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Constructing Higher Education STEM Theory From a Faith-based Case

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Introduction

Since the launching of Sputnik in the late 1950s, the STEM fields (science, technology, engineering, and mathematics) have enjoyed years in the spotlight as a critical component of United States national security. More recently, Americans have recognized the importance of the STEM disciplines in providing economic growth and strength (Sanders, 2009). In the United States, men of color and women of all ethnic backgrounds have traditionally been underrepresented in the STEM fields. As a result American society has lost the contribution of thousands of potential scientists, mathematicians, and engineers from these groups.

Over the past two decades various groups, including the United States government's National Science Foundation, have tried to engage a truly diverse student clientele in STEM education. This has included the granting of millions of dollars to support research, educational innovation, and student and faculty support. However, faith-based institutions have not typically been the prime contenders for this funding. Neither have faith-based institutions typically provided generative models for the higher education STEM field.

During the same 20-year period the biology program at Andrews University, a national faith-based university in the Midwestern United States, has graduated students from traditionally underrepresented groups at rates higher than national averages. Additionally, students from all ethnic backgrounds who started the program with an inadequate high school preparation in mathematics and science had a higher than expected success rate.

Primarily as a result of the existing biology program's record of attracting, retaining, and graduating students whose success exceeds predictions based on their admissions profile, the university was awarded a grant of approximately $500,000 from the National Science Foundation (NSF) for the creation and implementation of a new interdisciplinary STEM program in neuroscience. This new program was to be based on the curriculum design of the existing biology program.

One thing STEM education researchers and reformers found intriguing about the success of this biology program is that success occurred in spite of the fact that the faculty members describe their teaching methods as “traditional.” By traditional, they refer to the weekly pattern of three to five lecture periods combined with a laboratory session for most courses.

How does a STEM faculty that describes its teaching as “traditional” create success for its diverse student clientele? To answer this question a study was launched to discover the processes responsible for success of this program’s diverse alumni. As the study unfolded a seven-component model became apparent. However, some STEM educators may wonder if it is possible for a faith-based institution to provide a generative case for higher education STEM education. This paper discusses the methods we are using to construct a broadly applicable theory from a specific faith-based case.

Research Design

As the purpose of this study was to discover theory, specifically the processes that contributed to student success in these programs, we did not begin our study with a theoretical framework. Rather we began with a commitment to grounded theory design and processes (Glasser & Strauss, 1967; Charmaz, 2006; Corbin & Strauss, 2008). Thus the study unfolded from the perspective of grounded theory design.

Grounded theory relies on the collection and analysis of substantive amounts of data relevant to the topic of exploration. These data must come from sources with the best likelihood of providing good information. As a grounded theory study progresses and data first become available, the researchers begin analysis. This analysis focuses on identifying emerging principles of a nascent theory. The emergent theory must be grounded in, that is derived from, the data themselves. Thus, while the researchers may be familiar with the field of study (for example, Hunter, Laursen, & Seymour, 2006; Seymour, 2001) and the faith context of the institution, they chose to temporarily set aside their specialized knowledge and seek instead the concepts found within the data until the theory is formed. Thus the formal literature review is delayed until the theory is formed (Charmaz, 2006). Since this study sought to discover processes that led to student success, theory development needed to proceed from the perspectives of those involved in the learning process – current and former students.

Methods

As the data needed for theory building needed to come from the individuals who had experienced life as a student in these programs, our primary sources were current students and alumni of these programs. Our primary data, stories of experiences during enrollment in the two programs, were collected via interviews with these informants. Thus the grounded theory perspective that guided our study required a qualitative mode of inquiry and analysis (Glasser & Strauss, 1967; Merriam, 1997; Charmaz, 2006). The primary qualitative method utilized in our study was the semi-structured, in-depth interviews. We also made limited use of focus group interviews, observation, and document analysis.

By conducting interviews with individuals, researchers were able to focus on person's story at a time. Individual interviews, as opposed to focus group interviews, allow for the use of follow-up questions to probe the depth of the interviewee's experience. Semi-structured interview protocols were developed for each of the groups included in our study: biology alumni, current biology students, neuroscience alumni, current neuroscience students, and persons who transferred out of these programs.

The protocols were structured to allow participants to offer their assessment of their experiences, both in college and out of college that shaped their educational progress and career aspirations and decisions. Interviewees were asked to clarify which factors were of greater or lesser importance in their educational progress and career development. A goal for all interviews was to gain insight about experiences that the interviewee considers transformative. Naturally, as the context of the study was a faith-based institution, explicit questions pertaining to faith and spirituality were included on the interview protocol. To ignore such a core feature of the institutional context would have been negligent on the part of the research team (Merriam, 1997).

