna) Rita says, "The thing I take away from [the program] more than anything is…critical analysis of the research."

Some students express dissatisfaction with the how the program serves their purpose and with their learning. Karin, a current student who, at the time of the study, was working while she was enrolled in the program, says, "I don't know how much I've synthesized what I've learned here and I don't know how much I've actually applied what I've learned here to my job, which was my main purpose [in enrolling in the program]." Krissy (current student) says, "I don't think the program's made much of a change [in my interdisciplinary perspective]. Bella (current student) says, "I'm uncomfortable with the fact that I'm getting a master's that has the word brain in it, because I feel like if someone wants to ask me something about the brain I really don't think I'm qualified nor could I answer anything about it." Mark (current student) describes the MBE program as an introduction, saying, "it's not enough in and of itself – I don't think I'm going to be a master of much when I'm done with this program."

Program Length

Nearly every participant refers to the tension between having the one-year length of the program, the commitment of more time and money involved in a longer program, and the need for time to gain a deep understanding, to reflect, and to synthesize. Gary (current student) describes,

> I think it's real challenging to put everything in one year – It's beyond that – it's insane to put everything in one year. And maybe that's just the reality of it. That one-year aspect. It's real appealing from the sake of going without any income for a year and only paying one year of tuition, especially at Harvard tuition levels. So those are big draws, but I have to say, and I know in my conversations with a lot of my classmates, they are very glad they're not paying two years worth of tuition, but the idea that we're fitting all this in one year and the idea that we are trying to synthesize it well enough in that year is really difficult.

Susan (alumna) also notes the tension between the cognitive demands and the financial demands of the one-year program, saying:

> It was tough that it was only one year because I felt like so much was thrown at me and I didn't necessarily have time to reflect and process. It's interesting that I now think one of the greatest weaknesses of the program was that it's only one year but as I was applying to it that was one of the greatest strengths, [thinking] 'Oh, I only have to take out loans for one year.'

Among the most consistent findings is students' perception that they need more time to understand deeply, reflect and synthesize. Sally (alumna) says: "I wished it had been another two years…it seemed like so much information to assimilate so quickly." Steven (current student) refers to the impact of the length of the program on the depth of his understanding in saying, "It was very, very short with lots of pressure to learn things and this boiled down to memorizing things rather than really understanding them."

Careers and Employment

Students describe a broad array of ideas for what they hope to do and the change they hope to effect after completing the MBE program. Examples of their ambitions

include returning to teaching positions, continuing on for further graduate study, and returning to their home country to open new schools or other entrepreneurial innovations. A faculty/administrator respondent acknowledges "there is a subset of these students who are doing things that no has ever done before." Their plans include international efforts, as students talked about implementing change in many countries, including Canada, Brazil, India, Chile, and South Africa.

Students refer to the challenge of transitioning from the academic context and applying MBE in practice outside of the program. They offer metaphors describing the tension between their world within the program and the world outside academia. Lillian (current student) notes, "We're a little bit too much in [an] *Ivory Tower* – saying what good teaching looks like, but that's when we have [many] resources. Sometimes I [question] 'How is this going to work for my kids?'" Some students find uncertainty about careers and the practical application of their learning to be frustrating. Sally (alumna) notes:

> I saw frustration from some people, bordering on anger, because they didn't feel enough attention was paid to how they were going to use this degree. They are putting in an investment here of time and money and they want to see 'what's the payoff' – and who could blame them for that?

Students understand that the program is an open pathway and is designed to serve individual purposes and at the same time some students question whether the program provides the training necessary for a practical application. Karin (current student) says, "I don't know if they are really giving people the tools to figure out, 'OK, once I leave here how do I really integrate that science into what I'm doing?"

Research Question #1 Students' Perceptions of Their Development as Interdisciplinary Practitioners and Researchers

The MBE interdisciplinary program comprises coursework in cognitive science, neuroscience, and education, and enrolls students with a variety of educational backgrounds; no two students enter the program with the same disciplinary knowledge or the same outcomes intentions. Some aspect of the coursework is new material for each student and the students will integrate that new material into their existing knowledge base, along with material from courses in their own discipline, to create a new interdisciplinary understanding. Boix Mansilla's (2010) suggests that interdisciplinary understanding involves "constructing a system of thought in reflective equilibrium," and comprises four cognitive processes: *establishing purpose*, *weighing disciplinary insights*, *building leveraging integrations*, and *maintaining a critical stance*. In coding and analyzing the qualitative data, I used these four concepts as categories to reveal student perceptions about their development as interdisciplinary researchers and practitioners, seeking to answer the following questions:

- *Establishing purpose*: Why are students in the program? What does interdisciplinary study offer that strict disciplinary study does not?
- *Weighing disciplinary insights*: How do students perceive the process of gaining disciplinary knowledge?
- *Building leveraging integrations*: How do students perceive the process of integrating existing knowledge with new knowledge for deeper understanding? What personal characteristics and programmatic features support their synthesis?
- *Maintaining a critical stance*: How do students manage the intellectual and emotional tensions inherent in revisable knowledge and continual reflection? How do they perceive of themselves as critical thinkers?

Establishing Purpose

Why do students choose to enter a program of interdisciplinary study rather than focus more deeply on one subject? To answer this question, I investigated students' perception of the purpose of the interdisciplinary MBE program and their individual purposes for pursuing interdisciplinary study. Boix-Mansilla (2010) writes that interdisciplinary understanding involves "setting a purpose to guide the learning process" and "reframing that purpose in light of new understandings" (Boix Mansilla, 2010, p. 299). Boix Mansilla (2010) notes "interdisciplinary learners integrate information…to…solve problems." (p. 289). Jon (faculty/administrator) describes the admission process as seeking students who have identified a problem and purpose for interdisciplinary work. In selecting students, he describes individual purpose: "Our primary [admission] criterion is: Is this person asking interesting questions where we could actually help them, through the program, address those questions?"

Students describe the purpose of the program as individual and practical. Mark (current student) says of the purpose: "It depends on who you are…every person comes to it with a different idea of what it is." Missy (current student) says, " It's meant to really address what each student wants to get out of it, which I think is a really important concept." Lillian (current student) notes that the practical application is built upon a broad framework, which serves the individual, diverse purposes:

> It's not about saying 'This is going to be your job.' It's about giving you a set of tools and a framework to look at things - like pulling from a lot of disciplines and using as many disciplines as you can - bringing together everything and looking at context and individuals and groups to figure out about how individuals and groups learn best and I can teach better.

Lisa (current student) describes her problem-focused purpose in interdisciplinary work:

> It starts for me with a problem that you've identified in society, something that you actually want to find a solution for and I think it's very natural to come to the conclusion that no major societal problem is going to have an answer or solution that's bound by a constructive discipline. So for me that synthesis has come from the space around the problem. So the synthesis has come very natural to me because I've just said, 'Okay, this is the problem, these are all the things that make sense to the problem.' When I use that as the perspective rather than using a discipline as a perspective and saying, 'This is it, this comes from education and this comes from neuroscience, and this comes from psych.' That for me would be very limiting and very difficult because I would feel like I was pushing lines down and trying to build bridges between things. When I start with the problem space and work outwards it's very, very natural and I feel like it's been an effective strategy.

Students enter the program with an individual purpose and a passion for applying their work. Melissa (alumna) relates this motivation and dedication to the idea of *purpose*: "You seem to find especially passionate people, because being in something interdisciplinary you have to have chosen that thing. It has to be a very intentional path that brings you there." Students describe a desire to make change related to a larger social purpose. As a survey respondent says: "It's about understanding the greater encompassing context of the work you're doing and the potential societal value it may have."

Students experience an A*ha!* moment when they find the program and anticipate that an interdisciplinary approach will offer new insights and solutions to the problems they seek to address. They describe prior experiences as the basis of their motivation and interest in interdisciplinary study in MBE. Lori (alumna) writes: "I was seeing a big discrepancy in my students in math…and I was really interested in all kids' potential and how we could improve the learning situation." Elizabeth (current student) "wanted the science to explain what's going on with my students so I can …do *something* for kids that are just not fitting into public schools."

A student's purpose may become less clear, or change, during the course of their MBE year. Krissy (current student) describes *purpose* as a dynamic component, which she is in the process of revising. She says, "Right now it's hard for me to see how it's going to directly alter my own teaching – maybe as all of this settles in the next year, it will be become clear to me. Right now I think it's fuzzier than it was when I first came here." Students indicate that their purpose changed during the course of the program, for example, when asked about her purpose, a survey respondent replied: "When I started or when I finished?"

Weighing Disciplinary Insights

In the process of interdisciplinary learning, students "understand disciplinary contributions and weigh their role in informing the whole." (Boix-Mansilla, 2010, p.300). Weighing disciplinary insights requires an understanding of the knowledge, methods, and theory in the multiple disciplines (Boix Mansilla, 2010). Students enroll in the program with vastly different disciplinary backgrounds, ranging from no experience or education in neuroscience, psychology, or education to expertise in multiple disciplines. For each student in the MBE program, the relative contribution of the different disciplines varies depending on the student's prior knowledge and interests.

Students find the disciplinary learning challenging on many levels. Krissy (current student) describes her challenge with how the writing protocol in the MBE program differed from that in her prior experiences: "The style of writing was a huge shift for me;…to do this very rigid APA style - figuring out how to write the assignments was a different experience for me." Learning in a new discipline and communicating disciplinary knowledge also entails learning new vocabulary and the language associated with various

disciplines. Bella (current student) says: "The challenging thing for me was communicating things to varied audiences…the language is hard." Lisa (current student), who came into the program with a neuroscience background, echoes the challenge of language and jargon: "There are a lot of things [in education] that are colloquial and ubiquitous [and I often asked my cohort members] 'What are you guys talking about?'" A survey respondent notes, "there are different skill sets needed to absorb knowledge from different disciplines."

Students vary in their perception of the need for a deep understanding of each discipline. Some students say they must be "reasonably comfortable with the jargon, assumptions, objectives, and limitations of each relevant discipline." As Lillian (current student) says, "I just need to know enough [neuroscience] so that when I read an article I'm not 'What are these words?' and it's not like a foreign language to me." Others find that their lack of deep disciplinary knowledge is a barrier both for their individual process and for the social process of synthesis. They feel their contributions are not valued when they do not have sufficient depth, and they are concerned they will misinterpret and misapply knowledge.

Gaining new disciplinary knowledge and filling the gaps in their disciplinary knowledge is stimulating, as well as challenging, for students. Lori (alumna) says, " I remember being very excited about feeling like my brain was on fire all the time, trying to think of all of this at once…just trying to think of all these different spinning wheels all at once." The program provides structures for students to fill in the gaps in their knowledge, e.g., posting supplemental material on the HT-100 website, encouraging study groups, providing access to guidance from teaching fellows, and offering a flexible curriculum and

access to a wide variety of courses. Students perceive that they must be self-motivated and independent in filling in the gaps. Polly (faculty/administrator) says, " If you don't know anything about this particular concept, you need to learn it, it's really on you to do that." Sarah (current student) talks about specific courses filling in the gaps. She does not have a background in research and found that a course in statistics helped her to "understand a lot of the research…and examine it critically." Similarly, she found the course *Educational Neuroscience* a "way of acquiring a lot of science knowledge." Some students suggest that more explicit introductory courses would help fill in the gaps. Rita (alumna) says, " [It] would have been a valuable experience for those of us coming from neuroscience experience where we didn't have a lot of experience in education to have kind of a more solid grounding in that field."

Students, as well as faculty/administration, perceive that the interactions among diverse members of the cohort actually support students' learning. Students describe the ways in which the diversity of the cohort's prior experiences functioned to motivate them to explore both more broadly and deeply, to support and inspire them, and to facilitate both disciplinary learning and synthesis. A survey participant compares the diversity of the cohort as compared to her previous experiences:

> I was all of a sudden just so blown away that I had never realized before how limiting it can be to talk about things with a whole bunch of other 20 year olds. All of a sudden I had people with a whole career's worth of experience under their belt and I was 24 or 25 at the time. And that was really valuable and interesting to me.

Elizabeth (current student) describes the diverse prior experiences of members of her cohort: "In my cohort we have a neurosurgeon, we have people who worked in a research lab, we have a school superintendent, we have someone who wants to open schools in India – we *all* learn so much from each other." Jon (faculty/administrator)

describes the expertise of the diverse students as "just an enormous boon to the class." Students verify Jon's belief about the value of the diverse cohort, as seen in the following quotes:

- "I felt like I learned as much from my cohort as I did from the professors and the other courses that I had here." (Lori, alumna)
- "One of the best aspects of the program was the opportunity to learn from peers in my cohort, both in and out of the classroom." (Survey respondent)
- "The intellectual community provided by my cohort was my favorite part of the program." (Survey respondent)
- "Our backgrounds are SO diverse! Sometimes I would learn as much from having lunch with a friend as I would from a lecture." (Survey respondent)

Building Leveraging Integrations

An important component of interdisciplinary education is to not just combine knowledge from the different disciplines but to leverage those different knowledge bases to build a better understanding. Boix Mansilla (2010) describes the cognitive process of *building leveraging integrations* as "producing integrative understandings" and "discerning [the] best form of integration to meet [the] purpose" (p. 299). Her framework posits that the four components are dynamic and interdependent; she writes: "In interdisciplinary learning the [four core cognitive] processes interact dynamically, informing one another as learning progresses (Boix Mansilla, 2010, p. 298)." In describing the process of *building leveraging integrations*, students refer to the other components. For example, Missy (current student) says: "the easiest ways to think about integrating information is really to figure out what your specific question is." Similarly, Lori (alumna) describes the relationship between synthesis and purpose: "You were just trying to synthesize so many things at once, but it would depend on what your goal was and what you were there to

study." A survey respondent describes the relationship between disciplinary knowledge and synthesis: "the biggest challenge [to building leveraging integrations is] not knowing a particular discipline (its knowledge base and methods) well enough to actually integrate into my existing knowledge/methods repertoire."

