EXPLORING THE GENDER GAP IN STEM CAREER PARTICIPATION

by

MATTHEW MENDICINO

(Under the Direction of David Jackson)

ABSTRACT

Introductory college chemistry is widely considered to be a “gatekeeping” course relative to the pursuit of a career in STEM. The perceived difficulty of the course, and it being a requirement for a multitude of degrees in STEM, means that student performance in the course can have a major effect on a student’s academic trajectory and career. Particularly problematic is that women remain underrepresented within these STEM careers, even though they earn more degrees than men. This qualitative case study examined the experiences of eight female undergraduate students enrolled in introductory chemistry at a large southeastern university. The student cases were interviewed to understand how their social, familial and academic experiences, as well as epistemic beliefs, impact their interest in learning chemistry. This study also explored case beliefs concerning the role of gatekeeping within the context of the course. A key finding is that interest in learning chemistry is most strongly influenced by a student’s prior academic experiences. Overall, the gatekeeping function of the course was considered beneficial to preserving a necessary level of rigor for potential entrants into a STEM-related career.

INDEX WORDS: Gatekeeping, STEM career, Female undergraduate, Introductory chemistry, Chemistry learning

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DEDICATION

I dedicate this to my grandmother Martha, without whom this work would not have been possible. I am forever grateful for her love and caring encouragement throughout my life.

ACKNOWLEDGEMENTS

First and foremost, I would like to acknowledge my committee chair David Jackson for his steadfast support and essential encouragement during the process of this study. I would also like to express great appreciation towards Deborah Tippins for her invaluable guidance and assistance during the course of my graduate career. Likewise, I am grateful to have worked with my other committee members Andrew Gitlin and Tina Salguero for their insightful input, which was critical to the completion of this work.

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CHAPTER 1: INTRODUCTION TO THE STUDY

As our society further progresses into increasing dependence upon science and technology in our everyday lives, it stands to reason that an emphasis on cultivating a more scientifically-adept citizenry is an imperative goal of STEM educators. Particularly germane to STEM education is college-level introductory chemistry, owing to its status as "gatekeeper", effectively "weeding out" certain students. The phenomenon of "gatekeeping" has a documented historical precedent within introductory college science courses stemming from the early 1950s. Barr (2010) revealed that "introductory courses were often used at colleges and universities throughout the United States to prevent students who do not do well in them from, 'cherishing inappropriate professional ambitions too long'" (p. 53). Consequently, Barr explained how students were "weeded out" resulting from "an unduly tough attitude on the part of many chemistry teachers who claim with pride that only students of good ability who work very hard can get through their chemistry course" (p. 53). Seeing the situation as greatly unchanged in current times, Barr (2010) points to the fact that the "trial by fire" of first-year college chemistry is "overdue for reform" (p. 54).

Gatekeeping translates to many students being precluded from taking part in various and significant Science, Technology, Engineering and Mathematics (STEM) fields of study including medicine, pharmacy, physical and life sciences—subjects in which these same students might otherwise succeed and contribute. Speaking to the long-standing existence of the gatekeeping effect, Barr (2010) noted that "consistent with reports [for] over more than 50 years…undergraduate courses in chemistry have the effect of discouraging otherwise qualified students" (p. 45).

In order to overcome this gatekeeping and pursue science-related careers, students must successfully navigate borders to science (chemistry) culture. Taconis, et al. (2009) explained how "the lack of students in the field of science and engineering is related to the fact that students do not want to associate with 'science culture'… [thus] specialising in science is a process of 'enculturation' of individuals to the specific culture—or even 'subculture'—of science" (p. 1116). They further pointed out that "studies on the perception of science in student populations and among the general public found descriptions of the science culture to be more negative than positive… [which] might explain the negative attitudes towards and lack of interest in science encountered in many countries" (p. 1116).

A persistent concern, in particular, is the continued disparity between male and female participation in STEM fields. A report recently published by the U.S. Census Bureau noted that although "women's representation in STEM occupations has increased since the 1970s…they remain significantly underrepresented in engineering and computer occupations, occupations that make up more than 80 percent of all STEM employment" (U.S. Census Bureau, 2013, p. 5). In fact, "among science and engineering graduates, men are employed in a STEM occupation at twice the rate of women: 31 percent compared with 15 percent" (U.S. Census Bureau, 2013, p. 5). The phenomena of gender gap in STEM careers is especially curious in light of the fact that since 2002, "women have been awarded 58% of the bachelor's degrees in the United States" (Deemer, 2014, p. 142).

Rationale/Need for Study

Introductory chemistry, along with other introductory undergraduate science courses are widely identified as gatekeepers to a degree/career in science due to their perceived emphasis on "weeding out" certain students (Chang, 2008). Failure to pass introductory chemistry in particular has the potential effect of precluding a student from various fields of study related to medicine, pharmacy, physical and life sciences, since the course is typically a prerequisite for other "hard" science courses. As it pertains to the institutional context of this study, there is a strong statistical cause for concern with the introductory chemistry course in particular, since it is reported by the Department of Chemistry that only ~67% of students enrolled earn a grade of C or better. Barr (2010) noted that the "discouraging effects of gatekeeping in undergraduate chemistry courses appear to be felt more acutely" within underrepresented groups such as females (Barr, 2010, p. 52). Relatedly, the National Academies of Sciences, Engineering, and Medicine (2016) reported that in the United States, only 23% of college female "STEM aspirants" completed their degree within four years (p. 34). Accordingly, this study investigated the borders that female undergraduate students encounter in their academic pursuit of chemistry within the "hard" sciences. Specifically, the study aimed to examine ways in which navigation of these borders occurs. This study was significant since it had the potential to uncover findings that may lead to increased female participation in STEM careers.

Purpose of Study

The purpose of this study was to investigate undergraduate female students' epistemic beliefs and worldviews as they relate to the subject of introductory college chemistry. The ultimate goal of this study was to more closely understand female undergraduate student (academic) experiences in the context of an introductory college chemistry course (Freshman

Chemistry I). A longer-term goal was to apply these insights to address student learning needs with the goal of retaining more female students in STEM programs and careers, ideally leading to a greater inclusion of women within STEM fields.

Research Questions

1.) How do female undergraduate students develop an interest in learning chemistry?

2.) How do female undergraduate students' beliefs about the gatekeeping function of introductory chemistry influence their pursuit of a scientific career?

Overview of Theoretical Framework

The theoretical framework for the study was chiefly informed by tenets of Patricia Phelan's (1991) theory of (cultural) border crossings. Border crossing, as a construct, was useful in analyzing the influences of student's epistemic beliefs specific to the subject of chemistry, as well as experiential "world" factors comprised of familial, social and academic modalities. The study was thus framed around how the aforementioned beliefs and sociocultural factors interact with the process of border crossing into chemistry culture. An assumption of this study was that successful navigation of existing cultural borders into the culture of college chemistry is desirable for female students. However, in this study the researcher was also cognizant of the idea that the culture of introductory chemistry may also need to change to facilitate successful border crossing.

According to Phelan (1991), problems with border crossing surfaced when there was a mismatch between the culture of the student and the culture of school science, in this case, introductory college chemistry. The theoretical framework of this study provided a theoretical lens for examining how border crossing occurs, specifically in light of student epistemic beliefs and worldviews. Phelan (1991) delineated four types of border crossings as follows (p. 228):

1.) Smooth Transitions/Congruent (Cultures)

2.) Boundary Crossings Managed/Different (Cultures)

3.) Boundary Crossings Hazardous/Different (Cultures)

4.) Boundary Crossings Insurmountable/Borders Impenetrable

In relation to a "smooth" border transition, a student's epistemic beliefs about chemistry were "congruent" with chemistry's "domain" epistemic characteristics. The opposite scenario constituted an "impenetrable" chemistry culture border. For the purposes of this study, "worldview" was a collective term encompassing the experiential contributions to the "self" (student) stemming from the influential categories of "family" (familial), "school" (academic) and "peers/friends" (social). In terms of "worldviews", a "smooth" transition entailed the student's familial, academic and social "worlds" being conducive to successful navigation of the chemistry culture border.

As a continuum, the two extremes of "smooth" and "impenetrable" served to delineate a spectrum in which the intermediate degrees of border crossing ("managed" and "hazardous") are intermediate between each endpoint, within the gamut of variables tied to student epistemic beliefs and worldviews.

Student Epistemic Beliefs

Hofer (1997) defined epistemic beliefs as an "individual's beliefs about the nature of knowledge and the process of knowing" (p. 117). Dai & Cromley (2014) operationalized epistemic student beliefs as the "extent to which students would rather learn subjects or take courses that feature certain epistemological characteristics" (p. 263). According to Dai &

Cromley (2014), the (domain) epistemic characteristics of chemistry course were "collectively constructed by all practitioners in the domain" (p. 262). These characteristics consequently formed a set of basic conventions, wherein learning, research, and teaching are integrated within the subject domain (Dai & Cromley, 2014, p. 262).

Informed by Hofer's (2000) work, Dai & Cromley (2014) stratified student epistemic beliefs according to the following "distinct dimensions" (p. 264):

Simple and certain knowledge - "the extent to which an individual believes that knowledge in a subject domain is simple, discrete, certain, and unchanging over time"

Justification – "the extent to [that] which an individual believes about multiple knowledge claims and justifying [this] knowing through personal and first-hand experiences"

Source – "the extent to which an individual believes that authority figures in the field, such as textbooks or experts, pass on knowledge"

Attainable Truth – "the extent to which an individual believes that truth can eventually be discovered in a domain"

In terms of the theoretical framework of this study, a "smooth" border transition ostensibly occurred when a student's epistemic beliefs on chemistry were "congruent" with the chemistry's "domain" epistemic characteristics. The extreme opposite was true for the "impenetrable" case. Dai & Cromley (2014) explained how "student epistemic beliefs that are adaptive to a particular domain epistemology, may facilitate learning in the subject domain" (p. 272). Dai & Cromley (2014) elaborated further to explain that "adaptive" student epistemic beliefs may result in "achieving higher performance" (p. 272). In support of his assertions, Dai &

Cromley (2014) found a correlation between specific student epistemic beliefs and better performance in an introductory college chemistry course (p. 272).

Student Experiential (World) Factors

In her work, Phelan (1991) presented the "multiple worlds" model to illustrate the borders and interaction between "family, self, school and peers/friends" (p. 228) as seen below in Figure 1.