Selection of Participants

From the population of potential study participants, all current students, field-switchers, and alumni of the small neuroscience program were sampled. Purposive samples of current biology students and biology alumni were intentionally selected for participation. All identified field-switchers during the time of the study were also sampled. We constructed a sampling frame to allow us to target the type of informants we were seeking. As much as possible, the sampling frame included the following characteristics for each member of the population: sex, ethnicity/race, level of high school preparation, and participation in undergraduate research. For this study, we defined under-preparation on the basis of one of the following scores: ACT composite or mathematics, SAT composite or mathematics, or the local university's Mathematics Placement Examination (MPE) (see Table 1).

Table 1. *Criteria for Determination of Preparation Level by Cut-off Scores*

	SAT	ACT	MPE
Under Prepared	$\leq 970^a$ $\leq 650^b$	$\leq 20^a$ $\leq 20^b$	≤ P1
Adeq Prepared	--	--	=P2 or P3
Well Prepared	--	--	=P4 or P5

[a] Composite score
[b] Mathematics score

Since the purpose of this study was to discover processes that lead to success, particularly for traditionally under-represented groups (including women) and under-prepared students, students from these groups were over-sampled when compared to students in other groups. First, a purposeful sample of 160 individuals was selected in an attempt to ensure at least 67% of the informants came from the under prepared group, approximately 67% were female, and about 67% were persons of color.

Of our sample, 117 students or alumni sat for interviews, four of which were not usable due to recording problems. Thirteen declined our invitation to participate in the interview process, 13 agreed to be interviewed but failed to show up for interviews (sometimes multiple times), and we were never able to make contact with a group of 16 students and alumni. Surprisingly ¾ of the group we were unable to contact were current students (n=12) while only ¼ (n=4) were alumni. Thus we had more success in engaging the alumni in the study than the current on-campus students, even though current students were living in the local area. Many students who declined to be interviewed or who did not show up for their interview appointment cited their very busy schedules as the reason for not participating. In summary, approximately

73% (n=117) of our sample sat for interviews and we were able to get usable data from almost 71% (n=113) of the sample.

Analysis Principles and Methods for Theory Generation

While theory can easily be generated from specific cases, it is imperative that data analysis moves beyond rich description to conceptualization (Charmaz, 2006). To accomplish this move toward conceptualization our research team engaged in a series of iterative coding sequences. We began our coding adventure with the text of a focus group interview held with two biology professors and one behavioral neuroscience professor who was also an alumnus of the biology program. This interactive coding experience resulted in several codes that we decided to adopt as *a priori* codes with our early interviews.

As we started conducting interviews the research team met every 7 to 10 days to discuss the ideas and issues we thought we were hearing in our interviews. We began initial coding (Charmaz, 2006) of our early interviews with our *a priori* codes and developed additional codes as they emerged from additional interviews. Each potential new code was discussed at our research team meeting. If approved by the team the new code was then defined and added to our code book. At this point our coding tended to be closely tied to the participants' experiences – more descriptive than conceptual; we attempted to identify every analytical pathway that showed potential for our theory development.

Our second coding iteration alternated between continued initial coding techniques and focused coding techniques (Charmaz, 2006). In our focused coding we started looking for codes that were similar to each other to explore the possibility of merging this related codes into one conceptually rich code. For other codes we found we needed to either split a code into two or more new codes to accurately differentiate between concepts. As we moved into more focused coding, our coding structures began to become more complex and conceptual in nature.

To move our analysis further away from description and into abstract conceptualization, we began our third iteration of coding, what Charmaz (2006) refers to as axial coding. During this phase of coding, which began after approximately half of our interviews had been coded, I looked for core codes or identified new categories to serve organizing concepts. These central codes then served as an axis around which clusters of other codes could be organized to explain relationships within the category or explain nuances of the functioning of processes. I organized these interrelated codes into tree structures within the NVivo software package. By this stage of our analysis the top level code for each tree structure represented a much more abstracted conceptual representation of the processes revealed in our data than had our initial codes. In our research team we discussed my efforts at axial coding and made revisions until we came to consensus.

Visual representation (mind mapping) and a version of memo writing (Charmaz, 2006) aided me in the process of developing and refining the axial coding structure of our data. An initial mind map was created using Microsoft PowerPoint and shared with research team members (see Figure 1). This facilitated discussion of the adequacy of this visual model to communicate the theory as it had emerged at that point.