In interdisciplinary learning, students develop knowledge in separate disciplines and then make connections among the disciplines. This is an individual process and students have different perspectives on the amount of knowledge they need to synthesize. Some students find a lack of foundational knowledge in the various disciplines hinders progress in synthesizing, while others find that mastery of disciplinary knowledge is not necessary. For some students, the lack of deep knowledge is a barrier both for their individual process and for the social process. They feel their contributions are not valued when they do not have sufficient depth, and they are concerned they will misinterpret and misapply information. Students report that prior disciplinary and professional experience facilitates their interdisciplinary understanding. As Raquel (current student) says, "If I hadn't had and undergraduate background in sciences, if I hadn't had a lot of experience in education, I think it would be quite difficult."

The qualitative data suggest that students perceive synthesis/integration as a social, as well as an individual, process, requiring a wide variety of cognitive, intrapersonal, and social skills. They recognize challenges and supports to the process of *building leveraging integrations* and describe it as a slow, difficult process. Polly (faculty/administrator) says, "Everybody struggles [with integration and synthesis]…these are really hard questions that don't have good answers, or easy answers, or sometimes any answers at all." Among the factors affecting the process of building

leveraging integrations are the challenges of collaboration; the existing cultures and biases of academia and the larger society; and, the supportive structures within the program.

Collaboration

Students identify time, disciplinary knowledge, personal characteristics, and social skills as affecting collaboration in interdisciplinary work.

Students perceive that time constrains the individual and social processes involved in *building leveraging integrations*, especially since this is only a one-year program. A survey respondent finds one of the challenging aspects of integration is "having enough time to understand the information from [multiple] disciplines - really getting the nuances of each and then synthesizing the information as an 'expert.'" Time is a factor in the collaborative dialogues of interdisciplinary work as the "time it takes to get everyone up to speed" presents a challenge. Students perceive the process of synthesis as ongoing and continuing beyond the year of the program, as a survey respondent says, "One year is enough to start asking questions. The rest you need to do on your own." An alumna of the class of 2011 says, "I think I'm still in the process of synthesizing." Elizabeth, (current student) describes reflecting with her peers about the need to spend time after graduation thinking about her experience: "It's very fast paced and I don't think I've fully synthesized everything yet. It's like a bunch of floating information in my mind." Time affects the depth of quality of integrations, as a survey respondent describes:

> When you're trying to tackle a problem from three different angles at once, it's easy to focus on surface-level commonalities and differences, rather than the deeper constructs. Some of my papers would come out as watered-down as federal legislation. It wasn't that there wasn't opportunity to investigate with more rigor, but I felt that doing so would cost me more time than I had available in a one year program. Plus I felt overwhelmed – where to start when there are so many entry points to an issue?

Some students are comfortable participating in collaborative dialogue even though they have limited knowledge in one or more disciplinary areas, while others find they feel less valued in the collaboration if they are not well-versed in all of the subjects. Some students also express concern that the information will be misinterpreted if their collaborators have only superficial knowledge of the subject. They cite prior disciplinary and professional experience as facilitating their interdisciplinary understanding. A survey respondent describes the challenge of the intellectual process of working collaboratively with people who bring a range of disciplinary knowledge to the process: "There is a wealth of experiences, knowledge, jargon, and back-story that each field brings to the table, and being able to identify which sorts of understandings or pieces of information are not uniformly understood, is a tricky task."

Students perceive that working collaboratively with people with different levels of disciplinary knowledge affects their personal emotions as well as being intellectually challenging. Students find that revealing one's limitations and relying on others' expertise to collaborate and build integrations involves risk in terms of one's personal credibility and status. A survey participant commented: " I don't have in-depth knowledge of any particular field. I end up having to consult with people who do have it in order to move forward, and in doing so lose respect in their eyes." The risk and uncertainty pertains to professional, as well as personal, integrity and students express concern about misinterpretation when collaborators have superficial knowledge. A survey respondent finds "it difficult to speak about issues outside of my own experience, for fear of making claims about a different discipline that were not grounded in experience."

The social process of synthesis is challenging, rewarding, and requires diverse skills, as described by a survey respondent:

> I think that collaborating with people is hard enough, but collaborating with people with different disciplinary perspectives is even harder. The task of managing the different ideas and approaches while completing a task is quite challenging. However, in the best-case scenario, people listen to each other and try to understand their individual take. Once all the voices have been heard, they can be integrated and utilized to move the project forward.

Students experience personal challenges in "communicating complex material clearly" and in "explaining the thinking to…people who are not in one of the fields." They identify a number of strategies to facilitate communication, including "listening," "acknowledging all the stakeholders (Rita, alumna)," "creating a dialogue that's not full of jargon (Rita, alumna)," "helping others see where they fit in," and "taking time for everyone to sincerely understand one another's perspective." Individuals' trust and valuing of others' perspectives and contributions affect the process. Students find they "bump up against the invisible walls of [their] own and others' assumptions," contend with the "bonfire of vanities," struggle with "individuals [who] feel that what they do is the most important part," see miscommunication because "people are not able to disengage from their own way of thinking and consider others', and find "people do not realize they do not understand each other, and cannot see other forms of knowledge as valuable."

Students describe disciplinary hierarchies, variations in cultures, and disciplinary territorialism as affecting their integration and collaboration. Kristin (alumna) describes some disciplines as having a "culture of independence" in which the work is confined to a small group of people who work only within that group. She contrasts that approach with an interdisciplinary program "where everybody is collaborating, everybody is at the same table, everybody's lens is important." Some academics, as well as society in general, may

privilege certain disciplines over others. Students find some disciplines "less open to outsiders saying something," describe people being in a "bubble of [their] discipline" and "have seen neuroscientists getting up on their podium and talking down to the educators." Gary (current student) says it "feels much scarier to try to defend my credibility to have input" when working with a group of neuroscientists; he questions whether his emotion is related to his lack of disciplinary knowledge or is a reaction to his perception of the "inherent elitism within that science."

Students also describe interaction among members of the diverse cohort as a significant factor in facilitating synthesis. The "collaboration between members of the cohort who have different kinds of experiences, background, skills, and knowledge and methods from multiple disciplines" increases students' understanding of different disciplinary cultures and supports them in building integrations through cognitive and emotional support. Ginny (alumna) perceives the informal and academic interactions involved in "hanging out [and] working on projects " support her as she "got to know a lot of people who were teachers so I feel like I get that culture more and I'm much more comfortable." Krissy (current student) describes the generative effect of interactions among cohort members:

> [Engaging with] people…from different backgrounds is an amazing experience and I think it forces you to have these conversations and come up with ideas that you wouldn't come up with if you [are only] with people who had [similar backgrounds]. They pushed me to explore things that I wouldn't have necessarily explored.

Intrapersonal skills and personal traits facilitate students' ability to further their integrations and include confidence to take risks, as a survey respondent says, "I was…forced to think outside my comfort zone." Other skills include dedication to purpose;

perseverance; metacognitive skills, and comfort level with the uncertainty of the direction and outcome of the work. As a survey respondent describes:

> This is hard work! It is time consuming and difficult to get a working knowledge of big ideas in different disciplines and how/when they may be fruitfully brought together. Because this field is so new, there is a lot of *figuring it out* that we have to do – we are being trained but are also creators in this field.

Gary (current student) says:

> One thing I have really come to during this semester is feeling comfortable with no one is an expert in all of it and so when you're doing interdisciplinary work, part of it is you have to feel comfortable moving forward and accepting that. So I'm doing synthesis without full expertise. And *clearly* there are some dangers that can come with that and I feel like I'm starting to learn how to avoid those – like identifying 'I don't know quite enough to say that' or I'll lean on some of the other people in my cohort [who] is more knowledgeable than I am about [a particular topic]. It's not that I fully synthesize this stuff, it's that I feel comfortable doing so in the state that I'm in.

Students identify prior experiences as important in their process of integration. Lillian (current student) notes, "If I had…done this program straight out of undergrad, I would be lost – I would not be taking anything in – but having the experience to connect it has definitely made it easier." Elizabeth (current student) anticipates that "when I'm active with it, it might come together more."

Programmatic Support

The faculty/administration of the MBE program recognize that synthesis is a difficult cognitive process. A faculty/administrator says, "We are asking people to do really difficult things and it takes a lot of practice to figure it out." Students identify a variety of programmatic structures that facilitate their ability to integrate multiple disciplines including course assignments; the flexible curriculum; interactions with the diverse members of the cohort; practice, feedback, and modeling. Students find assignments such as papers, projects, and readings are critical to their integration of the material. Missy

(current student) says, "so many of our assignments are open-ended, and because they are open-ended, it allows for that integration." Students perceive the flexibility of the coursework supports synthesis and give examples of specific interdisciplinary courses and "taking a wide variety of courses" as facilitating synthesis. Students find their lab/research placements and case studies of interdisciplinary work helpful and suggest that more explicit practice and scaffolding with successful interdisciplinary collaboration would be beneficial. Sarah (current student) says, "I would be better at [synthesizing] if I was systematically presented with multidisciplinary problems and getting the chance to practice critical thinking and problem-solving that requires you to pull from various disciplines."

Maintaining a Critical Stance

Maintaining a critical stance involves "revising a system of thought in light of critique" and "weighing emerging insights against one another, and against prior knowledge and against competing understandings." As students reflect and revise knowledge in light of new understandings, they encounter uncertainty and challenges and have to reflect on and possibly revise their prior understandings and beliefs. The skills needed for maintaining a critical stance include an awareness of one's understanding, as a survey respondent writes: "I know what I know, but I am also well aware of my limitations."

Students find that limited time and the cognitive demands of the program present obstacles to reflection. A survey respondent says, "I would LOVE to have the mental bandwidth and time to take a step a back to reflect, but don't think this is really possible until school is over." A survey respondent identifies a lack of time as the reason he is

unable to reflect in the way he would prefer. "I like to think that I do both of these reflective behaviors [identified in the *Reflective Behaviors* survey scale], but time is so limited in this context, I don't think I do them as often as I'd like to!"

Revisable Knowledge

The idea of knowledge as revisable is inherent in Boix-Mansilla's (2010) framework of interdisciplinary understanding. A survey respondent describes the impact of the MBE program on her perspective of knowledge: "I came in looking for concrete answers, but what I have learned the most is that I don't think any one discipline has concrete answers. It is ever-evolving." Elizabeth (current student) describes the dynamic nature of maintaining a critical stance in the program: "I came in with my own questions but I'm leaving with different questions." Missy (current student) echoes her perspective in saying, "This is really not a program where you come in and get the answers, you come in with questions and you start searching for answers to those questions but you come out with a thousand more questions that you want answered."

As students develop a *system of thought in reflective equilibrium* and continually weigh insights and revise their knowledge they are in a constant state of critical reflection, adjustment, and uncertainty. Students perceive times of tension and disequilibrium as part of this process. Sarah (current student) finds the program has "complicated things for me, which is good." Lois (current student) says, "I feel like I've learned so much and I read all these studies but it's hard for me to connect how they all will lead sometimes." Students' comfort level with uncertainty of knowledge affects their success in the program. Calvin (alumnus) notes, "Those students who are ready to think differently thrive. Students who came looking for something very specific and didn't get it are

disappointed. Typically it's *the answer* – they are looking for the answer or a much clearer relationship between neuroscience and education."

Prior Experiences

Prior experiences both facilitate and impede students' ability to maintain a critical stance. Calvin (alumnus) describes students' prior academic experiences as having the potential to challenge students' success in maintaining a critical stance. Students who were successful in academic environments where static knowledge was valued find it to be a significant shift to adapt to a context where there is no *right* answer and where knowledge is revisable. He notes that student' responses vary when they enter an environment in which they find that the knowledge "we were hanging our hats on three years ago" is challenged by competing evidence. "For some [students] [it is] very exciting, for others it [is] very confusing and frustrating…Some of the students [are] not used to being critical thinkers, because they were never trained to be critical thinkers." A survey respondent says, " I think it was a challenge to come in and realize that I was not coming to a program where I would just enter and get all the answers to my questions as if there was this knowledge that had already been discovered out there and I just needed to get it."

The skills involved in maintaining a critical stance are challenging to acquire and become a lifelong habit of mind embodied in the phrase *intellectual courage and humility*, the ability to discern what one knows and doesn't know and to be open to learning. A faculty/administrator describes students' experiences in interdisciplinary critical thinking during the program year as a beginning:

> We make some progress in changing people's perspectives and helping to shape their thinking in terms of 'I need to wear many hats, I need to be able to put on and take off different lenses, I need to understand assumptions of different disciplines, I need to be able to evaluate the claims that people make.' I think we are successful

> in starting on that path…I think we plant seeds…we [reorient] people and [start] them down the road.

Critical thinking is a habit of mind, which continues to inform the way students evaluate and apply findings and products aimed at educators, as Melissa (alumna) describes:

> The strategies and the frames of mind that I was taught in the program [five years ago] have allowed me to continue to reflect back and back and back on things that I learned. I didn't have the experiences in my career yet to understand how to apply things. [I now] continue to reflect in meaningful ways. When you've got these sort of habits of mind about how to look at and interpret information you feel like you have some traction, a certain level of currency, in being able to talk about [multiple disciplines] – in a very conservative way to be sure. My experience in MBE allows me to be able to step back and say, 'Well, if [the product] really does [what it claims to], here is the stuff that's at stake, and if it does X, Y, and Z, that would make it really cool and maybe a useful thing for [educators], maybe a thing that really does what it says. *But* there are some other things to consider that might suggest that this isn't doing really exactly what they claim that it's doing, or what they think it's doing.' I think [MBE] makes me confident in my skepticism. I'm skeptical about the right things.