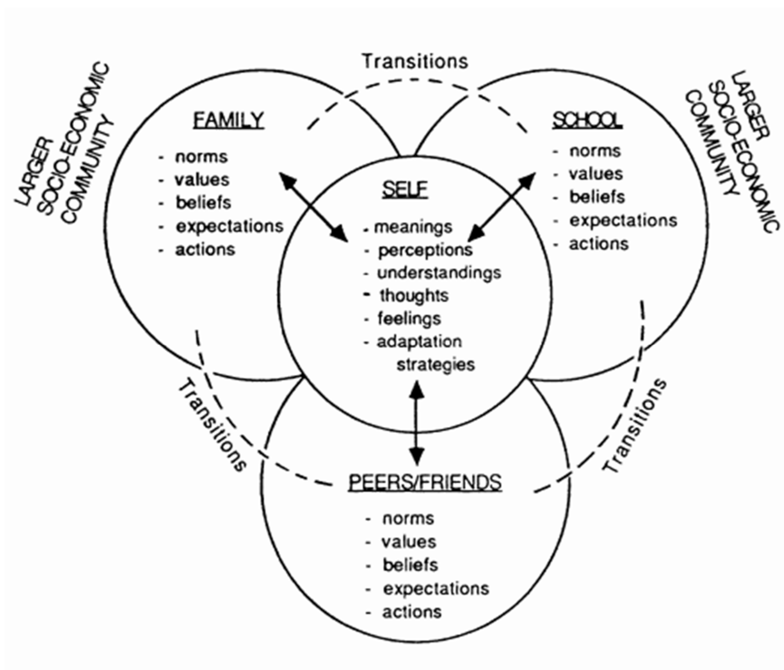

Figure 1: Model of Phelan's "multiple worlds"

For the purposes of this study the researcher modified Phelan's model (Figure 2) in order to emphasize the experiential contributions to the "self" (student) stemming from the influential categories of "family" (familial), "school" (academic) and "peers/friends" (social). Relative to experiential factors, a "smooth" transition entailed that the student's familial, academic and social "worlds" were conducive to success and/or interest in chemistry. Phelan (1991) defined these “worlds” as complex in that they contain specific “cultural knowledge and behaviors” tied to “beliefs, values, expectations, actions, emotional responses” (p. 225).

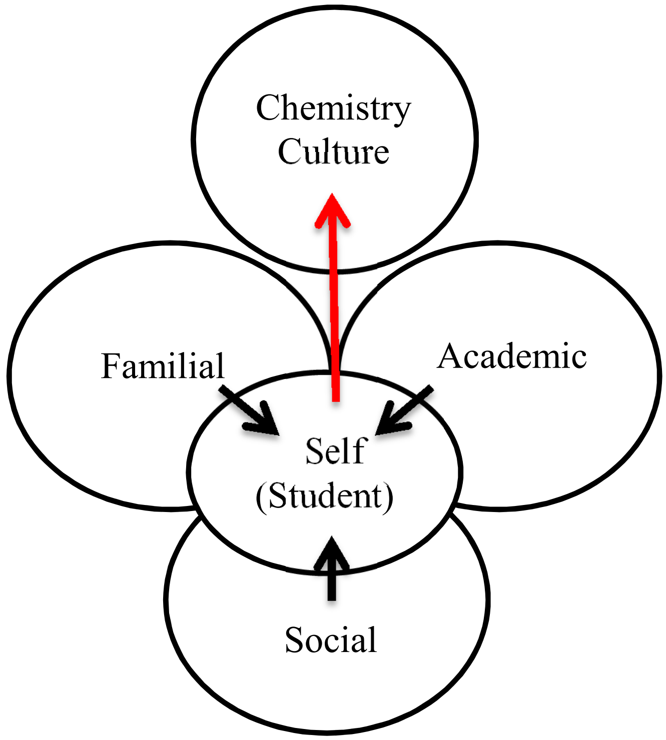

Figure 2: Modified model of Phelan’s “multiple worlds”

The modified model above was intended to function in granting a better, more direct understanding of those experiential factors which either supported or hindered a student’s navigation into the culture of chemistry. For instance, if a student had a family that esteemed science and included role models involved in scientific careers; this would have provided for easier navigation into chemistry culture. Likewise, the peers and friends of a student who showed interest and eagerness to learn science may have potentially imbued the study of science with a relatively higher, more “popular” social status. It was further conceivable that a student’s level of congruence and adaptability within chemistry culture was at least in part dictated by prior instructional experiences belonging to the “academic” category of experience.

Overview of Methodological Framework

An interpretive case study methodology was employed for this study. In the broadest sense, a case study is a "study of the particular", being a method of social research that offers an in-depth investigation of a real-life setting. The case itself is a "unique", "bounded" and "specific" system, whether it be a person or an organization (Stake, 1994, p. 236). As a "detailed analysis of a person or a group" (Hancock, 2006, p. 85), the purpose of the case method was to "generate knowledge and/or inform policy development, professional practice and civil or community action" (Simons, 2009, p. 21).

For this study, the cases investigated were 8 female students enrolled in introductory chemistry (Freshman Chemistry I). Of these, participants included both chemistry majors and non-chemistry majors.

Data were primarily gathered via interviews. Interview data were analyzed according to the Constant Comparative Method (CCM) (Glaser and Strauss, 1967). Additionally, each participant completed a pre-interview questionnaire to provide supplemental information pertaining to their chosen major, prior academic experience with chemistry, and overall interest in learning chemistry. The data generated from this study were expected to ultimately render salient categories and themes germane to answering the research questions of interest.

Overview of Relevant Literature

The literature salient to this study focused primarily on college chemistry learning and teaching with a particular emphasis on female chemistry learners. The literature review consisted of:

a) An investigation into historical and current literature regarding the gatekeeping function of college introductory chemistry

b) An examination of research that highlights the historical and current status and participation of females in college STEM courses and careers, especially regarding the phenomenon of "Stereotype Threat"

c) An examination of studies concerning student worldviews, particularly as they relate to college science learning

Subjectivity Statement

I was born and grew up in a university town. I spent a lot of time in my youth around a close family member who was a college science professor. He was always eager to teach me science, to such an extent that he would frequently give me purely scientific answers to my seemingly non-scientific questions. Over time, I grew to appreciate and admire his scientific knowledge. I attribute my interest in learning science to him and his enthusiasm for science.

As it pertains to the study, I have taken numerous chemistry courses in the process of obtaining my bachelor's degree in chemistry and in my time thus far as a doctoral student. In the span of enrollment throughout these courses, I experienced academic success as well as frustration and disappointment. And it is these experiences that propelled my desire to better understand the influence of experiences with and beliefs about chemistry learning. It is of further importance to note that, owing to several semesters as an introductory chemistry lab teaching assistant, I obtained both first-hand and anecdotal evidence of difficulties experienced in great part by female students trying to navigate the "culture" of chemistry. Ultimately, I did this study because I wished to understand how personal beliefs and experiences influence the study of introductory chemistry specifically for female students.

CHAPTER 2: REVIEW OF RELEVANT LITERATURE

In the review of literature that follows, the analysis began with an investigation into the historical and current literature regarding the gatekeeping function of college introductory chemistry. Moreover, research focusing on the historical and current participatory status of females in college STEM courses and careers was discussed. Of particular emphasis was an investigation of gender stereotypes within scientific disciplines. In a similar vein, literature related to the effects of "stereotype threat" on female science career involvement was elucidated. The review of literature concluded with an explication of studies related to college science learning and student worldviews.

Gatekeeping in Introductory College Chemistry

As far back as four decades ago, science education researchers identified student attrition within introductory science courses as a pressing issue (Rowe, 1976). Rowe (1983) went so far as to name introductory college chemistry a "killer course" (p. 954). According to Rowe (1983), the cause for concern stemmed from non-major students having failed, repeated or dropped out of introductory chemistry at a rate of around 30% "in many institutions" throughout the United States (p.954). In order to ameliorate the "killer" status of introductory chemistry, Rowe (1983) suggested a need for "improv[ing] student survival rates without sacrificing rigor", what she quipped as "rigor without *rigor mortis*!" (p. 954). Rowe (1983) cited a discrepancy between how much instructors expect students to learn versus what is actually possible: "as a rule it takes about 10 years for people to accumulate enough experience to show real facility in dealing with a great many [chemistry] problems…we act as if beginning chemistry students can do it in one year" (p. 954). Rowe (1983) contended that the way chemistry is taught via textbooks and lectures is vastly more mentally arduous than beginning to learn a foreign language (p. 954). Moreover, Rowe (1983) noted that chemistry textbooks and lectures are exceedingly data-dense such that "the rate at which ideas must be absorbed usually exceeds the capacity of the brain to absorb [them]" (p. 954). The complexity and novelty of the material to the typical student therefore must be taken into account if material is to be retained. Rowe (1983) remarked that chemistry relies "most heavily on visual models" of all the sciences, resulting in a figurative translational obstacle when it comes to relaying information to verbal and written forms of communication (p. 956). Additionally, Rowe (1983) identified four types of "mental lapses" that occur in the context of a traditional chemistry lecture (p. 955): (a) short-term memory overload; (b) momentary "confusion" about certain concepts (c) differing semiotic schemes between lecture and textbook (d) tangential/unrelated thinking unrelated to lecture material.

Ultimately, Rowe (1983) declared that computer technology may be implemented to provide unique and specific content delivery tied to the majors of students outside of chemistry who enroll in the course (p. 956). In this way, course material is "tailored" to engage all students with "chemistry ideas…embedded in the discipline from which the student comes" (p. 956).

In more recent times student difficulty with the subject of chemistry is more widely recognized as problematic, perhaps owing to its seemingly negative lore amongst undergraduate students. To further complicate things, introductory chemistry courses require an accompanying lab course in which experimental techniques and protocols are disseminated. In fact, the universal relatability of student difficulties with introductory chemistry lab itself has reached such heights that a reality show entitled "ChemLab Boot Camp" was filmed at the Massachusetts Institute of Technology (MIT). The series of episodes "follows a diverse group of 14 freshmen as they struggle to master the laboratory techniques of chemistry" (Cooper, 2012, p. 14). Highlighting the struggle beginning students encountered in a chemistry lab course, the executive producer of the program, Dr. John Essigmann, conceded that in chemistry experiments "failure is an option, and it's very frequent" (Cooper, 2012, p. 15).

Particularly germane to the discussion of gatekeeping was the demanding shift students make from high school to college. As Popejoy (2013) noted, students "making the transition to college chemistry courses may find themselves confronted with a faster pace and higher expectations than they experienced in high school science courses, while also being without previous support structures (p. 19). What makes introductory college chemistry courses particularly significant is their functionality as "gatekeepers". Per Popejoy (2013), "failure in chemistry often [drives] students out of science, technology, engineering, and mathematics (STEM) fields altogether" (p. 19). As of 2005, it was estimated that "half of all students who begin in the physical or biological sciences will drop out of these fields by their senior year, compared with a 30% dropout rate in the humanities and social sciences" (Popejoy, 2013, p. 19). A study conducted by Chen (2009) found that the majority, 55%, of students enrolled in STEM fields in their first year of college, either migrated to non-STEM fields or abandoned pursuing their undergraduate degree altogether (p. 11). Furthermore, of those students who began their college careers in STEM fields, only 37% earned degrees in a STEM area of study (Chen, 2009, p. 11). The remainder of students had persisted as STEM majors but had yet to complete their degrees within a timeframe of six years.