I used my first mind map as the starting point for my memo writing. My memos were constructed to aid me in writing my second annual report to the NSF. I wrote short descriptions for each of the seven categories that made up the theoretical model and attempted to explain the relationships between the various codes within each coding family. After describing each category I returned to mind mapping to try to represent how the seven categories of our theory interacted with and facilitated each other (see Figure 2). This new mind map in turn generated additional memo writing activity.

After discussion about the second mind map and my refined memos among the research team members, I shared these artifacts with the two biology professors who were my co-PIs for the evaluation

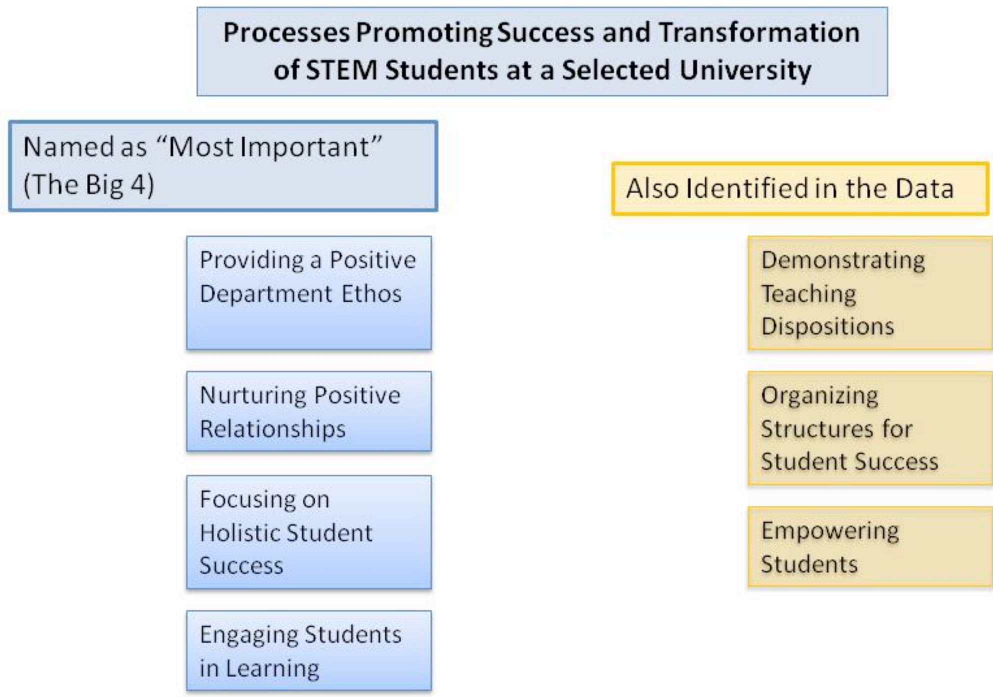

Figure 1. Core Processes from the Emerging Theory

grant. Discussion with each of them confirmed that from their perspective the visual model and the written explanations captured many important aspects of the biology program. One co-PI suggested a slight variation in the representation of one category by splitting it into university-specific support and department-specific support.

After all interviews had been transcribed and coded, we moved into our final round of coding, which is continuing through the month of May 2010. At this point our tasks include both "quality control" and "conceptual development." By quality control I mean sifting back through every set of coded data to ensure that our team had been consistent, both across time and across coders. This is a