Research Question #2 Potential of MBE

> It's just *really* challenging. There are a lot of barriers to overcome. There are a lot of parties to convince along the way. (Polly, faculty/administrator)

Students express both pessimism and optimism about the potential of MBE to influence educational practice and policy. A survey respondent describes the potential impact: "I think it could impact millions of people that would otherwise not have the opportunity to achieve in education and in society." Students perceive it is a "long process from research to practice" (Marcy, alumnus) and "bringing practitioners and researchers together…is really hard to do out in the world" (Eric, alumnus). Their enthusiasm and optimism for the potential of MBE to improve education are tempered by concerns and cautions about the challenges of misinterpretation, the time it takes to effect change; the

current state of education and the status of educators within the larger context; and the inherent personal challenges of working with uncertainty.

Interest and Misinterpretation

Students suggest that educators vary in their interest in considering the relevance of concepts and methods from neuroscience. Polly (faculty/administrator) says there are "people who think that anything and everything about the brain is amazing and people who are not interested at all." They find that "MBE research has a lot to offer to education, but there are also a lot of pitfalls and danger in misconstruing MBE research (survey respondent)" and suggest the integration of science and education is susceptible to oversimplification and misinterpretation because the culture of education is "inherently faddish" and "always looking for the latest magic bullet and whatever will fix it." (Melissa, alumna).

Additionally, those outside, as well as within, education and science, may contribute to the challenges of appropriately translating research. A survey respondent notes: "Scientific research can easily be sensationalized by the media and press, so that can be of some concern." Another survey respondent says of a popular conference aimed at educators, "I'd occasionally get overwhelmed and start to think that maybe 'the bridge' [between neuroscience and education] actually is too far, especially when I attended the *Learning and the Brain* conference and saw how much bad (oversimplified, incorrect, or misleading) stuff is out there – it's higher in volume than the good stuff."

Students feel the responsibility of being "responsible stewards of the knowledge." Faculty/administration acknowledge the risks and responsibilities of the program in preparing students to participate in interdisciplinary work. Kristin (alumna) sees "the

range of students [in the program] - those who epitomize this integration and those who might leave with neuromyths in their mind or who might come away still with their disciplinary lens and not having struggled to integrate." She says::

> This scares me, because putting a label to a movement and then sending people out who have the badge of that movement, who represent you in different ways can be dangerous. But if we do a good job in preparing them… then we can be reassured that this is a movement that could have a positive impact on practice and policy.

Time to Effect Change

Students are generally optimistic about the potential of MBE to influence education and expect the reality will take time and will be "a slow transition" (Marcy, alumna). "I think there is definitely potential there – some of it is happening already, but I don't think the field of MBE is going to magically fix education – that's a long, tough process (Susan, alumna)." Students use a variety of metaphors to describe the change, which imply a slow, steady process. They use phrases such as "trickle down into the classrooms," "change the tide," "move the ball forward" and "make these waves bigger."

Students attribute the time it takes to the field of MBE being "just too new now" and to the time it takes to develop interdisciplinary understanding and collaboration. Eric (alumnus) says: "[MBE] is as much a mindset as it is a discipline. It's a way of looking at the work and developing a set of mindsets, which take a long time to develop."

Once MBE does have an effect on education, students see it as a potentially powerful change. Elizabeth (current student) says, " I don't know if it's just a matter of every year a new graduating cohort of MBE people trickle into the work and start spreading the message, but I think it could potentially *really* make learning or school a better experience for children who currently don't enjoy school." Students anticipate that while "the potential is great, …changes in education move very slowly and the kind of

positive effect that MBE could have on education may take time and money - two things that those in positions of power in education don't like to spend." Rita (alumna) describes her doubt about the potential: "MBE gave me the tools to be critical…but as I've become more critical, I'm also 'I'm not really sure that they belong in the same place, neuroscience and education."

Transforming the Current Educational Landscape

To productively proceed with interdisciplinary collaboration to improve education, students describe a need for transformation of both individuals and the larger system:

> I think the challenge is developing not only the people who have the right mindsets, the right skills, and the right knowledge to be able to [generate new questions and new knowledge]. But also developing the infrastructure outside of academia in the world where that kind of work can be done. (Eric, alumnus)

Students recognize significant differences among the cultures and experiences of researchers and educators, which challenge communication and collaboration. Marcy describes the different experiences of both groups in saying, "neuroscientists are so far removed from the classroom and teachers don't have the time to be combing through the neuroscience journals." A survey respondent emphasizes the challenges of communication: "The struggle (which can seem overwhelmingly large at times) is that it's so hard to communicate complex ideas in a way that isn't too reductionist." In addition to challenges in communication, stakeholders from "different disciplines seek different outcomes and on different levels (survey respondent).

Eric (alumnus) describes some of the differences:

> How do you take what researchers know about why things happen and how they develop and infuse that that into what teachers are doing everyday, and how do you take the knowledge that teachers have about how things develop everyday through their actions because teachers are basically experimenting everyday with kids so they are getting valuable knowledge that should be cycling back. I think the

> challenge is that teachers don't see themselves like that. They are in two different endeavors where they're trying to build two different things and the language is different. Once you have that language, then you can be the bridge.

Teacher as Researcher

Students are "very hopeful that MBE has the potential to (slowly) transform the landscape of education (survey respondent)" and suggest that the culture, values, and practices of the larger society must shift in order for interdisciplinary research to inform educational practice and policy and for teachers to participate as collaborators. Krissy (current student) notes, "the system is very stuck in its ways. I think you have to keep trying, but it's easy to give up at some point." Sarah (current student) says: "The current structure of education, academia, and policy doesn't facilitate teacher-driven research and doesn't facilitate policy that's directly informed by research." She believes that "MBE's biggest potential to [inform] practice" depends on "establishing a new culture for education in which teachers are empowered to be their own researchers."

Eric (alumnus) describes an image of teachers as active, scientific researchers:

> I feel in a way teachers are developmental psychologists. They just don't see themselves that way but they really are, because that's what they do everyday in class, just trying to figure out this child. 'I want that child to move here and I want to help them bridge that gap and how do I do that.' So they're kind of applied, trying some of those things in psychology."

Emily (alumna) envisions a more active, autonomous role for teachers, which will "professionalize teaching and [engage] teachers more in asking important questions related to our practice – finding these ourselves and working towards the answers instead of having often a top down system in which we are being told, 'This is the research and this is what you need to do.' Sarah (current student) also sees MBE's potential as related to change in the status and responsibilities of teachers: "As a teacher…you have this

wealth of data in front of you all the time with your students [and] your peers. By establishing this new culture for education in which teachers are empowered to be their own researchers, that's probably MBE's biggest potential to affect practice."

The potential of teachers as researchers may be limited by the current structure of teachers' responsibilities and daily routine. Teachers feel "overwhelmed" in their daily work and recognize "how hard it is to be a teacher." They have neither time nor resources to think critically, reflect, or gain interdisciplinary knowledge. Rita (alumna) describes the reality of teaching as compared to academia:

> Now that I'm teaching there's no way that I could be that critical on a day-to-day basis, there's no way that I could consume that information to the same degree that I can in an academic setting, there's no way that I can thoroughly pour through all the research and come out with a very clear understanding of what this can accomplish and what this can't accomplish – there's just a lot happening at once for me to have that kind of critical eye – not that I don't try but it's just a different world.

Students perceive changes in teacher education programs would increase the potential of MBE to influence education. Bella (current student) believes that "[if MBE] knowledge [was used in] teacher training, it would change so much." Educator preparation programs may include coursework to fill gaps in knowledge and to support teaches in conducting research in their classrooms. Sarah (current student) finds that the a shift in the role of teacher to teacher as researcher is challenging, and potentially powerful, because "statistics is this critical language in research that most teachers don't have. I wonder what would happen if you had a school where all the teacher got some basic training in statistics and were encouraged to be in their classrooms and also conduct quantitative and qualitative research. I wonder what would happen in a place like that."

Gary (current student) considers interdisciplinary teacher education as critical and logical, saying, "neuroscience should be the equivalent for education as anatomy and physiology is to medicine. I don't need my doctor to always know about the heart when I go in, but I wouldn't go to a doctor who doesn't know how the heart runs. And it feels the same way in teaching, like we should be able to say the same thing about how the brain works. It doesn't mean you need it moment-by-moment in the classroom, but it should be somewhat at the core because theoretically that's how learning takes place, somewhere in there, so it should be at the core of what teachers do."

Sarah (current student) suggests the goals of MBE involve significant change, saying, "It's not only about disseminating findings, I feel like it's more about facilitating people's abilities to ask questions, draw from various knowledge bases, and solve problems.

Disciplinary Hierarchy, Power and Teacher Status

Students perceive disciplinary hierarchy and privilege as challenges to the potential of MBE, suggesting that all voices must be equally valued for MBE to inform educational practice and policy. As Lillian (current student) says: "I hopefully think [MBE] will have a great influence. I think as long as it makes sure that it equally holds the other frames besides neuroscience - like sociology, biology, culture, politics, - it will [bring] in a diverse group of people…so that a lot of voices are heard."

Students see teachers as less valued than those in other disciplines and believe they are not recognized for having knowledge to contribute; therefore, eliminating disciplinary hierarchy and privilege will require a significant shift in society's perception of teachers.

In order to "give a chance for educators to have a voice at the table [society must] recognize the knowledge that educators have in a way that isn't really done right now. I think it will be beneficial to educators, but also to the other disciplines to engage in dialogues." (Eric, alumnus). This shift will require others recognizing teachers' knowledge, changing the perception teachers have of themselves and their work, and restructuring the educational system.

Students perceive a power imbalance in education, with the value of teachers' knowledge and experience unrecognized both by the larger society and by teachers themselves. Eric (alumnus) says, "teachers don't see themselves as [having valuable knowledge from their classroom experiences] and researchers don't see teachers like that." Students perceive teachers are accorded a lower status than those with whom they might collaborate and than those who are responsible for setting policy. A survey respondent says:

> I think the potential is great, but teachers are still not seen as equals or as much as "professionals" in the same way that scientists, law makers, or other researchers are. In order for MBE to truly influence educational practice and policy, teachers need to be treated as equals and their input valued to know if things that work in a lab or other non-school setting would really work in a classroom.

The distrust goes both ways, as a survey respondent finds that "in the real world of education, there is very little trust in the science. Perhaps the most daunting problem is educators' flat out resistance to anyone implying that education can be improved by anyone outside of the classroom."

For some, the challenges seem too great. Krissy (current student) says:

> At the end of the day [there are some things] I can't do anything about, that's not something as a teacher that I have the power to do, that's more of a policy issue or administrative issue. Right now it's hard for me to see how [MBE is] going to directly alter my own teaching.

Steven (current student) suggests that effecting change must include those outside education, saying, "It's a political decision at some point and the MBE people have to make the politicians understand how the school system can be improved and politicians would have to make that decision."

Personal Challenges and Preparation

Interdisciplinary work requires personal skills and traits as well as academic preparation. The personal traits include leadership skills, comfort with uncertainty, the ability to be self-motivated, interpersonal skills, and security in taking risks:

> It's just challenging to…do hard work that takes a lot of time, a lot of self motivation, a lot of reflection and talking with other people, and being vulnerable. The strength is that it's really important and really valuable and we are creating something that could have a really positive effect. (Polly, faculty/administrator)

The uncertainty of the interdisciplinary knowledge is challenging because "a lot of times people aren't satisfied by answers that say, 'We don't know', or, 'We are uncertain' (Sarah, current student)." Eric (alumnus) describes the difference in the focus of researchers and practitioners regarding uncertainty:

> I think researchers are interested generally in theories of explanation, but not theories of practice. When practitioners talk to researchers, [they differ in their attitude towards] uncertainty towards knowledge. Researchers are never going to say, 'This is what it is,' and I think that's frustrating from a practitioner's perspective. The researchers ask 'why' and the practitioners say, 'How do I do that?' or 'What do I do?'

Most students feel prepared to "create the bridge between researchers and people in educational practice" while others are uncertain and "don't know where [their] skills fit in." Many students believe that they have the confidence and "tools to approach" collaborative conversations as a result of the program. They perceive the network of colleagues they developed through the program as a resource. There are limitations, and

students feel they "need to do homework beforehand" (Emily, alumna) and to "feel comfortable [synthesizing] in [a state of uncertainty] and knowing you may need to revise that" (Gary, current student). "). Some students express concern that the program has not adequately prepared them for effectively communicating and applying MBE to educational problems. As a survey respondent says, "I feel that our program's goal was not as cohesive as it could have been, nor are the foundations in place for our cohort to disseminate our learning effectively outside of HGSE. I think these things are in the emerging stages." Lisa (current student) echoes these perceptions in saying:

> I think there is … a lack of training…in the way the courses are being taught here and the way that leaders in the field, and people who are ostensibly going to become leaders in this field, are being trained. I don't think they're given those skills themselves. That makes it hard for me to imagine how they're going to transmit those skills elsewhere.

Research Question #3: Student Characteristics

I originally intended to analyze the data by the student characteristic of their disciplinary affiliation at the beginning of the program. I was unable to do so because many students had interdisciplinary experiences prior to entering the program. As a survey respondent describes: "Undergrad I would classify as primarily "Brain" since my major was neuroscience. However, I went to a liberal arts school and also took lots of education classes, sociology classes, and psych classes (in addition to the psych required for neuroscience), etc."

I investigated students' perception of the source of their affinity for interdisciplinary work through the interviews and open-ended questions on the survey. I describe the results in the section below.

Affinity for Interdisciplinary Study

> The idea of trying to bring disciplines and work at the intersection of things…attracts a particular kind of person. I don't think everyone is interested in how things intersect. I think some people are, and other people are interested in being an expert in one thing or really focus on a single thing deeply. (Eric, alumnus)

The qualitative data reveal students' perceptions of the prior experiences and personal characteristics they attribute to their interest in interdisciplinary approaches. Students describe having an affinity for making connections and appreciating multiple perspectives from early in their lives. They suggest that their interest in interdisciplinary work has been a part of their identity for many years and they have always felt drawn to multiple perspectives, making connections, and diverse interests. Mark (current student) describes having felt an affinity for interdisciplinary work from early in life: "I've always been…very interested in synthesizing or pulling things together and finding relationships – interdisciplinary relationships" and Lois (current student), says, " I have always thought of myself as a *jack-of-all-trades, master-of-none* kind of thing, where I've always been interested in a whole bunch of different things and trying to pull things together."