Female Participation in STEM Courses and Careers

There has been a long history of prejudicial norms and stereotypes that work against females participating in the sciences. The simplest, and perhaps the most common explanation is that science is typically perceived as a "masculine" endeavor and this conception has persisted through modern times. In this way, the practice of science was seen as extolling a patriarchal agenda, all the while controlled by prevailing political powers (Watts, 2014, p. 128). Watts (2014) revealed that women have been "excluded or pushed to the periphery [of science] despite changing perceptions of science and its expansion, differentiation and professionalization" (p. 127). Even female scientists who meet great success in their fields are marginalized and discounted in favor of male scientists. In fact, per Watts (2014), female triumphs in science may produced seemingly counterintuitive negative reaction (p. 127). In both the United Kingdom and the United States, there have been very plausible suspicions that there have indeed been backlashes against women being more academically successful than their male counterparts (Watts, 2014, p. 127). In the United States, one such backlash occurred around the year 1910 in response to middle class females thriving within the "physical sciences and mathematics…far more of them enter[ing] higher education than in Britain and continental Europe" (Watts, 2014, p. 132). What ensued, according to Watts (2014), was the discrediting of females in science as well as designation of the domestic sciences as "female science", which culminated in the status of the sciences in the United States becoming "elitist, masculinist and hierarchical" (Watts, 2014, p. 132). Watts (2014) stated the result has been the "systematic" favoring of men regarding "grants, employment and promotions" in the sciences (p. 132). Consequently, there are examples of more recent "backlashes", as it is alleged that Ivy League schools had become so alarmed by relatively higher female academic success, that they altered their admission protocols against women (Hinsliff, 2004).

The historical bias against women having a strong presence within the realm of science is well-documented. In the early part of the 20^{th} century, women faced difficulty entering medical studies owing to the prevailing notion that medicine ought to be carried out by "individuals… with strict and scientific qualifications" of which females were seen as innately lacking (Watts, 2014, p. 129). This restriction to access for women into the field of medicine occurred, in spite of an unprecedented amount of college degrees being offered to them (Watts, 2014, p. 129). Most women however were expected to enroll in domestic science studies (home economics) at a rate such that only a "minority of women [had] professional and academic opportunities" (Watts, 2014, p. 129). The domestic sciences themselves were said to have been wrought with instruction tainted by "social Darwinism and eugenicist ideas which portrayed women as inferior" (Watts, 2014, p. 130). As recently as the 1970s, quotas were implemented on "women's admission to medicine and opportunities were largely gender stereotyped" (Watts, 2007, p. 167-172).

The status of women in STEM careers was promising yet puzzling. On one hand, female students received an unprecedented number of doctoral degrees in the sciences, particularly in biology where women earned the majority of post-baccalaureate degrees (Heilbronner, 2013, p. 39). On the other hand, however, Heilbronner (2013) pointed out that although "women represent half of the workforce… [they] only [comprised] 25% of the entire STEM workforce" (p. 40). Furthermore, according to the United States Department of Commerce (2011), women in STEM careers earned just 86% compared to their male counterparts (p. 4). Nonetheless, it remained puzzling why, as Feist (2006) put it, "even [women] who are demonstrably among the most promising young scientists and mathematicians in the nation…decide [to] disproportionately…leave science" (p. 32).

Research concerning why women leave STEM careers elucidated various reasons, which were generally distinct from those of males. Of these, Subotnik (1993) suggested that women “object” to the “impersonal lifestyle” in laboratory science along with the “crowded, impersonal classes” (p. 167). Citing a later study by Subotnik, Heilbronner (2013) shared that women left STEM careers due to “disillusionment with scientists’ lifestyle, few job prospects, poor teaching in college, little encouragement from faculty and mentors, and the fact that other domains appear more appealing” (p. 42). In their own study, Heilbronner (2013) found that individuals of both genders predominantly cited “social isolation/loneliness” as the main causation for them to leave STEM employment (p. 49). Various studies have also acknowledged the importance of self-efficacy, functioning as a rough measure of interest, in the choice of career field (Heilbronner, 2013; Dweck, 2007). The prevailing finding was that males have substantially higher levels of self-efficacy in STEM fields relative to females, which was said to at least contribute to gender disparities in certain science domains (Heilbronner, 2013, p. 49). Other potential reasons for the gender “gap” in STEM fields were listed by Ceci (2010) including: women’s inclination towards non-mathematical careers; greater interest in “people-centered” careers like biology and medicine versus engineering and the physical sciences; and perceived greater compatibility of non-STEM fields with child-rearing. As for a specific reason why women entered STEM fields, Feist (2006) offered that a salient theme is that science, from the perspective of females, is generally perceived as helpful to humanity. This is in contrast to males who are said to typically regarded the study of science as a means of quenching their “curiosity” (p. 28).

Stereotype Threat

It has been theorized by Deemer (2014) that “stereotype threat” occurs when “stigmatized individuals (females) perceive themselves to be at risk of confirming a negative stereotype about their group (Deemer, 2014, p. 144). Gender stereotypes were additionally said to “work against those who care most about achievement and success, as well as women who identify most strongly with their gender" (Deemer, 2014, p. 144). Per Deemer, "stereotype threat" had negative impacts including reduced performance on exams… "identity conflict" and disengagement of one's identity from the stereotyped domain" (Deemer, 2014, p. 144). According to "stereotype threat", stereotypes associated with women in STEM "need not be made explicit" in a particular setting (Deemer, 2014, p. 144). Instead, the "negative influence [on] women's performance and experiences" occurred merely by being in an environment that is "male-dominated and/or known to relate to gender stereotypes" (Deemer, 2014, p. 144).

Student Worldviews in Relation to College Science Learning

Science educators exist at the boundary between culture and science. Effective science education, according to Matthews (2009), entailed that "students [have] some sense and appreciation of the interactive dynamic of science and culture…[having] a more refined and sophisticated understanding of that dynamic", with the instructor "support[ing] and nurtur[ing] students' decision making" with regards to "affirming, modifying or abandoning aspect[s] of culture that science bears upon" (Matthews, 2009, p. 10). Ultimately, as the American Association for the Advancement of Science (AAAS) (1990) contended, "the teaching of science must explore the interplay between science and the intellectual and cultural traditions in which it is firmly embedded" (p. xiv).

The traditional, naturalistic worldview of Western science was important to the discussion of what occurs in the context of a science classroom, especially the interaction with student worldviews. Western science, being naturalistic, asserts that "whatever occurs in the world is to be explained by natural mechanisms and entities; and that these entities and mechanisms are ones either revealed by science or in-principle discoverable by science" (Matthews, 2009, p. 8). At the most extreme, there is ontological naturalism, the "view that there is a scientific explanation for all events; that supernatural explanations (e.g. Divine interventions, miracles) are simply ruled out" (Matthews, 2009, p. 8). It can thus be inferred that naturalistic perspective of scientific worldviews may directly contradict the "cultural (including religious) worldviews" of some students (Matthews, 2009, p. 8).

Science has been broadly defined as the "effort of people and societies to identify, understand, and 'make sense of' the objects and processes in the world around them; to tabulate the properties of natural things and processes; and to ascertain how causal mechanisms in the world operate" (Matthews, 2009, p. 9). Importantly, science is said to be buttressed by the "seven pillars of science" as stated by the AAAS (1990). These pillars are as follows: (1) *Realism*, which asserts that the physical world that science seeks to understand is "real" (AAAS, 1990, p. 17); (2) *Presuppositions,* which involve the world as "orderly and comprehensible" (AAAS, 1989, p. 25); (3) *Evidence*, described as "science demand[ing] evidence for its conclusions" (AAAS, 1989, p. 26-28); (4) *Logic*, such that "scientific thinking uses standard and settled logic" (AAAS, 1989, p. 27); (5) *Limits*, as in science being "limit[ed] in its understanding of the world" (AAAS, 1989, p. 26); (6) *Universality*, in that "science is public, welcoming persons from all cultures" (AAAS, 1989, p. 28-29); and (7) *Worldview*, as in science being crucial to a "meaningful worldview" via its role as "one of the liberal arts…[being] a lifelong quest for knowledge of self and nature…seek[ing] meaning in life…[towards] a unity of knowledge" (AAAS, 1990, p. xi, 12, 21).

Matthews (2009) continued that "science is conducted by people living in societies in specific historic stages of scientific, philosophical, intellectual (including mathematical), religious, technological, economic and cultural (including ethical and artistic development…science has always been a dynamic part of culture; it is affected by culture and has effects on culture” (p. 9). The practice of science thus involved “interactions with domains outside itself” and contains “presuppositions” i.e. the aforementioned “pillars” that are “worldview dependent” (Matthews, 2009, p. 10). Effectively, “scientific ideas…influence…and are influenced by…the wider world of ideas” (AAAS, 1990, p. 24).

To understand how the worldviews of science and student cultures interact, it was key to delineate the meaning of what constitutes a “worldview”. Generally, a worldview is “an overall perspective on life that sums up what we know about the world, how we evaluate it emotionally, and how we respond to it volitionally” (Makkreel, 1999, p. 236). Kearney (1984) defined worldview as “culturally organized macrothought”, presuppositions dictating a great portion of “behavior and decision making” (p. 1). One’s worldview is also said to be defined by “who they are, where they have been, where they are going, and who they want to become’’ (Aikenhead, 2006, p. 108). Per Cobern (1996), worldview “provides a non-rational foundation for thought, emotion, and behavior…provid[ing] a person with presuppositions about what the world is really like and what constitutes valid and important knowledge about the world” (p. 5). Cobern (1996) argued that effective science instruction needs “to be more consistent with how knowledge is organized and used within one’s worldview”, since “science education is successful only to the extent that science can find a niche in the cognitive and socio-cultural milieu of students” (p. 21).

CHAPTER 3: RESEARCH METHODOLOGY

The purpose of this study was to explore undergraduate female students' epistemic beliefs and worldviews in relation to the subject of introductory college chemistry. The primary goal of this study was to more clearly elucidate the (academic) experiences of female undergraduate students within the context of an introductory college chemistry course (Freshman Chemistry I) intended for science majors. Furthermore, another goal of the study was to generate knowledge conducive to addressing the problem of the existing paucity of women participating in STEM fields.

The first section of this chapter provides a description and rationale for the chosen research method. The following sections furnish details regarding the following: the context of the research, an explanation and justification of case selection, methods of data collection, methods of data analysis, verification/trustworthiness of the study, ethical considerations, as well the limitations and delimitations of the study.

Rationale for Research Approach

An interpretive case study was utilized. The interpretive case study method is well-suited to a detailed, in-depth examination of a phenomenon situated within its specific context. Per John Creswell (2013), the case method ‘‘explores a real-life, contemporary bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of information... and reports a case description and case themes’’ (Creswell, 2013, p. 97).

Robert Yin (1981) operationalized the case study method as an investigation of a phenomenon "when the boundaries between phenomenon and context are not clearly evident" (Yin, 1981, p. 13). Helen Simons (2009) continued that the case method consists of an "in-depth exploration from multiple perspectives of the complexity and uniqueness of a particular" real-life scenario (Simons, 2009, p. 21).

The "interpretive" designation of the case method refers to the social constructivist approach that entails a direct, "transactional" interaction such that the case was "developed in a relationship between the researcher and informants" (Hyett, 2014, p. 2). Thus, the interpretive nature of this study asserted that "knowledge of reality…is a social construction by human actors…apply[ing] equally to researchers" (Walsham, 1993, p. 5).

Ultimately, the interpretive case method was appropriate for this study as it provided a wealth of insight into the experiences of female students as they related to their involvements in introductory college-level chemistry. The selected method was further desirable for the purposes of this study by virtue of the adaptability it permitted throughout the research process. Chiefly, methods of data collection were tailored to meet the demands of answering research questions.