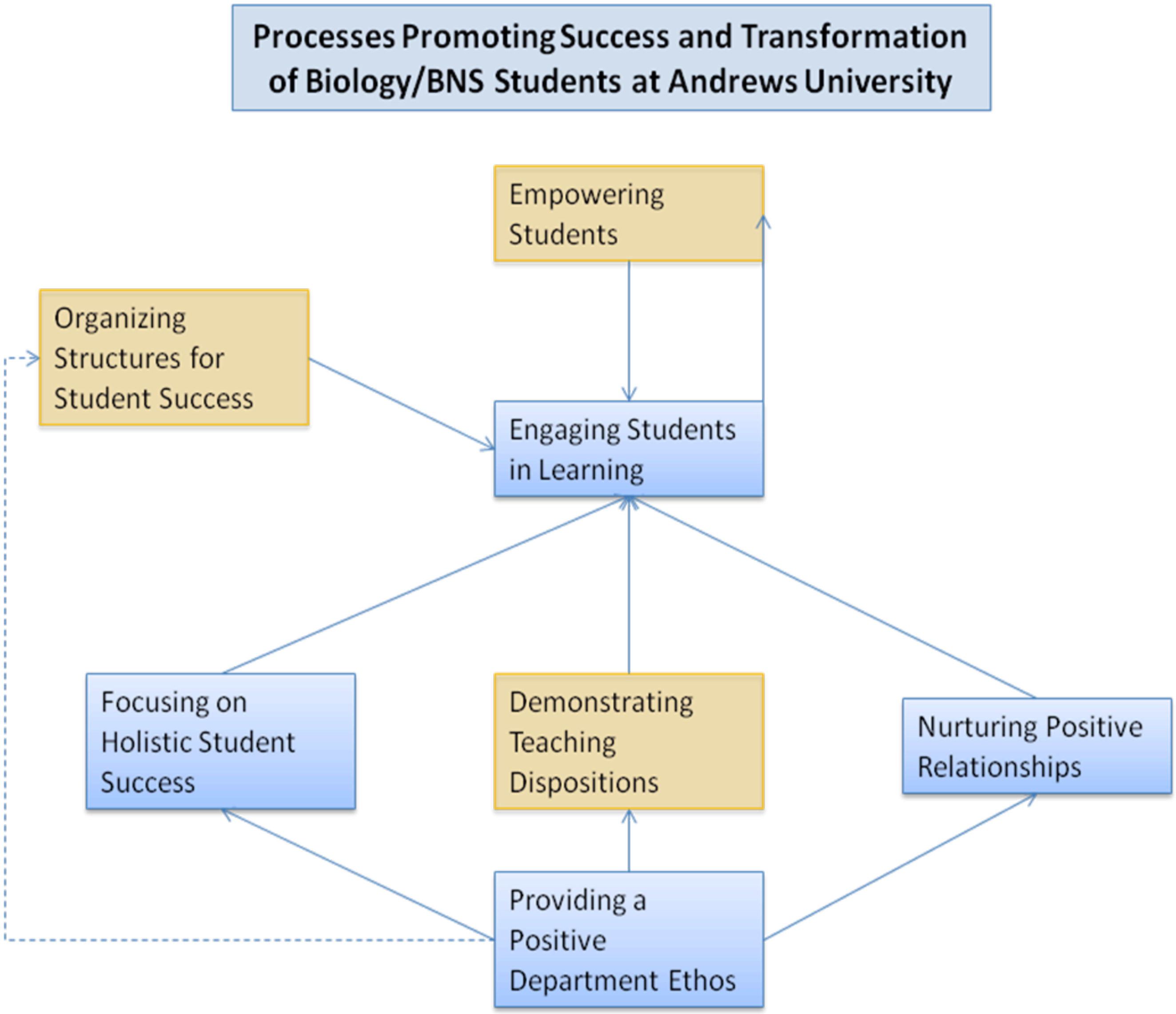

Figure 2. Proposed Model of Process Interactions

critical step as our coding structures had emerged over time and were likely to show variation in the content coded at that node. Even some categories that have remained from the beginning through the final analysis still have had subtle changes in their definitions along the coding path and need this quality assurance process. Final coding is occurring in tandem with creation of additional visual representations and memos. A strength we have discovered in the use of visual representations is their ability to reveal at a glance areas where the theory might be a bit "thin". This will aid us in making decisions related to any additional theoretical sampling that may be necessary to flesh out thin categories. This iterative process of coding, representation, and memo writing has helped us move from the specifics of our small, faith-based data collection context to the abstract conceptualization of theoretical propositions related to STEM success.

The primary purpose of this study is to generate a broadly usable theory for biology education. However, Charmaz (2006) warns against attempting to divorce a grounded theory from the context in which it was constructed. Such a separation of theory from context will limit readers and other theorists in their ability to critically interpret the theory and compare it with other theories that emerged from similar-yet-distinct contexts. This critical comparison can help identify nuances within theoretical conceptualizations and areas for additional theory building.

The theoretical model emerging from this research is firmly grounded in the experiences of under-represented minorities and under-prepared students in two STEM programs at a *small, faith-based* institution. Thus it will be necessary to accurately conceptualize what role, if any, faith or class size plays in student success at this university. As issues of faith are often of more import for under-represented, minorities than for majority group students, this aspect of the study has the potential to inform STEM educators at other institutions, both faith-based and not, of the role faith plays in the success of students from specific demographic groups. Isolating the effects of faith as well as factors related to institutional size in the Andrews University context will help us and our future readers determine what aspects of our theory are applicable in which contexts: whether large or small, faith-based, private or public.

Because of the rigor of our grounded theory design, including our processes for sampling, data collection, and data analysis, we are confident our final results will result in a theory applicable beyond the institution of its origin. In fact we are currently working with another biology department at a large public university to identify principles from our emerging theory that can be applied in their context. Initial conversations led to a small-scale effort to implement some of the theoretical concepts associated with one process form our emerging theory – Nurturing Positive Relationships. We anticipate continuing and hopefully expanding this collaboration as we seek to test the capacity of our theory to transcend its faith-based origins.

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