Students describe their early experiences and personal temperament as contributing to their interest in interdisciplinary work. In reflecting on their interest in interdisciplinary work, students suggest that their individual temperament plays a role - they describe a need for stimulation and multiple demands on their attention, as Raquel (current student) says, "I don't know how much interdisciplinarity is just a lack of focus. I think it's hard to do just one thing, for me." Bella (current student) describes her thought process as reflecting an interdisciplinary perspective: "When I see different things I tend to make connection and think about that from different perspectives."

Students relate family and community experiences in which they were exposed early in life to multiple geographic, cultural, and ethnic perspectives and activities, and where they thrived in family cultures in which parents modeled, encouraged, and valued diverse interests and their individual natures. Lillian (current student) describes growing up in family with a father who is a musician and a mother who had many careers, including one as a lawyer: "My parents always had a ton of different interests so I was always someone who was able to speak a little bit to everything. I like to bring everything in because to me everything relates, everything is important." Kristin (alumna) notes that the skills she needed to participate in two cultures in her early years are similar to those needed for interdisciplinary work:

> There was a very multicultural aspect to my upbringing, where I was having to live in two cultures, integrate the two cultures, and then kind of a hodgepodge of identities and languages and values, and knowing how to go back and forth and knowing in which settings to bring up certain values or bring up a certain language, or merge the two into Spanglish. I see that going back and forth between cultures and values as something that is important for someone who is doing interdisciplinary work. You need to know in which settings to talk in a certain way use certain languages, use certain buzzwords - what are the values of the community, the audience in which you are interacting? I see that as informing my interdisciplinary work.

Summary – Quantitative and Qualitative Results

The quantitative and qualitative data together offer insight into students' perceptions of their experiences in an interdisciplinary MBE graduate program. This section summarizes the results of the two results sections.

Perceptions of the MBE Program

Participants' survey responses indicate that students find the social and intellectual climate and their experiences in the MBE program to be positive, although they rate the social cohesion and integration the lowest of the items on the *Impressions* scale. The

qualitative data suggest students enter the program welcoming relationships with like-minded individuals who share a passion for social change and a dedication to a purpose. Students face many challenges in creating a cohesive group, including time commitments and flexible course schedules. The timing and length of students' enrollment in the core course, HT-100, varies, and may affect some students sense of cohort, as those who take the course in the spring semester may not be in courses with other MBE students, and no course is exclusive to the MBE cohort. The core course brings a strong emotional response from students; many find it challenging and rewarding. Approximately half of the students in this study elect to participate in a wide variety of lab/research experiences; those who do so describe the experience valuable in modeling interdisciplinary work and supporting connections and relationships, find it positively affects their appreciation of interdisciplinary work, and also suggest they would welcome additional support in obtaining placements. The lab/research participants are more positive about the program in general, based on the *Impressions* scale, and identify their disciplinary affiliation after the program as *interdisciplinary* more often than those who do not participate in an experience.

The qualitative data suggest students find the program transforms their thinking and they leave feeling ready to work collaboratively to bridge education and other disciplines; the quantitative data suggest they perceive they have a greater appreciation for interdisciplinary research, are ready participate in collaborative research, and shift from affiliating with one discipline to identifying as *interdisciplinary.* They perceive that time, the one-year length of the program and the academic load, limits their ability to gain disciplinary knowledge, synthesize, and reflect during the course of the program.

The quantitative data show that, after completing the MBE program, students are employed in interdisciplinary work that is related to MBE. The qualitative results describe the varied nature of students' post-graduation careers, which include an international scope and range from returning to previous positions to entrepreneurial efforts. Students describe the tensions involved in the uncertain nature of the career path and the challenge of translating research to practice.

Research Question #1: Development as Interdisciplinary Practitioners and Researchers

The interviews and qualitative survey data suggest students perceive the purpose of their interdisciplinary work as individual and problem-focused. They are passionate about their purpose and also find that over the course of the year, they revise their initial questions and purpose. The ratings on the survey scale, *Recognizing Disciplinary Perspectives,* suggest students see themselves as skillful in *weighing disciplinary insights*; the qualitative data suggest that they perceive tensions in the structures, values, and cultures of the different disciplines and find it challenging to learn the knowledge, vocabulary, and methods of multiple disciplines. The process requires students to be independent and take initiative, and also to collaborate. While challenging, collaboration with the diverse members of the cohort supports their learning.

The results of the *Interdisciplinary Perspectives* and *Interdisciplinary Knowledge* scales suggest students agree they have integrative skills and knowledge and maintain an interdisciplinary perspective. In the process of gaining interdisciplinary understanding, they struggle with tensions in how much mastery of disciplinary knowledge is necessary to make reasonable integrations. They perceive the process as dynamic and as both social and individual and find it intellectually and emotionally challenging. They see prior

experiences as well as the coursework, faculty, and lab/research participation during the program, as important. They suggest modeling and explicit connections between research and practice would enhance their learning.

The results of the *Reflective Behavior* scale suggest students perceive themselves to be critical thinkers. The qualitative data describe the ways in which they revise their questions and purpose, the challenges of time and academic load to reflective thinking, and the impact of prior educational experiences that did not value critical thinking.

Research Question #2: Potential of MBE

Students are optimistic about the potential of MBE to influence education and the role they may play as collaborators. At the same time, they are cautious about the timeframe and suggest that the magnitude of change is both significant and necessary on many fronts. They are concerned about the broader social values, which emphasize quick and certain answers and solutions, and about the possibility of misinterpretation.

Research Question #3: Student Characteristics

MBE graduate students participate in a range of interdisciplinary extracurricular interdisciplinary activities and participate in interdisciplinary professional experiences before entering the program. They attribute their affinity for interdisciplinary work to family, cultural, and educational experiences in their earlier lives. Their experiences within the program, such as participating in a lab/research experience, may relate to perceptions of their interdisciplinarity. Interdisciplinary learning requires individual characteristics and temperaments that support students as they manage the pressures of time, uncertainty, risk, tensions, power struggles, diversity, and change inherent in the process.

CHAPTER 5

DISCUSSION

This chapter reviews the major findings of this study; considers the meaning and importance of those findings; relates the findings to those of previous studies; and, describes the applied relevance of the findings, the limitations of this study, and possibilities for further research.

Introduction – Major Findings

The purpose of this study is to investigate students' perceptions of their experiences developing interdisciplinary understanding in an MBE graduate program; how these perceptions vary based on student characteristics; and, to explore student perceptions of the potential and limitations of MBE to address educational problems. The four components of Boix-Mansilla's (2010) framework of pragmatic constructionism (i.e., *establishing purpose*, *weighing disciplinary insights*, *leveraging integrations*, and *maintaining a critical stance*) provide a structure for investigating student perceptions of the cognitive, social, and emotional processes involved in interdisciplinary learning and understanding. The concepts *tension, uncertainty, risk, diversity, time, power,* and *transformation* emerge through a grounded theory approach and illuminate students' perceptions of the MBE program and the potential of MBE to improve education and their development as interdisciplinary researchers and practitioners. The results of a survey and interviews with current students and alumni provide rich description of students' general impressions of the program, the curriculum and co-curriculum, the learning outcomes, and their careers and employment. The findings highlight student perceptions

of the individual characteristics and experiences that challenge and support them in gaining interdisciplinary understanding.

Students enter the MBE program fueled by passion and purpose, stemming from their personal prior experiences, to create more just educational opportunities. They feel enthusiastic about both the need for interdisciplinary work and their membership in a cohort of students with similar passion, yet with diverse backgrounds, interests, and goals. Students' purposes span a broad range and are practical and theoretical, future- and present-oriented. They identify their purpose, for example, "to be a better educator," "to understand the science behind the learning process," and "to bridge the gap to go from practitioner to researcher." Many of the students have had prior interdisciplinary experiences. Students perceive they enter the program with an interest in interdisciplinary work and their personal characteristics, along with family, educational, and cultural experiences, influence their affinity for interdisciplinary work. The program "attracts[s] people with a lot of entrepreneurial spirit who really want to make a leap into the unknown" (Lynn, faculty/administrator) and the personal characteristics include those that support *risk*-taking and *uncertainty*.

The MBE cohort includes students with a wide range of backgrounds, interests, and goals; at the same time the cohort shares a common perspective on the need for interdisciplinary work to effect change. Opportunities to connect as an entire cohort are limited to the core course, HT-100, and planned social activities. Students feel positively about the intellectual and social climate of the program; they find the social integration and cohesion of the program to be less positive than other aspects. Students perceive the cohort to be a significant support during the program and after graduation, providing

emotional and academic support and stimulation as well as connections in their post graduate professional work.

Students perceive interdisciplinary understanding in a one-year MBE master's program to be a dynamic, challenging, and rewarding process. Each student brings unique prior experiences, understandings, and questions, seeking to address individual problems in the MBE program, and thus must create her own path to build and weigh disciplinary insights, to synthesize and integrate, and to revise her thinking within a *system of reflective thought* while at the same time collaborating with others. Students experience the program and their learning with strong emotions and find the individual and social dynamic processes require significant cognitive, social, emotional, and intrapersonal skills, which may differ from those that proved successful in previous education settings. Interdisciplinary collaboration presents ways of working and understanding that may differ from those valued by the broader culture, which presents challenges to students. The prior experiences of students who pursue interdisciplinary study affect their attitudes and outcomes in many ways, including their interest in interdisciplinary work and their success with gaining interdisciplinary understanding, which includes continual adjustments and revisions as students set a purpose, weigh disciplinary insights, leverage interactions, maintain a critical stance, and work collaboratively with a diverse team.

Students suggest a variety of programmatic features that support their learning, including foundational courses, the flexible curriculum, interaction with diverse cohort members, intentional and explicit models, practice, and scaffolding of interdisciplinary work, time for reflection, and practical experiences in a lab or research environment. They find collaboration rewarding and challenging and struggle with how much mastery

of individual disciplines is necessary to participate in collaborative work and to make knowledgeable claims, and with the amount of time needed to acquire new knowledge and skills, reflect, and collaborate. They perceive challenges to building disciplinary insights and leveraging integrations, including a sense of disciplinary hierarchies and differences in culture, vocabulary, protocols, and knowledge among the disciplines.

Students feel personally *transformed* and *empowered* by the year of study and are inspired to create innovative solutions for the complex problems facing educators today. They make a shift in their disciplinary affiliation to identifying as having an interdisciplinary affiliation and engage in professional employment that is interdisciplinary and related to MBE. They regard their interdisciplinary thinking as a process that continues after graduation as they maintain a critical stance and continually revise their thinking. They leave having thought critically about a wide variety of *tensions*, *uncertainties*, and *power imbalances* in the interdisciplinary work of MBE and feel prepared to participate in collaborative research and begin the slow, and significant, process of change to improve education.

Students are cautiously optimistic about the potential of MBE to influence educational practice and policy, suggesting the change is much needed, challenging, and likely to be slow. As a survey respondent says, "I feel optimistic that…MBE will grow enormously. The time frame is 10 – 15 years." They express concern about the misinterpretation and misapplication of interdisciplinary work in MBE. They suggest the current educational landscape is entrenched and resistant to change, emphasizes quick solutions and certainty, and believe educators are limited in their ability to effect change. They perceive educators as low status compared with other disciplines and as *powerless* in

decision-making processes. To fully participate as collaborators, students suggest changes in perceptions of the broader culture, in educator preparation programs, and in professional development are needed.

Tension and Uncertainty

Students must struggle with ambiguity, *tension*, and *uncertainty* in interdisciplinary study. Among the sources of these characteristics of interdisciplinary learning are the disequilibrium inherent in the cognitive processes of developing a system of thought in reflective equilibrium; the tensions involved in pursuing innovative solutions, which may run counter to traditional values and practices; and, the uncertainty inherent in efforts that are "messy and unstructured" (Kandel, 2008, p. 427) and have multiple solutions and unclear outcomes and impact.

The pragmatic constructionist framework of interdisciplinary understanding suggests that the system is dynamic and students will frequently be in states of disequilibrium as they revise and reframe. This system "affords no guarantees…a conclusion is deemed acceptable not through a linear source of argumentation but through a host of sources of evidence (much of which may not precisely 'match up," but paints a telling picture. "(Boix Mansilla, 2010, p. 295). Students must manage this disequilibrium emotionally and cognitively.

Students perceive *tension* in translating research to practice, as they perceive the differences between the "ivory tower" of academia and the reality of educational contexts and a tension inherent in interdisciplinary collaboration with the differences between the goals and understandings of researchers and practitioners. Students perceive a *tension* between the need and desire for quick solutions and the reality of the state of the

knowledge and the pace of change, between the cultural perception of educators and the role educators might play in interdisciplinary efforts. They feel the *tension* of time for reflection and for the disciplinary learning, collaboration, and synthesis.

Students perceive a *tension* in balancing breadth and depth in understanding and coursework. Many students' prior experiences involve a focus and value on disciplinary learning. Interdisciplinary learning differs from disciplinary learning, emphasizing breadth over depth (Holley, 2009), and at the same time involves developing disciplinary knowledge in multiple disciplines. Gardner (2008, p.71) suggests that "mastery of disciplinary work" may be unattainable, however *multiperspectivalism,* a term he uses to describe the ability to "appreciate the complementary strengths of different perspectives" (p. 72), is achievable. Students perceive the cognitive and emotional stress of uncertainty and tension in achieving and valuing multipersectivalism, including the risk and vulnerability in making unsubstantiated claims and in being perceived as not having the depth of knowledge that is culturally valued.

Students experience many uncertainties such as: How much disciplinary knowledge is enough? How do I design my program to acquire the knowledge and skills I need to address my questions? "Am I preparing myself adequately…should I be doing that, should I be doing this?" (Raquel) Is the synthesis I am proposing useful and appropriate? Where do I fit in the field - what are the career options when I graduate? Will my work have an impact? The uncertainty is a stressor, which may be perceived as positive and motivating, may also challenge students.