Research Context

This study took place at a large southeastern university during the Fall semester of 2015-2016 academic year within the context of an introductory chemistry course (Freshman Chemistry I). The study was conducted on the campus of said university, in the "natural" setting, to more fully comprehend the contextual depth of student academic experiences. Enrollment in the course was comprised of a majority of freshmen.

The introductory chemistry course of interest consisted of both lecture and lab sections. The lecture portion of the course met three times a week and typically took place within a large auditorium seating roughly 300 students. The lab portion of the course convened once a week and occurs within designated teaching laboratories under the tutelage of graduate students. There are generally at least 3 course sections, each implemented by separate instructors.

Case Selection

For this study, the cases studied were comprised of 8 female students enrolled in introductory chemistry (Freshman Chemistry I), including both chemistry majors and non-chemistry majors.

A preliminary survey was administered to the students, after which roughly 12 female students were selected as potential "cases" to be studied. The survey functioned as a means to provide information concerning the female students' career goals, prior academic experiences with chemistry, and other topics considered to be of import in determination of the sample. The sampling strategy of the study was "purposeful", with maximum variation sampling. Margarete Sandelowski (1995) states that such sampling is performed "in order to have representative coverage of variables likely to be important in understanding how diverse factors configure as a whole" (Sandelowski, 1995, p. 182). Such heterogeneous sampling enables aggregation of data from the unique perspectives of each case participant, facilitating a more holistic understanding of the phenomenon in question. Additionally, it was expected that there would be some meaningful commonalities within this set of "deliberately" distinct cases, such that a "typical" case may be characterized. Over the course of the study, the focus was narrowed to 8 cases of particular interest.

Methods of Data Collection

Data in this study was primarily obtained via semi-structured interviews with each case participant. Supplemental information about each case was provided by a pre-interview questionnaire.

Interviews

Semi-structured case interviews occurred on campus and were expected to last around one hour in duration. The interviews were audio-recorded such that their content was properly analyzed at a later time. Additional notes about the interviews were logged to provide more contextual information during the analysis stage.

Consent forms were signed, prior to the interviews of each participant. Furthermore, a pseudonym was assigned for each interviewee to protect their identities. Interview protocols were created which were intended to probe how influential factors including the student's familial, academic and social experiences affected their participation within college-level introductory chemistry. Moreover, interview questions also aimed to investigate the extent to which the student's epistemic beliefs were compatible with those of the chemistry discipline, defined according to the following parameters per Barbara Hofer (2000): (a) "the extent to which an individual believes that knowledge in a subject domain is simple, discrete, certain, and unchanging over time" (b) "the extent to [that] which an individual believes about multiple knowledge claims and justifying [this] knowing through personal and first-hand experiences" (c) "the extent to which an individual believes that authority figures in the field, such as textbooks or experts, pass on knowledge" and (d) "the extent to which an individual believes that truth can eventually be discovered in a domain" (Dai & Cromley, 2014, p. 264). Ultimately, data generated through interviews rendered salient categories and themes germane to answering the research questions of interest in this study.

Methods of Data Analysis

Data in this study were analyzed using the Constant Comparative Method (CCM) (Glaser and Strauss, 1967). CCM prescribes that the interview data gathered in this study be analyzed and coded as soon as possible to ensure the information is as fresh in the memory of the researcher as possible. Said analytical coding facilitated "constant comparison" of data such that data collection becomes an iterative process informed by analysis of data codes from the prior instances of data collection. The CCM of analysis involved three main coding steps: *open coding, axial coding* and *selective coding*. The analytical process proceeded with researcher sensitivity towards both the theoretical underpinnings of the study as well as the extent to which specific data/codes served to answer research questions.

In this study, recorded case interviews were transcribed and the resultant text analyzed initially using *open coding* to generate concepts that fit the data as closely as possible. *Open coding* is defined by Anselm Strauss and Juliet Corbin (1990) as the "process of breaking down, examining, comparing, conceptualizing, and categorizing data" (Strauss, 1990, p. 61). Data were analyzed very "minutely" as suggested by Anselm Strauss (1987, p.31). According to Strauss (1987), this strategy for open coding "minimizes the overlooking of important categories, leads to a conceptually dense theory… [and] forces both verification and qualification" of the findings (Strauss, 1987, p. 31).

Once open codes were established, *axial coding* took place in which connections were made between open codes (categories). *Axial coding* involved consideration of parameters including “conditions, context, action/interactional strategies and consequences” (Strauss, 1990, p. 96).

The final stage of coding, *selective coding,* sought to “systematically” determine “core categories” germane to the study to the extent that “the other codes [open, axial] become subservient to the key [core] code under focus” (Strauss, 1987, p. 33). The core categories subsequently served as a “guide to further theoretical sampling and data collection” (Strauss, 1987, p. 33). Strauss and Corbin (1990) stated that core categories, once generated, were to be processed by “systematically relating [them] to other categories, validating those relationships, and filling in categories that need further refinement and development" (Strauss, 1990, p. 116).

Verification/Trustworthiness

Interview questions were adjusted according to participant responses given in the prior interview for clarification purposes, thereby enhancing the validity of the study.

Ethical Considerations

This study was seemingly very low risk relative to any ethical considerations. Firstly, the participants were adults who were assumed to be engaging in the study in autonomous, voluntary fashion. Secondly, the research process was as transparent as possible, with the participants being made aware of the nature and purpose of the study, as well as any potential risks involved.

In the case that a participant did not feel comfortable answering a personal question about their academic history and/or families, the question was skipped and the interview resumed only with assurance that the participant was ready to do so. Additionally, owing to the gender focus of the study, participants may have found certain questions about topics such as male dominance in STEM fields uncomfortable.

The researcher proceeded with potential ethical issues in mind, with protection of identity at the forefront. To the greatest extent possible, there was full disclosure to participants of their role in the study. Participants were also kept apprised of the researcher's understanding and interpretations of their statements or actions.

Limitations and Delimitations

Within the practice of interpretive case study research it was important to be cognizant of the fact that "what we call our data are really our own constructions of other people's constructions of what they and their compatriots are up to" (Geertz, 1973, p. 9).

As a potential pitfall of the case method, Stake claimed that "damage occurs when the commitment to generalize or create theory runs so strong that the researcher's attention is drawn away from features important for understanding the case itself" (Denzen, 1994, p. 238). Stake held that in a case study "not everything about the case can be understood", so subjective choices must be made to determine what is relevant to study (Denzen, 1994, p. 238). In the process of the study, it was prudent to keep in mind Simons' (2009) suggestions that there may indeed be a "high probability of [researcher] bias" and "lack of control" over large amounts of data within the context of a case study (Simons, 2009, p. 16).

CHAPTER 4: RESULTS OF THE STUDY

The cases were analyzed and thematically categorized into the students' academic, social and familial "selves", as well as epistemic beliefs. Specifically, the "academic self" encompasses the influence of instructional experiences; whereas the "social self" is characterized by the effects of influential friends and peers, and finally, the "familial self" comprises the impact of family and familial values. Beyond the case's "selves", *epistemic beliefs* represent the extent to which the case's beliefs about the nature knowledge are compatible with those of chemistry culture. Put together, these analytical categories serve as tools to elucidate those factors affecting student navigation of the border into chemistry culture.

Case 1: Antimony

Antimony is a second-year undergraduate majoring in chemistry. She is taking this chemistry course for the first time and took AP chemistry in high school. She describes her experience in high school chemistry as "positive". She reports being "very much" interested in the subject of chemistry outside of an academic context owing to prior academic experiences, peer influences and popular media.

Academic Self

As a student, Antimony is characterized by an innate, strong drive to learn chemistry regardless of its admittedly challenging nature. She goes as far as to say that she is "totally fascinated by chemistry" because "it challenges the mind… I think about chemistry every day".

As she sees it, “if you love chemistry, you're probably naturally wired to have a brain that can be compatible with it”.

Antimony references positive experiences learning chemistry that provided impetus for her deep interest in the subject. She recalls learn[ing] about water…a polar molecule…keep[ing] the Earth cool…that set me happy the whole semester, and I'm more appreciative of water… I'm a happier person”. She has also been greatly encouraged by positive experiences with former teachers, specifically in high school. She describes her high school chemistry experience as “awesome” owing to the “great teachers” she had. Consequently, she claims that their influence made the transition into college-level chemistry from AP chemistry “not significant[ly]” difficult and despite not passing the AP exam, she has persisted in pursuing chemistry. She credits these teachers with helping to instill within her a sense of “self-reliance” and taking “initiative” and doing “lots of learning on your own”. She views these qualities as fundamental requisites for succeeding in a chemistry course.

Antimony points to the difficulty some students encounter in a chemistry course as being a result of much of the material being conceptually abstract, like in the case of the atom, stating that “it’s so abstract a thing, you can't physically see it in your hand, and you don't have proof in your mind what it looks like”. She additionally notes that learning chemistry is further complicated by general chemistry in particular being so “math heavy”. She considers math to be “a language unto itself” and “hard for some people”.

Antimony identifies general chemistry at the college level as a useful gatekeeper to other sciences. She explains that “it serves its purpose because the people who aren't willing to put the effort into it usually aren't passionate about science”. Regarding gatekeeping, she contends that "if you have a passion for something or you love something, you can get past the gate… you have no business in the courses if you don't love science".

Social Self

Antimony asserts that chemistry is unduly maligned and undervalued among her undergraduate peers. She bristles that her fellow students "don't appreciate chemistry…they're just going through the motions". She further argues that, on the whole, many students have trepidations about learning chemistry since "they don't think they will understand it". Moreover, students have "pre-conceived ideas" about the difficult nature of the course to a deleterious degree, which prevents them from being interested in learning the material. Antimony likens her seemingly unique love of chemistry amongst her peers as isolating. She explains that "it would be easier if I had friend" …who found chemistry "interesting" and "as something that's fun to do".

Antimony takes issue with how chemistry is "not portrayed enough in popular media". For her this is a consequence of a "dumbing down in our culture", where celebrities are revered as "more valued and more interesting" than scientists. Antimony suggests that as far as science in general goes, there are "things that are cool that people should be excited about". She contends that it would be "better if we were more exposed to new discoveries in science" wherein we could "spend a little bit of time… challeng[ing]" ourselves to the "benefit of society".

Familial Self

Antimony has had very little influence on her scientific career path with respect to her family. Both of her parents, as well as her brother have careers in accounting. Prior to beginning college, she recalls her father suggesting a career in a business-related field.

She reveals that the “biggest influence” her father, a college professor, has had on her career is “encouraging” her to pursue education beyond undergraduate studies. Similarly, she describes her mother as being fully supportive of whichever career path she chooses as “she just wants`` me to be happy...and would even be cool with me doing art”.

Epistemic Beliefs

Antimony believes in the compatibility of religion and science. Growing up she was “super Catholic” and attended Catholic school. As an adult she has become more Agnostic and questioning, but still maintaining a belief in a “supreme something”. Despite the shift towards a more secular belief system, Antimony contends that she “doesn’t think everything can be explained by science”. In her view, science can only explain “how things exist… not why things exist”, here specifically making reference to the Big Bang. Certain things are thus off-limits and unknowable to the scientist, and as such, Antimony posits that a “good scientist” should remain “humble” to the majesty of a universe that is “endless” and beyond human comprehension.