Meaning and Importance of Findings

As a result of institutions of higher education, government, and international organizations seeking multiple perspectives on complex issues, there has been an increase in interdisciplinary programs in many fields. The field of education faces difficult problems such as poor educational outcomes, changing demographics, and the need for citizens to participate in the global, knowledge-based economy. Advances in developmental and neuroscience research, and the corresponding media publicity, are driving educators and researchers to explore how interdisciplinary efforts joining education, cognitive and developmental sciences, biology, and neuroscience might improve teaching and learning. MBE programs in higher education aim to provide students with the knowledge and skills to participate in collaborative research and apply the results of scientific research to educational problems. The results of this study will guide faculty and administrators in developing MBE programs to support students in gaining the skills and knowledge to participate in interdisciplinary research.

I have divided this section into five subsections, one to address the findings related to students' general perceptions of the program, three related to the three research questions, and one relating the concept *transformation* to the findings.

Perceptions of the MBE Program

Students find both a lab/research experience and a diverse cohort are important to their experience in the MBE program. According to the quantitative data, students who participate in a lab/research experience have more positive impressions of the program and also identify as *interdisciplinary* after the program more frequently those who do not participate. According the qualitative data, the interactions students have with diverse

cohort members supports them both intellectually and emotionally while in the program and provide resources and connections after graduation; the quantitative data suggest students are least satisfied with the social integration and cohesion of the program. These findings may guide administrators and faculty as they select which students to admit and plan the curriculum and co-curriculum. They may consider the diversity of the cohort in promoting the program and admitting students and may plan to build the cohesion of the cohort through opportunities for interaction and community-building. As faculty and administrators consider the curriculum and co-curriculum they may plan to integrate a lab/research experience into the students' program of study.

The results of this study suggest the MBE program is effective in shifting students' self-reported disciplinary affiliation from a single discipline to an *interdisciplinary* affiliation. Students find they value and are prepared to participate in collaborative interdisciplinary efforts, and then proceed after graduation to engage in interdisciplinary work related to MBE. These findings suggest that intentional interdisciplinary MBE programs may be effective in achieving the desired outcomes, validating the allocation of resources needed to develop such programs.

Research Question #1: Development as Interdisciplinary Researchers and Practitioners

The data support Boix Mansilla's (2010) framework of pragmatic constructionism. The concepts of *setting purpose*, *weighing disciplinary insights*, *leveraging integrations*, and *maintaining a critical stance* were evident in the qualitative data. In the quantitative data the adapted scales, *Recognizing Disciplinary Perspectives* (Lattuca et al., 2011), *Interdisciplinary Skills* (Lattuca et al., 2011), *Interdisciplinary Perspectives* (Misra et al.,

2008)*, and Reflective Behavior* (Lattuca et al., 2011)*,* measure the components of the framework. The results of each of the scales suggest the framework models students' interdisciplinary learning. The qualitative data suggest that students experience *uncertainty* in the process of continuous revision and the unknown outcomes of interdisciplinary work; struggle with resolving *tensions* such as between the amount of mastery necessary in disciplinary learning and balancing breadth and depth in their knowledge; and, perceive *risk* in interdisciplinary learning and work. These findings may guide program development to include opportunities for students to understand the dynamic nature of interdisciplinary learning and to gain experience and knowledge of each of the components. Admission counselors may seek students who have identified a problem-focused purpose for their study. Faculty may plan co-curricular support systems for students to explore the tensions, uncertainties, and risks they perceive in the process.

Research Question #2: Potential of MBE

Students are optimistic, and also cautious, about the potential of MBE and their contribution to the field. They perceive *risk* in the misinterpretation and misapplication of research and envision it will take significant *transformation* and *time* to change educational systems and the broader societal values to embrace interdisciplinary efforts in education. These findings may guide teacher education programs in planning for educators to fulfill course requirements in multiple disciplines and to acquire the skills and knowledge needed for collaborative work.

Research Question #3: Student Characteristics

Students enter the program having had interdisciplinary experiences and attribute their interest in interdisciplinary work to prior experiences. They participate in a variety

of activities that reflect their interest in multiple areas. Students' prior experiences affect their interdisciplinary work both positively and negatively, e.g., prior experience with disciplines is helpful in setting purpose and in synthesizing whereas a prior experience in a context that values the *right answer* hinders synthesis. Students find they need both individual and social skills in gaining interdisciplinary understanding, as it is both an individual and collaborative process. These findings may guide education programs serving learners before undergraduate and graduate school. If interdisciplinary research is necessary to address complex problems, students will need to develop the skills and habits of mind in their earlier educational experiences.

An understanding of the diverse skills and characteristics that students need in interdisciplinary learning can guide programs in selecting students and in developing those skills and characteristics. Interdisciplinary learning, as a problem-focused endeavor, is influenced by the broader culture. Kandel (2008) provides insight into some of the characteristics and skills needed for interdisciplinary work:

> "…it is important to be bold, to tackle difficult problems, especially those that appear initially to be messy and unstructured. One should not be afraid to try new things, such as…working at the boundaries of different disciplines, for it is at the borders that some of the most interesting problems reside." (p. 427)

Interdisciplinary learning in MBE draws on cognitive, emotional, social, and intrapersonal skills and traits that span a broad range. Students must be analytical and imaginative, think in linear and divergent ways, practice reflection and persuasion; they must build on existing knowledge and be open to new ideas and connections. They must be cognitively flexible and persevere when frustrated, overwhelmed, experience failure, and are confronted with uncertainty and ambiguity. They must be motivated, comfortable taking personal and professional risks, and pushing the boundaries of the existing culture

to proceed in entrepreneurial, and innovative ways. Students must be comfortable with a level of ambiguity and uncertainty in their work to be successful - feeling comfortable knowing they do not, and do not need to, *know it all*.

The students describe strong emotions and passion for solving problems stemming from their prior experiences, about the relationships they form with the cohort, about the faculty and administration, the workload, the stimulation and stress they experience, and the potential for change. Students must be able to self-regulate their emotions and maintain motivation in the face of uncertainty and challenge. As Carl says, "to make progress in a new field you have to be self motivated, because it is a new field and there is not an existing support structure."

The metaphors and phrases students use to describe their experiences reflect emotions of risk and anxiety, as well as excitement and stimulation, for example: "leap into the unknown," "choose your own adventure," "no safety net," "sacrifice," "drinking from a fire hydrant," "spinning plates," and "brain on fire." These findings on students' emotional responses, and the skills needed to regulate those emotions, may guide faculty and administrators in supporting students during the program.

Connections to Previous Studies

This case study fills a gap in the literature by exploring the perceptions of students in a graduate program in the field of MBE; to my knowledge, no previous study has investigated the student perceptions in MBE. This study adds to the limited empirical research on MBE, on student perceptions of the development of their interdisciplinary understanding and on the potential of MBE, and on characteristics and prior experiences of students in a graduate level interdisciplinary program.

This study reveals student characteristics and experiences to include a comfort level with uncertainty and risk-taking, strong individual cognitive and emotional skills, an ability to consider multiple perspectives and engage in collaboration, and an interest in solving problems at the intersection of traditional disciplinary boundaries.

I used two broad categories to review the literature for this study: *Dimensions of Interdisciplinary Understanding* and *Challenging and Effective Features of Interdisciplinary Programs*. The results of this study relate to and extend the findings of those in the literature review.

Dimensions of Interdisciplinary Understanding

The results offer empirical support for the four dynamic cognitive processes proposed by Boix Mansilla (2010) involved in developing a system of thought in reflective equilibrium in interdisciplinary understanding (Boix Mansilla, 2010) and illuminates students' perception of the challenges they face and the program structures, strategies, and the personal skills and characteristics they find effective in interdisciplinary study in the developing field of mind, brain, and education.

Previous studies investigate the dimensions of interdisciplinary understanding through the perceptions of researchers working in interdisciplinary institutions (Boix Mansilla, 2006) and those of faculty members teaching in highly regarded interdisciplinary undergraduate programs (Boix Mansilla and Duraising, 2007). My study adds to the literature, providing empirical evidence for students' perceptions of the processes involved in interdisciplinary understanding, revealing similar dimensions, including purpose, disciplinary grounding, integration, and critical awareness, which are

the elements of the pragmatic constructionism framework of interdisciplinary understanding (Boix Mansilla, 2010).

Borrego & Newswander (2010) analyze and review proposals submitted for IGERT funding and peer-reviewed interdisciplinary literature in the humanities to inform interdisciplinary graduate education. They find scientists emphasize *critical awareness* while those in the humanities emphasize *teamwork*. The findings of my study suggest that MBE students find both the individual cognitive skills involved in critical awareness and the social skills involved in teamwork to be important in MBE.

Misra et al. (2008) raise the question of the influence of students' prior educational experiences on their interdisciplinary learning. They find the research projects of students in the interdisciplinary program are no more integrated than those of students in a traditional program and suggest that the students in the traditional program may have experienced interdisciplinary mentorship in prior experiences My study suggests many students enter the program with prior interdisciplinary experiences, and identify as *interdisciplinary* prior to the program. In studies of interdisciplinary learning in the field of engineering, disciplinary affiliation appears to relate to students' interdisciplinary learning and skills (Knight, 2011); I found many of the MBE students identified as interdisciplinary before the program, or had engaged in interdisciplinary experiences prior to the program. My study adds to the literature by investigating student perceptions of the source of their interest in interdisciplinary work, and finds that students perceive these prior experiences with family, culture, and education to have influenced their affinity for making connections.

Spelt et al. (2009) review and analyze the literature on interdisciplinary learning and teaching to identify the subskills and conditions necessary for developing interdisciplinary understanding. They find that none of the studies meeting their criteria for inclusion investigate the personal characteristics or prior knowledge of students. My study fills this gap and provides empirical evidence for the personal characteristics they propose may be a *subskill and condition* for interdisciplinary higher education. They note personal characteristics of *curiosity, respect, openness, patience, diligence, and self-regulation.* My study reveals how these characteristics relate to interdisciplinary learning and suggests additional characteristics, such as tolerance for uncertainty. Spelt et al. (2009) suggest students' prior educational and social experiences may relate to interdisciplinary understanding; my study details student perceptions that their prior experiences are important in their interest in and affinity for interdisciplinary work, as well as in the processes involved in interdisciplinary understanding (i.e., setting purpose, weighing disciplinary insights, leveraging integrations, and maintaining a critical stance). Students perceive that early experiences, and the support they receive, in participating in diverse activities and interests relates to their interest in interdisciplinary work.

Challenging and Effective Features of Interdisciplinary Programs

The findings of this study support the findings of previous studies, which suggest that interdisciplinary programs are effective in enhancing students interdisciplinary skills (e.g., Drezek et al., 2008) and that the social environment (e.g., Gilkey & Earpe, 2006, Graybill et al., 2006), team projects (e.g., Lattuca et al., 2011, Minnis & John Steiner 2005), lab/research experiences (e.g., Holley, 2009), and an overarching structure with explicit connections among disciplinary concepts (e.g., Lattuca et al., 2011) relate to students'

interdisciplinarity. This study extends these findings and illuminates the importance of the cohort in students' interdisciplinary learning, as students find the diverse members of the cohort to be among the most supportive aspects of the program.

Misra et al. (2008) find that the Social Climate Scale predicted the *Behavior Change Collaborative Activities Index* and the *Interdisciplinary Perspectives Index*. The descriptive statistics in my study suggest the social climate of the MBE program may also relate to students' interdisciplinary understanding. Students' prior experiences suggest they have been thinking or acting in ways that are on the fringe of the traditional culture – they are dissatisfied with the current state of teaching and learning, have been seeking alternatives with a passion to effect change, experience an A*ha!* moment when they find the MBE program, and find the cohort to be a critical aspect of the program. The social climate and sense of a cohesive cohort community may affect students' interdisciplinary learning by providing a sense of belonging and community while they engage in an endeavor that is in many ways on the fringes of the established academic and broader communities. Students' passion and motivation may stem from the excitement of the *risk* and *tensions* involved in working at the boundaries of disciplines and developing innovative solutions. As Kandel (2008) says, "Few things are more exhilarating than bringing a new way of thinking to another discipline." (p. 310). This work may also be solitary and alienating; the positive social climate and cohesive cohort may provide a supportive sense of belonging to a community of like-minded people.

Holley (2009) interviewed students, faculty, and administrators in an interdisciplinary graduate neuroscience program and finds that students perceive the most valuable experience is participation in a lab/research environment. My study finds

that students find the experience positively affects their appreciation for interdisciplinary work and suggests the students who participate in a lab/research experience are more likely to shift their disciplinary affiliation to *interdisciplinary* and find the program more positive than those who do not participate in such an experience.

Students who participate in a lab/research experience report more positive responses on most of the items relating to the social emotional climate on the *Impressions* scale (e.g., *socially alienated to integrated* (5.52 v. 4.46, *socially fragmented to cohesive* (5.19 v. 4.36), *cold to warm* (6.08 v. 5.14), *competitive to cooperative* (6.42 v. 4.91; students without a lab experience report higher ratings on some categories, e.g., *progress hindered to advanced*, *unstimulating to stimulating*, *frustrated to satisfied*, although the differences on these items are less than .25).

Students who have a lab/research experience also more frequently identify as *interdisciplinary* after the program than those who do not have the experience (the percentage of students reporting interdisciplinary after the MBE program triples for those with a lab/research experience and doubles for those without a similar experience). Holley (2009) suggests future research might explore the role of laboratory communities in interdisciplinary education. The findings of my study suggest that the lab/research community may provide students with another community, in addition to the cohort community, which fosters a sense of belonging that results in students feeling more positively about the social climate of the program and enhancing their identity as interdisciplinary.

Applied Relevance

As interdisciplinary work becomes more prevalent and valued as a way to solve the many complex problems in education, an understanding of the student characteristics and their perceptions of the experiences related to interdisciplinary understanding will support their development. The results of this study are relevant to individuals and institutions engaged in MBE programs, to the field of MBE, and to interdisciplinary work in general, offering insight for institutions developing MBE programs to guide admissions; program development and evaluation; and, systems to attract and support students in MBE programs and in other interdisciplinary programs. This study illuminates some of the challenges students perceive the field of MBE faces in effecting change in educational practice and policy.

MBE and Interdisciplinary Programs

Admission

The findings of this study may guide institutions in attracting and selecting students who are engaged and motivated to participate in interdisciplinary efforts. The results suggest students perceive the diversity of the knowledge, skills, and backgrounds of the cohort to be among the most supportive aspects of their experience in interdisciplinary learning and understanding, as well as in their future interdisciplinary work. This finding may be relevant to programs and guide the admission process in selecting a diverse cohort in terms of age, experience, and disciplinary background. Programs seeking student satisfaction in MBE may also consider individual student characteristics such as cognitive flexibility, openness, tolerance for ambiguity and uncertainty, and strong intrapersonal and social skills in the admission process. Admission

counselors may talk with prospective students about the initiative and dedication that is necessary to attain disciplinary knowledge in multiple fields, as well as the struggles inherent in interdisciplinary learning, such as the tensions, ambiguity and uncertainty that students experience. Students looking for a clear practical application or career option may be counseled about the ongoing nature of interdisciplinary understanding and the entrepreneurial nature of work in the field.

Program Development

Faculty may plan for curricular and co-curricular experiences such as participation in a lab/research environment, foundational courses to fill gaps, time for reflection, explicit connections and models, and opportunities for students to practice interdisciplinary work in practical contexts and to develop skills for collaborative work, such as communication skills.

The findings may guide program administrators in planning infrastructures to support the development of a cohesive cohort and positive social climate. These relationships and interactions will support students while they are in the program as well as provide the foundation for connections after graduation. Structures to support students in developing the skills needed for collaborative work and for managing the tensions and ambiguities may facilitate student success and future engagement in interdisciplinary work.

Institutional leaders may consider how the culture of the institution conveys messages of disciplinary hierarchy, the relative status of researchers and practitioners, and the value of interdisciplinary work. Students find the hierarchy of the disciplines, perceiving education as less valued than the sciences (biology, psychology, neuroscience),

challenging in interdisciplinary collaboration. The traditional disciplinary organization of higher education may reinforce a hierarchal structure through domain-specific departments, physically separated facilities, and differentiated compensation.

As interdisciplinary collaboration becomes more prevalent and necessary, educational systems at all levels may consider how to support students in developing the characteristics and skills that emerge as necessary for interdisciplinary work: flexibility; comfort with risk, tensions, ambiguity and uncertainty; social skills; and, critical thinking skills.

Field of MBE

Students are optimistic about the potential of MBE to influence educational practice and policy, however they perceive significant challenges and a slow process. Among the challenges are the potential for misinterpretation and misapplication in a search for a quick solution to educational problems and to counter the influence of commercial marketing. MBE's influence may be dependent on a cultural shift of significant magnitude in academia, as well as the larger society, in the perception of the status and roles of educators; and, in the perception of the potential contribution of interdisciplinary and collaborative work. Teachers' contributions may be valued, and teachers empowered, when the larger society recognizes and values what educators may bring to collaborative efforts in terms of knowledge of the individuals in their classrooms and knowledge of child development. The structure of educational contexts may need to change to facilitate greater cross-disciplinary interaction, to value multi-disciplinary interests, to emphasize social skills, and to structure time for reflection. To support interdisciplinary collaboration, changes in the culture of schools may include changes in values, such as

valuing the *right* answer and accumulation of static knowledge. Making such a shift is a slow process and may begin with changes in educator preparation programs to include more coursework in critical thinking and group skills, research methods, and interdisciplinary study.

To empower teachers to work collaboratively and contribute to interdisciplinary research, students perceive the need to revise the current model of education, including educator preparation, school cultures, and society's perception of the role and status of educators. They suggest schools of education may consider additional coursework in research methods and interdisciplinary knowledge, an emphasis on skills needed for collaboration and critical thinking, and strategies to influence student educators' perception of themselves as collaborative researchers. School cultures may reward and support risk-taking, innovation, and collaboration. This may mean changing the workload and structure of the traditional educational environment, schedule, and calendar to allow for more reflection, collaboration, and knowledge building. Society may perceive practicing educators as having relevant knowledge to contribute to research to address educational problems. At the same time, we must proceed cautiously and with consideration.

Limitations

Generalizability is a major limitation to this study. As a case study of one well-established program within a highly regarded institution, the findings may not be generalized to other MBE or interdisciplinary programs. The generalizability of the study may also be limited because Boix Mansilla's work is closely connected with the Harvard Graduate School of Education; this circular connection of the theoretical framework of this

paper to the program may limit the generalizability of the findings to programs without such a connection. Boix Mansilla is associated with the program through her role at Project Zero, an organization affiliated with HGSE. Boix Mansilla is a co-principal investigator with Howard Gardner on the Interdisciplinary Studies Project at Project Zero and has co-authored articles on interdisciplinarity with Gardner. Gardner has been involved with the MBE program since its inception, is listed as faculty in the MBE program, has taught HT-100, and is senior director of Project Zero.

The sections below describe how the study is further limited by the small sample size, programmatic factors, the experiences of the participants, and the design of the study.

Programmatic limitations

My analysis was limited because I was unable to obtain application, admission and enrollment statistics due to HGSE policy, which restricts access to this information. The University denied my request for the information due to University policy.

The study is limited because the participants took the core course, HT-100, at different times of the year and for different lengths of time. Some of the alumni took HT-100 as a full-year course and some took it as a fall semester course. Some of the current students took HT-100 as a fall semester course and some took it as a spring course. The core course provides the foundation of concepts, skills, and domain knowledge of the field of MBE (Table 16) and serves as the primary structure for the cohesion of the cohort. Because the participants experienced different content and amounts of time in the course, and because some students had not yet completed the course during the time of the study, all participants did not have similar experiences.

Participant Experiences

The survey and interviews included alumni from the graduating classes of 2007-2012; these alumni participants relied on their memory of their experiences from several years prior and their recollections may not accurately reflect their perceptions during the program. Similarly, the respondents may be biased in self-reporting and in remembering their experiences.

The results are limited because many students enter the program with interdisciplinary experiences, identify as interdisciplinary before the program, and attribute their interest in interdisciplinary work to prior experiences. More than 20% of the students identified as interdisciplinary before entering the program, and 30 of the 55 students had interdisciplinary professional or educational experiences prior to the program. Many of the respondents pursued multiple disciplines in their undergraduate programs or had majored in science or psychology and subsequently pursued education-related jobs. For example, one respondent replied: "I studied neuroscience in college and, after graduating, became interested in the field of education research and innovation. I enrolled in the MBE program because I wanted to transition from the field of neuroscience to the field of education." Almost all the interview participants had multidisciplinary educational and professional backgrounds and 12 of the survey participants described in the comment section of survey question 7 that they had interdisciplinary experiences and an appreciation for interdisciplinary work and collaboration prior to entering the program. As one survey participant wrote: " I came in with an appreciation for interdisciplinary and collaborative work, so the program simple reinforced my conviction for the necessity of this kind of work."

Design limitations

The timing of the data collection may limit the study. In scheduling interviews with the current students in the classes of 2012 and 2013, some students interviewed during the fall semester and some interviewed during the spring semester. As a result of this discrepancy, some students had experienced nearly the full program, while others had just begun; their perceptions of the program and their academic experiences may be very different.

Because the online survey and face-to-face interview participants are not exclusive (i.e., a respondent may have participated in both the online survey and face-to-face interview) the data may over-represent some students. Additionally, because I had access only to the general listserv address, not to specific individuals, and because the surveys are anonymous, alumni of years prior to 2012 received the survey in the spring of 2012 and of 2013 and I am unable to determine if an alumnus responded to the survey twice.

There are concerns with the validity and reliability of the scales as used in this study. I used the following scales from Lattuca et al. (2011): *Recognizing Disciplinary Perspectives, Interdisciplinary Knowledge and Skills, Reflective Behavior,* and *Teamwork Skills.* A used Misra et al.'s (2009) *Interdisciplinary Perspectives Index, Behavior Change Collaborative Activities Index,* and *Lab Impressions* scales. In adapting the scales I changed the wording of some of the questions, eliminated some questions, and used the scales with a different population than the original authors, which affects the reliability and validity of the scales. The participants in Lattuca et al.'s (2011) study are undergraduate engineering students and those in Misra et al.'s (2009) are undergraduate health care students. It is possible that undergraduate students and graduate students differ, and that MBE students

differ from engineering students or from students interested in health care. In changing the wording of the questions and the number of items on the scales, the validity of the scales may be affected.

Further Research

Future study of MBE and interdisciplinary programs may build on the findings of this study to further explore the aspects of the program that relate to student characteristics and the core course and lab/research experience.

Student Characteristics

This study suggests that student characteristics and skills such as the ability to tolerate risk, uncertainty, and tension are necessary for interdisciplinary work in MBE. Future research may further explore students' perceptions of these characteristics. Research may focus on students' ratings of particular skills and characteristics before and after the program and analyze the relationship between student characteristics and their interdisciplinary knowledge and skills.

Further research may also investigate how experience relates to students' perceptions of MBE and the influence it may have on education. Alumni rate the potential of MBE to inform education and the potential for their personal contribution to collaborative MBE efforts slightly higher than do current students, suggesting alumni are more optimistic about the potential of MBE and their contribution to collaborative efforts than are current students. It is possible that the alumni's optimism may be related to the time they have had for reflection within the context of experience; it is also possible that the alumni who chose to participate in this study had been more involved in the program, i.e., their experience in the program relates to their optimism.

Curriculum: Core Course and Lab/Research Experience

Students in this study respond to the core course with strong emotion, referring to the cognitive and social challenges and rewards of their experience in HT-100. The course as taught during the time of the study offers opportunities to provide a broad and systems perspective and explicit models of interdisciplinary work; facilitate a cohesive cohort community; and, to support students in developing individual and social skills and foundational knowledge. Future research may explore the relationship between the length and timing of a core course and students' perception of their membership in a cohort, the social climate of the program, and students' interdisciplinary skills and knowledge.

This study suggests there may be a relationship between students' interdisciplinary learning and their participation in a lab/research experience. Future research may elucidate the features of the experience that are related to interdisciplinary understanding, such as the focus of lab/research environment as disciplinary or interdisciplinary, how closely the experience relates to a student's coursework, and the impact of prior lab/research experiences. Studies may also explore the programmatic support for the experience, e.g., the number of options, the ease and convenience of access to an experience, and length and number of hours of participation to identify the factors that may relate to students perceptions of the program and their interdisciplinary skills. Future research may also investigate the characteristics of students who participate in the lab/research experience. For example, students' prior experiences, such as their backgrounds in research, may relate to their decision to participate in a lab/research experience.

Conclusion

Students enter the MBE program fueled by a passion to solve a complex problem stemming from their personal prior experience and bring skills and characteristics that support their interest and affinity for interdisciplinary and innovative work. They join a diverse cohort eager to change some of the social injustices in the education system and are both challenged and inspired by their struggles with the uncertainty, ambiguities, and tensions of the path, goals, and work involved in gaining the knowledge, skills, and habits of mind needed to gain disciplinary insights, synthesize vast amounts of information, and continually reflect and revise. They are personally transformed and inspired to create innovative solutions. They are optimistic about the potential of MBE to influence educational practice and policy and perceive a need for significant change in power structures, value systems, and long-standing practices and beliefs to effect much-needed reform in education.

Boix Mansilla (2010) suggests a system of thought in reflective equilibrium, unlike propositional knowledge, requires students "be prepared to criticize, revise, reinterpret, and abandon intellectual commitments when more reasonable ones are conceived (p. 295)." The results shed light on the skills students use to do this; how they "manage the tensions, incompatibilities, and complementarities among insights from multiple domains" (Boix Mansilla, 2010, p. 304); and describes students' struggles and the aspects of programming they find supportive.

Boix Mansilla (2010) suggests the dynamic process of interdisciplinary learning necessarily involves transformation and innovation ("revision of understanding, new setting of purpose, novel disciplinary insights, integrations and the construction of yet a

new system of thought in reflective equilibrium" p. 302) as students revise their thinking and beliefs in a problem-focused endeavor. The results of this study suggest that students perceive interdisciplinary work in MBE involves transformation and innovation in multiple ways, as they themselves are transformed and they perceive a need to transform the educational system and social perceptions.

The results of the study reveal the characteristics of students who thrive in an environment of tension, uncertainty, and ambiguity. These findings reflect Gardner's (2008) *synthesizing minds* and *creating minds*. Gardner (2008) distinguishes between the *synthesizer*, who demonstrates "the ability to knit together information from disparate sources into a coherent whole" (p.46) and the *creator,* who "generates a product in a particular domain [that] is recognized by the relevant field as innovative and in turn, sooner or later, exerts a genuine, detectable influence on subsequent work in that domain" (p. 81). The characteristics of individuals reflect this distinction, as Gardner (2008) describes:

> Indeed, no sharp line separates synthesis from creation…yet, the impulses behind the two mental stances are distinctive. The synthesizer's goal is to place what has already been established in as useful and illuminating a form as possible. The creator's goal, on the other hand, is to extend knowledge, to ruffle the contours of a genre, to guide a set of practices along new and hitherto unanticipated directions. The synthesizer seeks order, equilibrium, closure; the creator is motivated by uncertainty, surprise, continual challenge and disequilibrium. (p.98 – 99)

The emerging field of MBE may involve both *synthesizers* and *creators* as interdisciplinary work in MBE has the potential to both provide additional evidence for current educational practice and to create significant change.