Overall Case Findings (Antimony)

Figure 3 shown below illustrates the selective codes generated for each input type as well as epistemic beliefs.

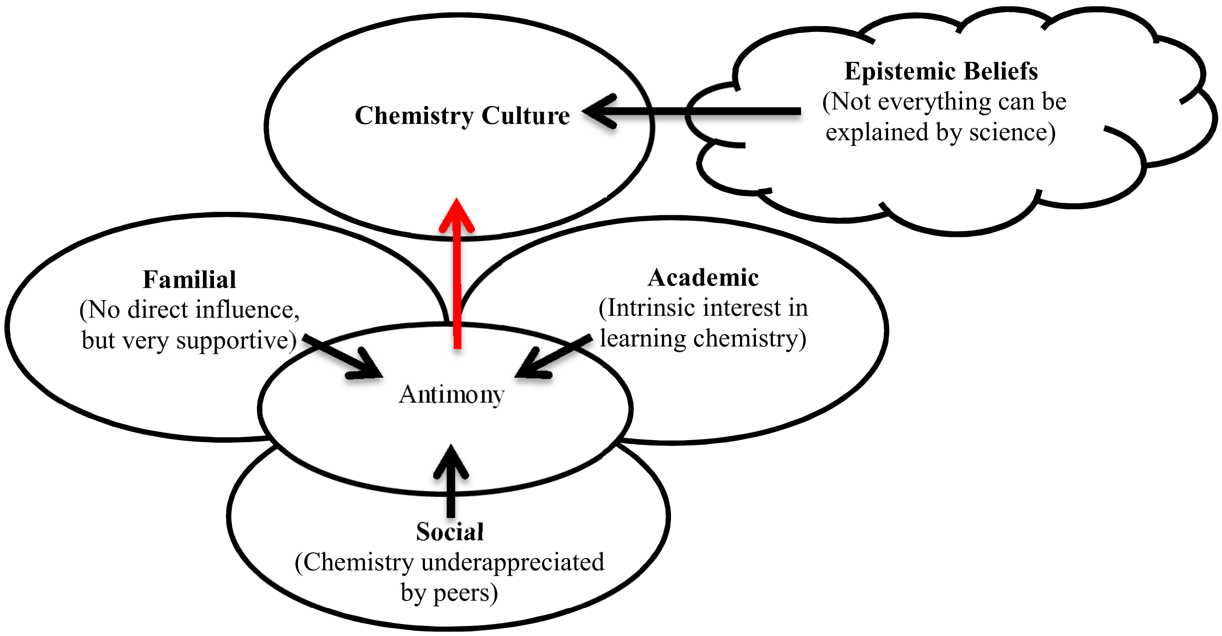

Figure 3: Representation of findings related to Antimony's case.

Case 2: Hydrogen

Hydrogen is a second-year undergraduate student majoring in Animal Science. She is taking this chemistry course for the first time and did not take AP chemistry in high school. She describes her experience in high school chemistry as "favorable/positive". She reports being "not at all" interested in the subject of chemistry outside of an academic context due to fact that she finds the course "harder than it needs to be".

Academic Self

Hydrogen's perspective on learning and succeeding academically is epitomized by an ethos of self-determinism. She feels very strongly that academic achievement within chemistry courses entails "go[ing] through it in order to get to whatever you want to do" career-wise. She views the course as a test of one’s mettle, as “it takes a certain person to know that they're not doing well in the class [and yet] to keep going even though they know they don't have the best grade in there”. Regarding the prospects of her own grade in the course, Hydrogen laments “I'm fine with passing. I have a C plus right now… but it's not just the fact that I have to pass, I have to pass with, a B or B plus in order to get into vet school… passing [alone] is not fine”. She expresses having perpetual anxiety over the potential gatekeeping effect of the course on her career, “Oh my gosh, am I'm going to get into vet school or am I going to have to go to a really sucky vet school just because of this class? It's kind of like you feel like your dreams are being shattered just because you have a C plus”.

Despite her uneasiness about her eventual grade, Hydrogen concedes that gatekeeping is a useful facet of the course. She argues that although the course is a “barrier for me getting into vet school, I think it's good in a certain way” … [without gatekeeping] “then anybody could be a doctor, anybody could be a vet, anybody could do it… it's not about that… it's being certain to make sure we have good doctors and good vets”. Per Hydrogen, gatekeeping justifiably functions to “filter for things like intelligence, effort, and ambition”, and success in the course “has a lot to do with the effort that you put in… people that do make A’s really work their tails off to get that A… also, if you're not a certain level of intelligence, I don't feel like you could do it”.

To illustrate what constitutes gatekeeping, Hydrogen contrasts her chemistry course experience in high school versus college. She particularly emphasizes that “college chemistry makes it so stressful on the student, rather than the student having fun and learning the class, [instead] you're stressed out about it”. She identifies the difference between the two as stemming from how chemistry is taught in each. She fondly recalls that in high school she had a “really good teacher who went more in-depth and tried to work one-on-one with each student… in high school they went through all the basics and explained it… in college [however], you have to figure out the basics on your own". She testifies that the course in college is "made a lot more difficult than it really needs to be, it's the teachers and how it's taught that makes it a lot harder… I don't think the content is difficult at all yet the material covered in class is not sufficient…I never really learn anything… I have to go Google things… I have to do extra work for stuff that I feel like should be provided [in lecture]… even the questions on the test could be asked in a much more simple way". She further describes her experience with lecture, "you go in and you do these clicker questions, you don't know what the heck you're doing for them because you didn't go over the material because you didn't have time, and then that lowers your grade, and then you're lost the whole lecture, and then you ask yourself 'why am I even here?'". She describes the overall mindset of the students in lecture as detached, if not resentful: "when we go to chem class, it's just kind of like nobody pays attention in chem class… it's not just people on their phones, [they're] doing stuff for other classes, because it's just a waste of time for everybody because you don't learn anything… and you feel lost and then it's just kind of like, 'why am I even doing this if I don't understand it?'". Hydrogen summarily concludes that she "remember[s] learning the same concepts as now [in college]… but ended up with a better understanding in high school".

Social Self

Key to Hydrogen's social self is marked independence from the influence of her peers as well as prevailing stereotypes about science altogether. She notes the at-large notions from her peers are that chemistry is "hard" unless you're "smart, intelligent, and good at it… [those are] the only people that can do it". She claims however that her strong focus on career goals preempts her from any consideration of peers' opinions as she's "heard both good and bad about the chemistry courses here but neither has had any effect on me". She continues that "I don't really think my peers have much influence on me and what I think about". This is particularly evident in her statement "all my friends are married and having kids… I have ten years left for that stuff".

Regarding the relative paucity of females in STEM careers, Hydrogen points to innate gender differences affecting the careers women pursue. She argues that, in college, "females are already thinking they want to get married, settle down and have kids, whereas the guys still want to continue college life… I think it's a maturity level kind of thing". Hydrogen asserts that females are thus likely "to not want to go through the further education that most STEM careers require", adding that "a guy doesn't stay home and watch the kids while the woman goes off to med school. It's the other way around". In bridling fashion, she recalls sensing sexism when enrolled in computer engineering courses, "It's kind of like 'what are you doing here?'… they thought they were better than me… they really weren't, it was just because I was a girl… but in my vet program, this isn't so, because it's mostly girls". Despite her experience though, Hydrogen refutes even the suggestion of a "sinister" chauvinist agenda afoot which prevents women from participating in STEM careers. Rather, to her it can more simply be attributed to some women "just not being interested in STEM stuff".

Familial Self

Hydrogen's career choice has been strongly influenced by the pressure and expectations of her family, even to the extent that she has altered her career path as a consequence. She recalls, "I actually transferred here from a Christian college. I had gone to the Christian college in order to do missionary work, but that was looked down upon by my family, it wasn't prestigious, and I wouldn't be making any money with that, so that's why I came here". She adds "my family is very prideful, so it's a I have to follow in my family's footsteps kind of thing. If I don't do that, it's going to look bad for the family". Hydrogen further details the expectations put upon her by her family: "It's basically looked down upon in my family if you don't do something that's big… even the nurses in our family are kind of looked down upon because they're nurses and not doctors, vets or engineers… it's a prestige kind of thing". Despite these apparent pressures from her family, Hydrogen states that her family "wants the best for me… I would call it a mixture of pressure and encouragement". She sees herself, by virtue of pursuing a "prestigious" career as a veterinarian, as fulfilling her duty within the structure of her family as her "father is a veterinarian, [her] mother is a lawyer… and [her] two brothers are going into science careers".

Epistemic Beliefs

Hydrogen's religious beliefs are traditional yet lightly tempered by a measure of agnosticism. She declares "I believe in Creationism… I do go by the Bible… I do think that Creation happened how the Bible says it did, although I don't know about the creation of the Earth for sure". She discusses interactions in which she says, "people argue with me and tell me 'Hey! You can't believe that!'… and my response is 'Well then, why can you believe what you believe if you weren't there, either?'". In this way, she acknowledges the presence of subjectivity in beliefs. As she puts it, "everything is really unknowable".

Hydrogen's seeming anti-evolution stance complements her view that knowledge via science is ultimately limited in scope. She explains that "there's a lot of things that aren't really known to man and that we can't really figure out or haven't witnessed, but I don't think even those things could [eventually] be 100 percent proven right or wrong by science".

Overall Case Findings (Hydrogen)

Figure 4 shown below illustrates the selective codes generated for each input type as well as epistemic beliefs.

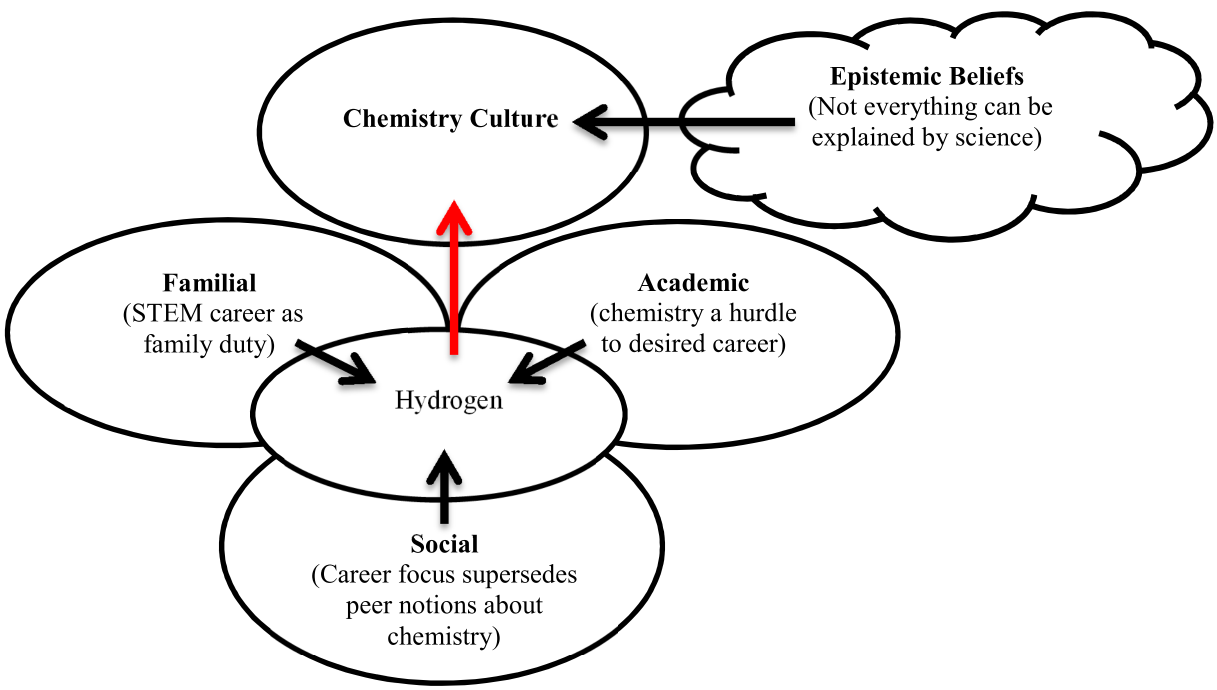

Figure 4. Representation of findings related to Hydrogen's case.