The characteristics of students in this study reflect Gardner's (2008) *creators*. Eric exemplifies the *creator* saying, "I've always loved being able to see something from

multiple sides because it generates conflict in some ways and I like the conflict. I think that's what pushes you to do that more and go deeper." Gardner (2008) notes, "the aspiring creator needs a generous supply of intelligence(s), skill, and discipline…[and] stands out in terms of temperament, personality, and stance." (p. 82 – 83). The students in this study are extraordinarily passionate, intelligent, and disciplined. They seek change and improvement, are curious, motivated, and engaged in diverse interests. They are aware the value of their work may not be recognized immediately; they accept being on the fringes of the broader culture, yet enthusiastic to develop a supportive community among like-minded peers.

This study illuminates student perceptions of the social, emotional and cognitive skills needed in interdisciplinary work; the personal characteristics, prior experiences, and programmatic features that support interdisciplinary understanding; the tensions and uncertainties inherent in the work; the potential of MBE to improve educational practice and policy; and, the challenges of achieving that potential. The study adds literature on MBE programs and empirical study to replicate and extend findings from previous studies regarding the diversity of the cohort, participation in a lab/research experience, the social and emotional skills and characteristics of students, and the cognitive processes involved in interdisciplinary learning. The findings will guide MBE program development and evaluation and has implications for the developing field of MBE and interdisciplinary teaching and learning.

Appendix A

MBE Course Requirements

This list of courses was taken from the website designed for the 2013-2014 year.

MBE Foundations Courses

Students must choose **two** courses from the following list. These courses are designed to provide foundational knowledge about mind, brain, and education, including a survey of key concepts, findings, and practices from the field.

- H-107 Introduction to Education Neuroscience
- H-112* Cognitive Neuroscience and Education
- H-137 Emotional Development: Biology, Relationships, Culture
- H-156 Research Schools
- HT100 Cognitive Development, Education, and the Brain (required during the time of the study)
- HT-104 Foundations of Developmental Pedagogy, Assessment, and Research
- T-560* Universal Design For Learning: Meeting the Challenge of Individual Differences

The following course at the Harvard Faculty of Arts and Sciences (FAS) also counts as an MBE Overview Course:

*PSY 2354r Advanced Laboratory in Cognitive Neuroscience

Additional MBE Courses

At the time of the study, MBE students chose two additional MBE Courses from the three didactic categories listed below. Students can take any combination of courses from these lists; there is no distribution requirement across the categories. In addition, MBE Foundations Courses beyond the required two courses (as listed above), can also count toward the three additional MBE courses.

Cognition & Neuroscience

- A133 Cultural Explanations for Ethnic and Racial Inequality in Education
- H-110G* Learning in a Globalizing World: Language Acquisition, Cultural Awareness, and Cognitive Justice
- H-156 Research Schools
- H-175 Good Work in Education: When Excellence, Engagement and Ethics Meet
- H-180 Cognitive Development and Trust in Testimony
- H-250 Developmental Psychology: Psychology of Early Childhood

- *H-331 Risk and Resilience in Social Contexts from Birth to Young Adulthood: Strategies of Prevention and Intervention
- H-382* The Challenges Kids Face: Developmental, Cultural, and Contextual Perspectives on Risk and Resilience
- H-392* Childhood Trauma: Dynamics, Interventions, and Cross-Cultural Perspectives
- H-700 From Language to Literacy
- H-870 Reading Comprehension
- HT-500 Growing Up in a Media World
- S-105 Philosophy of Education
- S-504* Introduction to Qualitative Research
- T-006 Adult Development
- T-543 Applying Cognitive Science to Learning and Teaching

The following courses offered in Harvard Faculty of Arts and Sciences can be counted toward the Additional MBE Course requirements:

- Computer Science 182 - Intelligent Machines: Reasoning, Actions, and Plans
- MCB 80 Neurobiology of Behavior
- MCB 105 Systems Neuroscience

Note: students may also choose from any course listed as part of the Mind/Brain/Behavior concentration in the Faculty of Arts and Sciences.

Learning & Instruction

- A-111J Critical Issues in Special Education Policy and Practice (winter, Schifter)
- A-117 Implementing Inclusive Education (fall, Hehir)
- A-418: The History of Education in the United States (fall, Reuben)
- AH-103 Educational Outcomes in Cross-National and Cross-Cultural Perspectives (spring, Harris)
- H-803 Developing Adolescent Literacy (spring, Lesaux)
- H-804 Writing Development (spring, Faller)
- H-810C Advancing Literacy through Learning in Content Classrooms (fall, Jacobs)
- H-813 Bilingual Learners: Literacy Development and Instruction (spring, Uccelli)
- H-818 Reading Instruction and Development (fall, Mason)
- HT-123 Informal Learning for Children (winter, 4 credits, Blatt)
- HT-500 Growing Up in a Media World (fall, Blatt)
- S-105 Philosophy of Education (fall, Elgin)
- S-305 Active Learning in Museums (winter, 4 credits, Tishman)
- T-407 Teaching and Learning Across the Curriculum (fall, Star)
- T-440 Teaching and Learning: "The Having of Wonderful Ideas" (fall, Schneier)
- T-523* Formative Evaluation for Educational Product Development (spring, Reich)

Research Methods & Assessment

- H-156 Research Schools
- *H-397 Research Experience in Prevention Science & Practice
- H-818 Reading Instruction and Development

- *HT-820 Introduction to Psychoeducational Assessment
- S-005 Introduction to Educational Research
- S-011 Understanding Today's Educational Testing
- S-012 Empirical Methods: Introduction to Statistics for Research
- *S-030 Intermediate Statistics: Applied Regression and Data Analysis
- *S-040 Introduction to Applied Data Analysis
- *S-061A1 Methods of Educational Measurement
- *S-061A2 Methods of Educational Measurement
- *S-504 Introduction to Qualitative Research
- T-800: Research and Evidence: Framing Scientific Research for Public Understanding

Electives

As part of the required eight courses, MBE students take three courses of their choice at HGSE or at other Harvard or MIT schools through cross-registration. MBE students should consider that at least four of their courses must be taken at HGSE.
Many HGSE students choose to take courses at other Harvard graduate schools such as the Faculty of Arts and Sciences (FAS) and the Harvard Kennedy School.

*Note: research commitment/permission of the instructor is required to take this course.

Appendix B

Scales adapted from Misra et al., 2009

Misra, S., Stokols, D., Harvey, R., Pine, K., Fuqua, J., Shokair, S., & Whiteley, J. (2009). Evaluating an interdisciplinary undergraduate training program in health promotion research. *American Journal of Preventive Medicine*, 36*(4)*, 358-365.

Interdisciplinary Perspectives Index

The following items pertain to some of your thoughts and expectations about your ID-SURE project. Please indicate how strongly you agree with each of the following statements. Additional comments can be added to the right or under the questions.

Comments:

1. **In my own research, I typically use multiple research methods drawn from more than one discipline rather than rely exclusively on a single disciplinary approach.**

( )	( )	( )	( )	( )
strongly agree	agree	not sure	disagree	strongly disagree

2. **I prefer to conduct research independently rather than as part of a group.**

( )	( )	( )	( )	( )
strongly agree	agree	not sure	disagree	strongly disagree

3. **I would describe myself as someone who strongly values interdisciplinary collaboration.**

( )	( )	( )	( )	( )
strongly agree	agree	not sure	disagree	strongly disagree

4. **Generally speaking, I believe that the benefits of interdisciplinary research outweigh the inconveniences of such work.**

( )	( )	( )	( )	( )
strongly agree	agree	not sure	disagree	strongly disagree

5. **I am optimistic that interdisciplinary collaboration among ID-SURE collaborators will lead to valuable scientific outcomes that would not have occurred without that collaboration.**

( )	( )	( )	( )	( )
strongly agree	agree	not sure	disagree	strongly disagree

6. **Overall, I believe that a high level of good will exists among the research associates at UCI affiliated with my research.**

( )	( )	( )	( )	( )
strongly agree	agree	not sure	disagree	strongly disagree

7. **Overall, ID-SURE members as a group, are open-minded about considering research perspectives from fields other than their own.**

( )	( )	( )	( )	( )
strongly agree	agree	not sure	disagree	strongly disagree

Misra, S., Stokols, D., Harvey, R., Pine, K., Fuqua, J., Shokair, S., & Whiteley, J. (2009). Evaluating an interdisciplinary undergraduate training program in health promotion research. *American Journal of Preventive Medicine*, 36*(4)*, 358-365.

Behavior Change Collaborative Activities Index

Considering your involvement with any kind of research activities at UCI, please assess the degree to which you engage in any of the following activities, referring to the 7-point scale below where "1" indicates "never" "4" indicates "sometimes" and "7" indicates "very often"

1	2	3	4	5	6	7
Never			Sometimes			Very often

a. Read journals outside your field or major? ___

b. Attend conferences outside your field or major? ___

c. Participate in groups with researchers in other fields with the intent to integrate ideas?___

f. Obtain new insights into your own area of research through discussion with other researchers (e.g., developed a new concept or hypothesis that bridges or integrates different disciplinary or theoretical approaches to your research)? ___

g. Attempt to establish links with other interdisciplinary researchers that may lead to future collaborative studies? ___

j. Actually design a new collaborative study as a result of working on an ongoing interdisciplinary project? ____

k. Take classes outside your field or major?___

Over the course of your involvement as an ID-SURE fellow, please assess the degree to which each of the following behaviors has increased, decreased, or remained the same referring to the 7-point scale below where "1" indicates "decreased," "4" indicates "remained the same," and "7" indicates "increased."

1	2	3	4	5	6	7
Decreased			Remained the same			Increased

d. Your appreciation for interdisciplinary research collaboration____

e. Your "readiness to collaborate" with researchers from other fields?____

Misra, S., Stokols, D., Harvey, R., Pine, K., Fuqua, J., Shokair, S., & Whiteley, J. (2009). Evaluating an interdisciplinary undergraduate training program in health promotion research. *American Journal of Preventive Medicine*, 36*(4)*, 358-365.

Lab Impressions Scale

For each item below, please place a check mark in the box that best describes the social climate of the research lab or group you work in.

3a. Discouraging	☐	☐	☐	☐	☐	☐	☐	Encouraging
3b. Competitive	☐	☐	☐	☐	☐	☐	☐	Cooperative
3c. Un-stimulating	☐	☐	☐	☐	☐	☐	☐	Stimulating
3d. Cold	☐	☐	☐	☐	☐	☐	☐	Warm
3e.Socially Fragmented	☐	☐	☐	☐	☐	☐	☐	Socially Cohesive

For each item below, please place a check mark in the box that best represents your personal experiences as a member of the research lab or group you work in.

4a. Pessimistic	☐	☐	☐	☐	☐	☐	☐	Optimistic
4b. Socially Alienated	☐	☐	☐	☐	☐	☐	☐	Socially Integrated
4c. Intellectually Isolated	☐	☐	☐	☐	☐	☐	☐	Intellectually Integrated
4d. Frustrated	☐	☐	☐	☐	☐	☐	☐	Satisfied
4e. Progress Hindered	☐	☐	☐	☐	☐	☐	☐	Progress Advanced

Appendix C

Scales adapted from Lattuca et al., 2011

Interdisciplinary Skills (alpha=.80) Do you agree or disagree?[A]
I value reading about topics outside of engineering.
I enjoy thinking about how different fields approach the same problem in different ways.
Not all engineering problems have purely technical solutions.
In solving engineering problems I often seek information from experts in other academic fields.
Given knowledge and ideas from different fields, I can figure out what is appropriate for solving a problem.
I see connections between ideas in engineering and ideas in the humanities and social sciences.
I can take ideas from outside engineering and synthesize them in ways to better understand a problem.
I can use what I have learned in one field in another setting or to solve a new problem.
Recognizing Disciplinary Perspectives (alpha = .69) Do you agree or disagree?[A]
I recognize the kinds of evidence that different fields of study rely on.
If asked, I could identify the kinds of knowledge and ideas that are distinctive to different fields of study.
I'm good at figuring out what experts in different fields have missed in explaining a problem or proposing a solution
Reflective Behavior (alpha = .73) Do you agree or disagree?[A]
I frequently stop to think about where I might be going wrong or right with a problem solution.
I often step back and reflect on what I am thinking to determine whether I might be missing something.
Teamwork Skills (alpha = .86) Please rate your ability to:[A]
Work in teams of people with a variety of skills and backgrounds.
Work with others to accomplish group goals.
Work in teams where knowledge and ideas from multiple engineering fields must be applied.
Work in teams that include people from fields outside engineering.
Put aside differences within a design team to get the work done.

[A]1: Strongly disagree; 2: Disagree; 3: Neither agree nor disagree; 4: Agree; 5: Strongly agree
[B]1: Weak/none; 2: Fair; 3: Good; 4: Very good; 5: Excellent

Appendix D

Interview Questions

Faculty and Administrators

What are the goals and purpose of the MBE program?

What careers do you anticipate students may have?

What educational backgrounds and experiences do you prioritize in admitting students?

How do you think the subscales on the survey relate to the MBE program?

How do you support students in gaining skills and knowledge in multiple disciplines?

How do you support students in integrating skills and knowledge from multiple disciplines?

What challenges do you see in fostering interdisciplinary understanding?

How do you assess students' interdisciplinary learning?

What were the major influences on the evolution of the program?

What do you perceive to be the greatest strengths and the greatest challenges to the program?

What do you believe about the potential of MBE to influence educational practice and policy? How would you describe the potential of MBE to influence educational practice and policy?

Alumni

Why did you enroll in the MBE program?

How would you describe the purpose of the program?

What were your educational and professional experiences before entering?

How would you describe your experience in the MBE program? What was challenging and was effective?

In what disciplines was it necessary for you to gain new knowledge?

What was your experience synthesizing and integrating knowledge and skills from multiple disciplines?

How prepared do you feel to communicate with professionals in other disciplines?

In what ways was the program successful and what changes would you recommend?

What have you done since completing the program?

How did your experiences influence your choice of work/education after completing the program?

How did family, community, and educational experiences contribute to your interest in using an interdisciplinary approach to problems?

Is the interdisciplinary perspective you bring to your work in MBE evident in other areas of your life?