Case 3: Phosphorus

Phosphorus is a first-year undergraduate student majoring in Pharmaceutical Sciences with hopes of one day becoming a pharmacist. She is taking this chemistry course for the first time despite the fact that she was able to exempt the course with AP credit from high school. She describes her experience in high school chemistry as "positive", this, along with supportive familial influence accounts for her being "very much" interested in the subject of chemistry outside of an academic context.

Academic Self

Phosphorus views success in chemistry and a subsequent career in STEM as chiefly predicated upon one's natural ability in the domain of science. She argues that "it's not for everybody… like someone who is not very good at science… it's just difficult for the majority of people to understand… we should just leave it to the experts who really, really know how to do it." Phosphorus attributes the disparities in ability as stemming from the extent to which abstract concepts in chemistry can be mentally visualized. She remarks that "science is an attempt to explain what you see. Science however is not [always] synonymous with what you see…it's hard to grasp because, being abstract, it's not directly obvious… so there is a disconnect between learning [chemistry] theory and what is actually there… you just have to be able to visualize chemistry… like in the case of molecular geometries, I'm able to picture those geometries in my head, but I know some people who just can't… you have to understand it at the molecular level before you understand anything else… I like chemistry because of that." She continues that chemistry "makes me think in a way that develops my critical thinking skills… the same way I solve chemistry problems… I use the same type of thinking to critically solve problems in life … that is maybe really [too] challenging for a lot of people… but I use the way that I think in chemistry, that's just my life."

Phosphorus regards gatekeeping as a "good idea" within an introductory chemistry course since its concepts are foundational to the pursuit of a STEM career. She explains that introductory chemistry provides “the basics to everything else you’re going to learn… you need to understand it in order to keep going… even biology has the basics of chemistry, so I would say it's okay to gatekeep science majors using that course.” Phosphorus additionally sees said gatekeeping as a valid measure of student effort since learning the material “can be difficult… but it takes time to actually learn it… it’s not one of those things you can just BS and do a good job in the course… you really have to sit down and work at it.”

Social Self

Among Phosphorus’ peers there is a prevailing sense of chemistry being intimidating, so as to be avoided altogether. Phosphorus explains that “people just shy away from it… scared they're going to mess up… that they might fail the course… a lot of my friends really wanted to take the course, but they were just too scared to take it… even to switching majors… they’ve been telling me not to take it”. Despite these social pressures, Phosphorus relishes the “challenge of science”, stating that it “just drives me to take it more, because I like science… so telling me not to take it is just going to make me want to take it even more… I want to be [of] the few that succeed in that course.”

As a female, Phosphorus has, additionally, had to contend with cultural norms in relation to a career path. She explains that “I’m Nigerian… in my culture if I were a male it would be completely different… [males] are expected to become lawyers, engineers or doctors… [while] women have the duties of cooking, cleaning and taking care of children.” Phosphorus continues “I feel that’s a little sexist… I once had a youth group mentor at church who discouraged my being a doctor instead of a nurse… why can’t I be a doctor?”.

Phosphorus observes however that there is a shift away from such “antiquated” cultural norms. She notes that “the new generation of women are taking a further step towards science and technology, the biggest growing industries… that’s where women are moving right now… [whereas] before you were home with your children due to gender roles.”

Familial Self

Phosphorus’ early and keen interest in chemistry has been strongly facilitated by her family. She shares that “everyone in my family is associated with science… my mom is a charge nurse, my dad is a psychiatrist, my sister wants to be a physical therapist, and my grandmother taught secondary school Biology in Nigeria”. She recalls, “my family introduced me to science… I knew I wanted to be some sort of chemist since the age of 10… I even used to make potions when I was little… and around age 14 or 15 I found out about pharmacy and decided on being a pharmacologist.”

Epistemic Beliefs

Phosphorus considers science being limited with regards to any capacity of “explaining everything”. She contends that science “attempts to explain everything… but there are a lot of things that you just can’t explain with science.” She likens science to a sort of “language” that falls short in articulating an explanation for “all things in the world”. Phosphorus however stops short of suggesting that other “languages”, in the vein of religion or spirituality, can reveal the answers that science cannot. In agnostic fashion, she questions the legitimacy of “truth” that is based on religious beliefs and asks “why do people feel the need to do a certain thing or think a certain way and be exactly right about it?”.

Overall Case Findings (Phosphorus)

Figure 5 shown below illustrates the selective codes generated for each input type as well as epistemic beliefs.

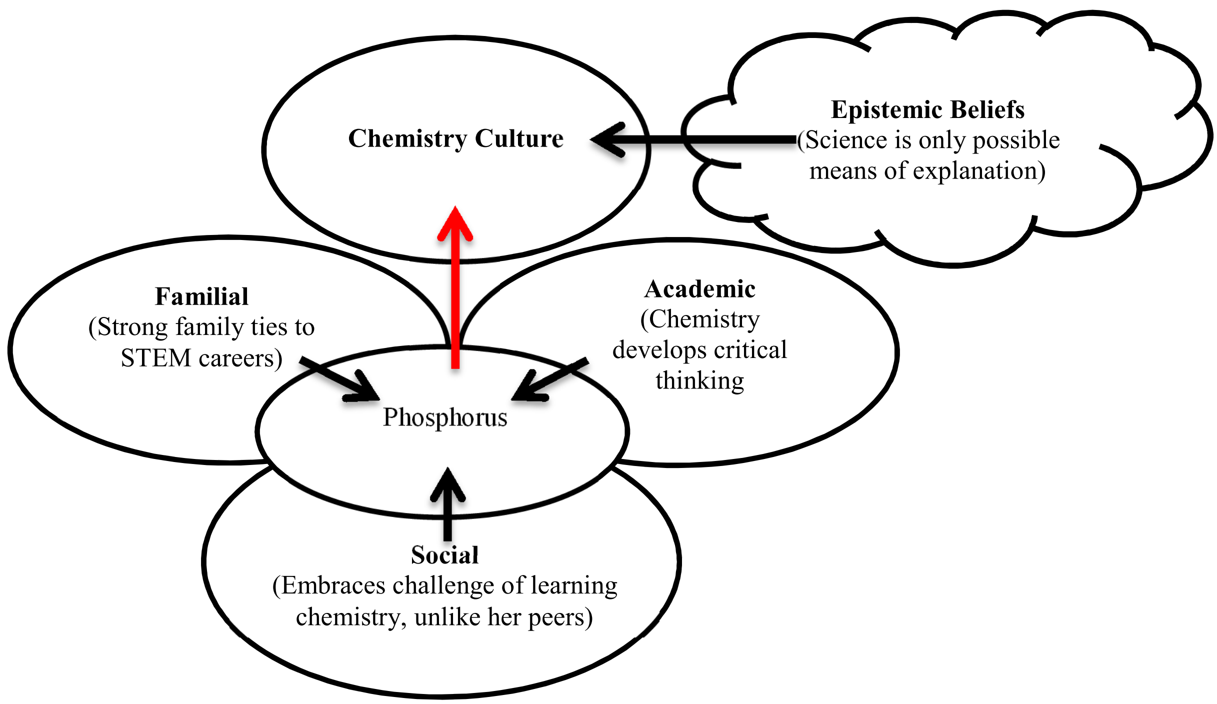

Figure 5. Representation of findings related to Phosphorus' case.

Case 4: Mendelevium

Mendelevium is a first-year undergraduate student majoring in chemistry. She is taking this chemistry course for the first time and did not take AP chemistry in high school. Her experience in high school chemistry is described as "neutral" she claims to be "somewhat" interested in the subject of chemistry outside of an academic context.

Academic Self

Mendelevium’s interest in science is due to her positive “experiences in high school taking science classes”, which are what inspired her “to pursue chemistry as a major and be in a pre-dental program”. She elucidates that “once I got into high school, I found out that I really enjoyed science… when I was younger I much more preferred literature… there was that shift”. She recalls that her freshman year in high school she was accepted into a “program called the Academy of Medical Arts… [in which] you had to take two science classes each year… so my freshman and senior year I took biology, but AP bio in the senior year, and then a research class, which was mostly dedicated to working on science fair projects… so, our freshman and senior year we had to do science fair, but then my sophomore year I had to take human anatomy with chemistry and then my junior year I took physics with environmental science”.

Mendelevium views her Honors chemistry course experience in high school as being “a lot different than freshman chemistry in college”. She contrasts the courses by explaining that in high school she “felt like everything was straight forward and [she] got it… but now taking chemistry in college… everything's harder to understand… more difficult, like there's more steps to do in the problem… more room to make mistakes… and it's moving at a faster pace… I'm not learning so much when I go into lecture”. She further points out that “lecture is more like reviewing what you’re supposed to have learned [outside of class]…and if you didn’t learn it already, you're not going to get it in class… you have to learn it all by yourself… your teacher sort of just guides you… not so much teaching us in class”. She concludes that she would much rather “have it the other way around… [where] your teacher teaches you, and then your homework is your time for review”.

Mendelevium furthermore finds the lecture class sizes in the course to be problematic since “there's like 200 people and if I have a question I don't want everybody in the class to hear it too… I don't ever want to ask questions… and I just wouldn't want to ask a dumb question… I'd rather just have a smaller class because then I [would] feel closer to my teacher and then more comfortable so I could ask questions like: How do you do this? Can you help me out?... that would be better for learning”.

On the topic of gatekeeping in introductory college chemistry courses, Mendelevium argues that it is “smart” thing to do. She clarifies that “if you're not going to do good in chemistry and you can't get the hang of it, then you're not going to be able to do well in your higher-level major classes… that’s why gen chem is the gatekeeper for science majors… [it] is supposed to be the weed-out course… it’s all based on how you do… if you don't do well, then you probably should rethink what you’re doing and find something that suits you better… but then again if you do well, then you're just like ‘Well, this is great, I can stay where I'm at!’

Social Self

Mendelevium asserts that media portrayals of science are politicized to negative effect, as they solely focus on “arguments about global warming… and other environmental issues like oil spills or power plant malfunctions”. But when it comes to innovations or developments in the domains of “chemistry or biology”, she argues that these are “things you have to go seek out rather than [being] something that’s told to you”.

Mendelevium declares that the social perception of science has become “cooler”, as there has been a shift away from characterizations of science itself as “nerdy, dorky or geeky”. She continues that even the connotation of the word “nerdy”, used to describe “scientists and engineers”, has shifted into a “good light” nowadays. She explains that “when most people come into college they come in want[ing] to be biology majors, chemistry majors, all that jazz… it's definitely gotten a better rap now, because that's where all the jobs are stemming from… science”.

Mendelevium, however, recalls witnessing prevailingly negative views of chemistry, particularly amongst her peers. She recalls that when she would tell people she was majoring in chemistry, they would say things like “Wow, you're crazy!... You're going to hate chemistry!... You actually like that stuff?... They're trying to kick you out of the class!... Why would you enjoy that?”. Despite this discouragement of her majoring in chemistry, she reveals “I definitely doesn’t let other people's opinions of chemistry sway mine, I still enjoy chemistry!”.

Mendelevium expresses frustration and puzzlement at the thought of “science fields like engineering… and research labs” being “mostly male-dominated”. She argues that societal gender stereotypes perpetuate these issues since “engineering is [the] harder stuff that us girls apparently can't handle” and thus are “guided… or kind of forced… into different professions like nursing… or things like teaching and dealing with children versus going into engineering or being a doctor or a lawyer”. Ultimately though, Mendelevium sounds a hopeful note relative to the aforementioned gender disparity when she points out that “there's still women out there and they're tough… getting through all that, because it's hard for not just women, but for everyone”.

Familial Self

Mendelevium has effectively had no influence from her family on her chosen career path in science. This is reflected by the fact that although her father “works with satellites… satellite technology… for the government", Mendelevium expresses a lack of interest in what sort of science her father does when she admits that she's "not entirely sure what [he] does".

Ironically, Mendelevium underscores the extent to which antiquated gender roles are strongly reinforced in modern times by how families, including her own, raise their children. She states that "even though it's the 21st century, children are raised by people that think boys are still supposed to do this and girls are still supposed to do that… it's definitely something to do with gender roles… it's so easy to shape [young] people's minds… when you're little, your parents tend to have a lot of influence on you versus you having an influence on yourself".

Epistemic Beliefs

Mendelevium believes that although "there's definitely things that can be explained by science, like water ha[ving] its own molecules made up of hydrogen and oxygen… crazy things like miraculous healings and that sort of thing happen" [too]. Her faith in such "unexplainable" things is evident when she mentions that her "friend [is] in the hospital right now, and [she's] really hoping for one of those miraculous healings [for them]". These unexplained "miraculous" events and such are tied to her "religious views" and as such, she concludes therefore that "not everything's explained by science". She does however ultimately contradict herself and concedes that "anything could happen… maybe in the future… if we manage to somehow make technology even more amazing… it's possible to [be able to] explain everything".

Overall Case Findings (Mendelevium)

Figure 6 shown below illustrates the selective codes generated for each input type as well as epistemic beliefs.

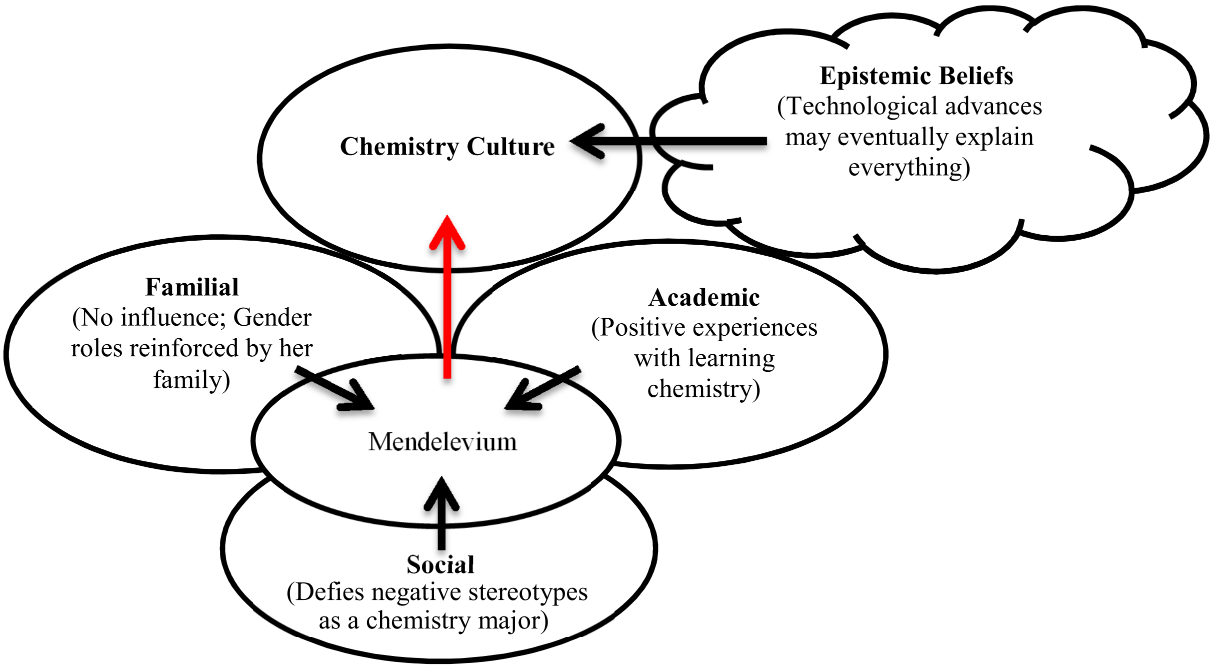

Figure 6. Representation of findings related to Mendelevium's case.

Case 5: Xenon

Xenon is a first-year undergraduate student double-majoring in biology and theater. She is taking this chemistry course for the first time and did not take AP chemistry in high school. Her experience in high school chemistry is described as "positive" and she reports to be "not at all" interested in the subject of chemistry outside of an academic context.

Academic Self

Xenon regards the subject of general chemistry as singularly challenging. Per Xenon, chemistry entails "a unique type of learning that I've never experienced in any other subjects… it involves different types of problem-solving…I think it's very difficult to be able to do it… to put your mind in two different places at the same time…combin[ing] math with abstract concepts…

you're [often] dealing with things you can't see… it's just a large amount to learn in a short amount of time".

Notwithstanding the difficulty of understanding chemistry, Xenon is intrinsically motivated to study chemistry primarily for the sake of learning. She explains that she "enjoys sitting in class and learning [it]", despite her claim that chemistry is "not something I'm good at". For Xenon, grades are of secondary importance relative to learning: "I just try to learn the topics more than I'm concerned with the grade I'm going to get… I'm more interested in learning the material than necessarily getting a perfect grade… [in the long run] I'll benefit more by [really] understanding it rather than just memorizing things… I think I just hold myself to a high standard and I have big respect for people who love doing all the hard work to learn". To Xenon, the "joy" of learning manifests itself when real-world connections are made with the course material. Xenon recalls her chemistry lecturer "talking about how molecule structures inspired architecture and how there's lots of [other] stuff you don't realize… but you can look around you and it just makes sense".

Xenon additionally extols the gatekeeping functionality of general chemistry as a metric for student initiative. She asserts that "It shows people the effort that they have to put in to pursue what they want [career-wise] since people can be lazy and not want to put a lot of effort in… it really is a culture shock for some people who may not have worked that hard in high school… and they just don't want to put in the work. They get to college and realize that there's a lot more effort they have to put in… it's a big reality check… it gets people ready for college, especially a career. It sets that precedent". Xenon further argues that the material "is not impossible to learn… there are plenty of resources [for students] to do exceptionally well". Xenon concludes that the general chemistry course ultimately benefits students in that it "really helps you to see if your major matches your interests, because you're going to have to pull material from the course later".

Social Self

Xenon's interest in learning chemistry is strongly influenced by her friends in high school. She reveals that chemistry was "a hugely respectable thing to be good at" amongst her friends who were "really, really smart… and really interested in it". Consequently, she notes "It made me want to do better. I didn't want to fall behind them… my friends were really kind and were willing to help me if I needed a few questions answered… it was fun for [both of us] to learn… they enjoyed tutoring me, so it was easy to get help". Xenon regards this experience as profoundly edifying: "it definitely made me realize that I could achieve [academically]".

Contrary to Xenon's sense of self-efficacy in learning science, she notes it is often the case where people find science to be "off-putting" as a consequence of how scientists are (inaccurately) perceived. She suggests it is "assume[d] that *all* people who do science are smarter than they are, or really, really smart compared to other people… [thus] scientists stand out from the average person". According to Xenon, this can "intimidate" and "shy people away" from pursuing science, who ostensibly tell themselves "'I can't be that smart, I'm not that smart [like those scientists]'".

Familial Self

Xenon's pursuit of a career in science has been greatly influenced by her grandmother, a professor of biology, who she claims "made me realize I really liked biology". Xenon believes that her grandmother "started [her] interest in every type of biology… [especially] animal biology… she did everything and anything you can do in that field… she wasn't tied down to one [thing]… she exposed me to [it all]... she opened up my mind [beyond only] being a professor or working in a lab… I didn't necessarily have to do the same work she did, but I could take the interest in biology into a different field… her passion for the subject and her growing up in a time when sexism in the sciences was an issue… really inspired me”.

Xenon speaks fondly of her freshman year of high school when her grandmother “helped a lot through AP biology”. She recalls thinking “it was going to be a really big struggle and I was going to hate it because it was really different… but having her sit down and teach me… and see[ing] all the stuff she has, all her old textbooks and research, made me realize that I really could do it”.

Xenon additionally notes further support from her parents. She shares that she “had a very encouraging upbringing”, and that her “parents are just happy that I want to do something”. She continues that, “my parents were [even] supportive of me doing a theater major… whatever made me happy… I never felt pressured by them” to follow a specific career. Xenon shares that although her mother decided to “stop working to have a family”, she herself is “going to keep working no matter what… it's going to be a long time before I’m married [with her grandchildren]… I'll be 80 years old!”.

Epistemic Beliefs

Xenon finds the assertion that everything “can and should be explained by science” problematic. She explains that “science can figure out 99 percent of things… and provides a strong basis for explaining things”, but she doesn’t “necessarily think science would be the best way to explain [all] things”. Xenon argues instead that, even though she’s “not affiliated with [any] religion”, “there's a happy medium between science and religion… they can work together… you can fill in the gaps with religion or science and vice versa… it's okay to have other means of explaining something, even if it's not [proven to be] 100 percent true... there's always things that we're not going to understand… and that’s okay with me”. She elaborates that “there's times that people just miraculously heal, and you can run [medical] tests all day, but you can't get a definitive answer… there’s [perhaps] another way to explain it.”

Overall Case Findings (Xenon)

Figure 7 shown below illustrates the selective codes generated for each input type as well as epistemic beliefs.