How would you describe the potential of MBE to influence educational practice and policy?

Students

Why did you enroll in the program?

How would you describe the purpose of the program?

What were your professional and educational experiences before you began the program?

How would you describe your experience in the MBE program? What is challenging and what is effective?

In what disciplines was it necessary for you to gain new knowledge?

What is your experience synthesizing and integrating knowledge and skills from multiple disciplines?

How prepared do you feel to communicate with professionals in other disciplines?

In what ways was the program successful and what changes would you recommend?

What do you plan to do when you complete the program?

How did your experiences influence your choice of work/education when you complete the program?

How did family, community, and educational experiences contribute to your interest in using an interdisciplinary approach to problems?

Is the interdisciplinary perspective you bring to your work in MBE evident in other areas of your life?

How would you describe the potential of MBE to influence educational practice and policy?

Appendix E

MBE Survey

Introduction

Thank you for participating in the following online interview, which is part of a dissertation case study of the Harvard Graduate School of Education master's program in mind, brain, and education (MBE). The results of this research will be valuable in illuminating student perceptions on the development of interdisciplinary understanding and the potential, as well as the limitations, of the field of mind, brain, and education.

The following questions include responses on a Likert scale, open-, and closed-questions. This online interview is anonymous and will take approximately 20 - 30 minutes to complete. Please complete the entire interview - there are 43 questions on 8 pages; the final page consists of demographic questions. A progress bar will show at the bottom of each page.

Your informed consent to participate in the study under the conditions described is assumed by your completing the interview and submitting it to the researcher. Do not complete the online interview or hand it in if you do not understand or agree to these conditions

Thank you for your participation,
Martha Christenson Lees

MBE Program Experiences

1. Why did you enroll in the MBE program?

2. Please rate your overall experience in the MBE program. The ratings range from socially alienated to socially integrated.

- ◯ Very socially alienated
- ◯ Moderately socially alienated
- ◯ Slightly socially alienated
- ◯ Neutral
- ◯ Slightly socially integrated
- ◯ Moderately socially integrated
- ◯ Very socially integrated

Comment

3. Please rate your overall experience in the MBE program. The ratings range from intellectually isolated to intellectually integrated.

- ◯ Very intellectually isolated
- ◯ Moderately intellectually isolated
- ◯ Slightly intellectually isolated
- ◯ Neutral
- ◯ Slightly intellectually integrated
- ◯ Moderately intellectually integrated
- ◯ Very intellectually integrated

Comment

4. Please rate your overall experience in the MBE program. The ratings range from frustrated to satisfied.

- ◯ Very frustrated
- ◯ Moderately frustrated
- ◯ Slightly frustrated
- ◯ Neutral
- ◯ Slightly satisfied
- ◯ Moderately satisfied
- ◯ Very satisfied

Comment

5. Please rate the effect of the MBE program on your overall intellectual development. The ratings range from hindered to advanced.

- ◯ Very hindered
- ◯ Moderately hindered
- ◯ Slightly hindered
- ◯ Neutral
- ◯ Slightly advanced
- ◯ Moderately advanced
- ◯ Very advanced

Comment

6. Please rate:

1.) how you feel about the potential of the field of MBE to inform education; and,

2.) how you personally may contribute to collaborative MBE efforts to inform education.

The ratings range from pessimistic to optimistic.

	Very pessimistic	Moderately pessimistic	Slightly pessimistic	Neutral	Slightly optimistic	Moderately optimistic	Very optimistic
The field of MBE	◯	◯	◯	◯	◯	◯	◯
Your personal preparation	◯	◯	◯	◯	◯	◯	◯

Comment

7. Please assess the degree to which each of the following behaviors increased, decreased or remained the same as a result of your participation in the MBE program.

	Significantly decreased	Moderately decreased	Somewhat decreased	Remained the same	Somewhat increased	Moderately increased	Significantly Increased
Your appreciation for interdisciplinary research collaboration	○	○	○	○	○	○	○
Your "readiness to collaborate" with researchers from other fields	○	○	○	○	○	○	○

Comment

8. What experiences help(ed) you most in integrating knowledge and methods from multiple disciplines?

9. What challenges did you face in integrating knowledge from multiple disciplines?

10. What challenges did you face working on an interdisciplinary project that you think you would not have encountered working on a non-interdisciplinary project?

11. Were you involved in interdisciplinary employment, research lab or internship experience while enrolled in the MBE program?

- ◯ Yes
- ◯ No

Please describe

12. How did this experience affect your appreciation of interdisciplinary work?

- ◯ Very positively
- ◯ Moderately positively
- ◯ Slighlty positively
- ◯ Neutral
- ◯ Slightly negatively
- ◯ Moderately negatively
- ◯ Very Negatively

Comment

13. How would you describe your affiliation before and after completing the MBE program?

	"Mind"	"Brain"	"Education"	Interdisciplinary	Other (please describe)
Before the MBE program	◯	◯	◯	◯	◯
After the MBE program	◯	◯	◯	◯	◯

Comment

Interdisciplinarity

14. How would you describe the purpose of MBE?

15. How would you describe the potential of MBE to influence educational practice and policy?

16. Teamwork Skills

Please rate your ability to:

	Weak/None	Fair	Good	Very Good	Excellent
Work with others to accomplish group goals	◯	◯	◯	◯	◯
Work in teams of people with a variety of skills and backgrounds	◯	◯	◯	◯	◯
Work in teams where knowledge and ideas from multiple fields must be applied	◯	◯	◯	◯	◯
Work in teams that include people from fields outside education	◯	◯	◯	◯	◯
Put aside differences within a team to get the work done	◯	◯	◯	◯	◯

Comment

17. Interdisciplinary Knowledge and Skills

Please indicate your level of agreement with the following statements.

	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
I value reading about topics outside of education (psychology, neuroscience, biology, politics, history, etc.).	○	○	○	○	○
I enjoy thinking about how different fields approach the same problem in different ways.	○	○	○	○	○
In solving educational problems I often seek information from experts in other academic fields.	○	○	○	○	○
Given knowledge and ideas from different fields, I can figure out what is appropriate for solving a problem.	○	○	○	○	○
I see connections between ideas in education and ideas in the sciences and psychology.	○	○	○	○	○
I can take ideas from outside education and synthesize them in ways that help me better understand or explain a problem.	○	○	○	○	○
I can use what I have learned in one field in another setting or to solve an educational problem.	○	○	○	○	○

Comment

18. Reflective Behavior

Do you agree or disagree?

	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
I frequently step back and reflect on what I am thinking to determine whether I might be missing something.	◯	◯	◯	◯	◯
I frequently stop to think about where I might be going wrong or right with a problem solution.	◯	◯	◯	◯	◯

Comment

19. Recognizing Disciplinary Perspectives

Do you agree or disagree?

	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
If asked, I could identify the kinds of knowledge and ideas that are distinctive to different fields of study (psychology, biology, neuroscience, etc.).	◯	◯	◯	◯	◯
I recognize the kinds of evidence that different fields of study rely on.	◯	◯	◯	◯	◯
I'm good at figuring out what experts in different fields have missed in explaining a problem or proposing a solution.	◯	◯	◯	◯	◯

Comment

20. Interdisciplinary Perspectives Index

Please indicate how strongly you agree with each of the following statements.

	Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly agree	N/A
In my own research, I typically use multiple research methods drawn from more than one discipline rather than rely exclusively on a single disciplinary approach.	◯	◯	◯	◯	◯	◯
I prefer to conduct research independently rather than as part of a group.	◯	◯	◯	◯	◯	◯
I would describe myself as someone who strongly values interdisciplinary collaboration.	◯	◯	◯	◯	◯	◯
Generally speaking, I believe that the benefits of interdisciplinary research outweigh the inconveniences of such work.	◯	◯	◯	◯	◯	◯
I am optimistic that interdisciplinary collaboration among MBE collaborators will lead to valuable scientific outcomes that would not have occurred without that collaboration.	◯	◯	◯	◯	◯	◯
Overall, I believe there is a high level of support within HGSE for MBE research.	◯	◯	◯	◯	◯	◯
Overall, MBE members as a group are open-minded about considering research perspectives from fields other than their own.	◯	◯	◯	◯	◯	◯

Comment

Social Climate of the MBE Program

21. Please rate the climate of the MBE program. The ratings range from discouraging to encouraging.

- ◯ Very discouraging
- ◯ Moderately discouraging
- ◯ Slightly discouraging
- ◯ Neutral
- ◯ Slightly encouraging
- ◯ Moderately encouraging
- ◯ Very encouraging

Comment

22. Please rate the climate of the MBE program. The ratings range from competitive to cooperative.

- ◯ Very competitive
- ◯ Moderately competitive
- ◯ Slightly competitive
- ◯ Neutral
- ◯ Slightly cooperative
- ◯ Moderately cooperative
- ◯ Very cooperative

Comment

23. Please rate the climate of the MBE program. The ratings range from un-stimulating to stimulating.

- ◯ Very un-stimulating
- ◯ Moderately un-stimulating
- ◯ Slightly un-stimulating
- ◯ Neutral
- ◯ Slightly stimulating
- ◯ Moderately stimulating
- ◯ Very stimulating

Comment

24. Please rate the climate of the MBE program. The ratings range from cold to warm.

- ◯ Very cold
- ◯ Moderately cold
- ◯ Slightly cold
- ◯ Neutral
- ◯ Slightly warm
- ◯ Moderately warm
- ◯ Very warm

Comment

25. Please rate the climate of the MBE program. The ratings range from socially fragmented to socially cohesive.

- ◯ Very socially fragmented
- ◯ Moderately socially fragmented
- ◯ Slightly socially fragmented
- ◯ Neutral
- ◯ Slightly socially cohesive
- ◯ Moderately socially cohesive
- ◯ Very socially cohesive

Comment

Employment

26. What is your current primary employment status?

- [ ] Employed full-time
- [ ] Employed part-time
- [ ] Self-employed
- [ ] Employed as a graduate assistant
- [ ] Not currently employed

Comment

27. Please describe your current employment.

28. How would you describe the focus of your current employment?

- [ ] "Mind"
- [ ] "Brain"
- [ ] "Education"
- [ ] Interdisciplinary
- [ ] Other (please describe)

Other (please specify)

29. How closely are your current job responsibilities related to your MBE degree?

- ◯ Directly related
- ◯ Somewhat related
- ◯ Not related

Comment

30. What are your professional goals?

Disciplinary Experiences Prior to the MBE Program

31. Please describe the disciplinary focus of your experiences prior to entering the MBE program.

	Undergraduate Education	Graduate Education	Internship or Volunteer Experience	Employment
"Mind"	☐	☐	☐	☐
"Brain"	☐	☐	☐	☐
"Education"	☐	☐	☐	☐
Interdisciplinary	☐	☐	☐	☐
Other (please describe)	☐	☐	☐	☐
Not Applicable	☐	☐	☐	☐

Other/Comment

Prior and Current Interdisciplinary Experiences

32. How frequently do you engage in the following?

	Never	Infrequently	Occasionally	Frequently
Read professional material outside of your primary discipline (e.g., newspaper articles, journals, books, websites)	◯	◯	◯	◯
Participate in professional activities outside of your discipline (e.g., attend conferences or talks, take courses, participate in journal or book clubs, cross disciplinary/cross campus initiatives, student activities or government, etc.)	◯	◯	◯	◯
Engage socially with people whose professional interest is in a different field	◯	◯	◯	◯

Comment

33. Please select a rating that best describes your participation in the following activities.

	A single focused interest	A few interests	Many interests	A wide range of interests
Leisure time activities, e.g., music, dance, drama, museums, sports, book clubs, etc.	◯	◯	◯	◯
Pleasure reading, e.g., newspaper articles, journals, magazines, books, websites, etc.	◯	◯	◯	◯

Comment

34. Please rate the degree to which you agree with the following statements.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I consider myself to have an "interdisciplinary worldview."	◯	◯	◯	◯	◯
The interdisciplinary perspective I bring to my work in MBE is evident in other areas of my life.	◯	◯	◯	◯	◯
Family experiences influenced my interest in an interdisciplinary approach to problems.	◯	◯	◯	◯	◯
Community experiences influenced my interest in an interdisciplinary approach to problems.	◯	◯	◯	◯	◯
Educational experiences influenced my interest in an interdisciplinary approach to problems.	◯	◯	◯	◯	◯

Comment

Demographic Information

35. Are you: (please check all that apply)

- [ ] American Indian or Alaska Native
- [ ] Asian
- [ ] Black or African American
- [ ] Native Hawaiian or other Pacific Islander
- [ ] White

Other (please specify)

36. What is your gender?

- ◯ Man
- ◯ Woman

37. What is your enrollment status?

- ◯ Current Student
- ◯ Alumnus/Alumna

38. What was your score on the GRE exam?

Not Applicable	
Verbal Reasoning	
Quantitative Reasoning	
Analytical Writing	

39. What degree did you earn/are you earning through the MBE program?

- [ ] Ed.M.
- [ ] Ed.D.
- [ ] Ed.M and Ed.D

Comment

40. What year did you complete/do you anticipate completing the MBE program?

- ◯ 2013
- ◯ 2012
- ◯ 2011
- ◯ 2010
- ◯ 2009
- ◯ 2008
- ◯ 2006
- ◯ 2005

comment

41. How old were you when you completed/will complete the MBE program?

42. Did you take/are you taking the core course, HT100, as a semester- or year-long course?

- ◯ Semester-long
- ◯ Year-long

Comment

43. Did you obtain additional degrees or certification after completing the MBE?

- ☐ Yes (please describe in the text box below)
- ☐ No
- ☐ Currently enrolled in a degree program (please describe in the text box below)

Degrees or certifications

Thank You!

Thank you very much for completing this online interview. If you would like the results of the research when the data are analyzed, please e-mail me, mlees@acad.umass.edu, and I will share the results.

Thank you for your participation,
Martha Christenson Lees

Please see attached document or visit https://www.surveymonkey.com/s/GR3MMWK

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