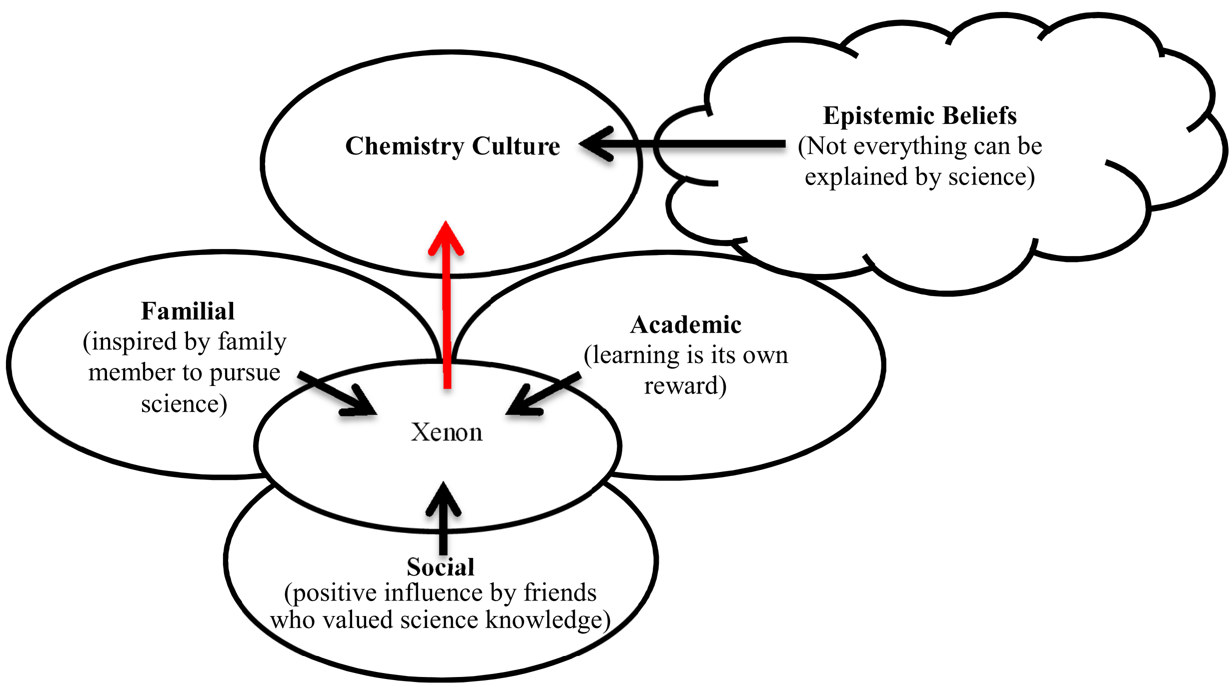

Figure 7. Representation of findings related to Xenon’s case.

Case 6: Magnesium

Magnesium is a first-year undergraduate student majoring in biochemistry. She is taking this chemistry course for the first time and took AP chemistry in high school. Her experience in high school chemistry is described as “positive”. She also reports she is “somewhat” interested in the subject of chemistry outside of an academic context which is attributed to her prior academic experiences, familial influences and popular media.

Academic Self

Magnesium’s interest in learning chemistry has been markedly influenced by her positive experience with the subject in a high school AP course. She recalls that “in tenth grade, my teacher was really funny…entertaining… [and] we applied it to real life in some way… [like] whenever we had to fill out the [orbitals] of electrons… my teacher would say something like ‘When you have a bunk bed, you have to fill them up’… so stuff like that interested me even more.”

Magnesium points out that her interest in chemistry is very much tied to her teacher’s use of “mini experiments”, whereby she “could actually see the chemistry occurring… see what's going on... [otherwise] you're just doing it on paper… just reading… and it's just a bunch of numbers and words… when I can't see the chemistry… that's what makes it hard [as] I consider myself a visual learner and I’m involved in art, so I like to see things”. Magnesium concludes that this course provided the impetus for her current career path, noting that “the way she taught it to us was just fun… so from then on I started looking into [chemistry]… that's why I'm majoring in biochemistry.”

Magnesium views the gatekeeping facet of introductory chemistry as a bit unfair but nonetheless necessary. She explains that "I don't like [gatekeeping] because sometimes a person can be better at another area besides chemistry… I mean, biology is easier to me than chemistry… [but] when you take biology, there's still chemistry in it, so you still need it. If you don't have that foundation… that basic understanding of chemistry, the other stuff is going to be hard for you". As it applies to her own career aspirations, Magnesium notes that "being forced" to learn chemistry via gatekeeping is a "good thing", since she is "considering being a pediatrician" and "it would be really useful to have that chemistry background, because it will be a better way to explain to my patients what's going on".

Social Self

Magnesium contends that the media portrayal of scientists has shifted dramatically in a positive direction. She describes the way scientists are presented now as "positive", stating that "now, there's a better representation of the actual person of a scientist, as someone not avoiding society… they're [still] nerdy, but at the same time they're people smart... [whereas before they were] just nerdy". Magnesium recounts that "in elementary school, we would listen to Bill Nye The Science Guy… he was just nerdy and awkward… but then when we got to high school, [we] would watch videos for my AP bio class… [by] Mr. Anderson… he was funny and he was really smart… it was just different [than Bill Nye]".

Despite the aforementioned "positive" portrayal of scientists, Magnesium suggests that there yet exists a gender bias against women in media. Aspiring to become a physician herself, Magnesium takes issue with the paucity of female doctors in popular shows like Grey's Anatomy, in which "the main doctors are men… [while] women don't really get that role being the doctor [as much]". Magnesium asserts that this has the effect of reinforcing "traditional", "stay at home" societal female roles, adding that some "women might [still] be afraid of taking on another role in society than what they're accustomed to". In relation to her career goals, Magnesium derives motivation from defying these "old" norms, finding it "encouraging [that] you have to prove yourself… hav[ing] to break the ice and go for it… to show people that you can do it".

Familial Self

Magnesium credits her sister with having the strongest impact on pursuing a career in STEM. She shares that her sister "influenced me a lot. She is and was a role model… my sister majored in biology… [and] was very passionate [about it]". Magnesium recalls that when she was in the sixth grade, her sister "would come home and try to explain [biology to me]… I think it's because of her I [went] towards science and not anything else".

In addition to her sister, Magnesium's career choice is supported by her mother. She reveals that her mother once told her "I'm good with anything you do… as long as you don't work… in a carpet factory [like me]". In contrast, Magnesium's father does not endorse her chosen career path. Magnesium clarifies that "my dad doesn't like that I'll be in school for, like, ten years or something. He wants me to be a teacher [instead]". Despite the disagreement with her father about her career, Magnesium takes solace in the fact that she has "the support of [her] sister and mom".

Epistemic Beliefs

Magnesium asserts that science can explain "most things", but "not everything". Per Magnesium, "advancing science" could help to "explain stuff that we don't [yet] know about", but she holds that things like “history can't be explained through science… [like] how humans were created… how we got here”. In light of her religious beliefs, she finds problematic the notion that the Big Bang was brought about in the absence of some “greater power”. In her own words Magnesium wonders, “It’s [all] there, but who brought it?”.

By her own admission, Magnesium’s Catholic faith “contradicts science” and she concedes that “sometimes I have to go towards the facts and not just my beliefs”. To exemplify this, she eschews the “seven days of creation” as not “being the way life came [about] on the planet”. Additionally, Magnesium explains that “although evolution contradicts the Catholic Church, the science is there and there's evidence in the Galapagos… you see all those finches… [and] you know how they evolved”. According to Magnesium, “religious beliefs and science are not mutually exclusive… there is at least some synergy there… they aren't complete opposites. So, a belief in science and a belief in God or gods can coexist”.

Overall Case Findings (Magnesium)

Figure 8 shown below illustrates the selective codes generated for each input type as well as epistemic beliefs.

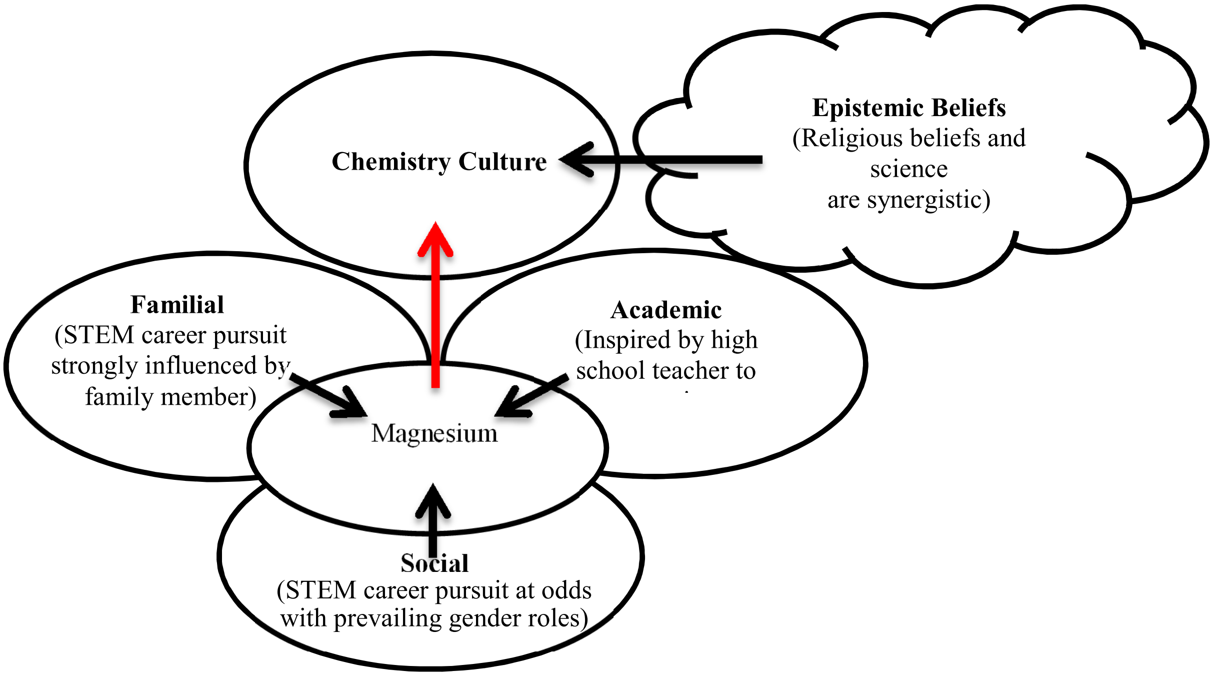

Figure 8. Representation of findings related to Magnesium's case.

Case 7: Tungsten

Tungsten is a second-year undergraduate student majoring in animal science. She is taking this chemistry course for the first time and did not take AP chemistry in high school. Her experience in high school chemistry is described as "neutral". She also reports she is "somewhat" interested in the subject of chemistry outside of an academic context which is attributed to her prior academic experience, as well as her "enjoyment of math" and "strategic thinking".

Academic Self

Tungsten views learning general chemistry as uniquely challenging. She states that unlike "other subjects [where] it's just memorizing things", "you have to put a lot of work… and time" into studying chemistry. She explains that "every [chemistry] problem is different" and as such, each entails application of "[various] concepts".

As a student, Tungsten finds satisfaction in being able to assess the extent of her learning being as how she "like[s] taking tests… to see what I know". For Tungsten, "math-based problems" in the chemistry course are appealing to her as they involve "strategic thinking" and are thus "enjoyable [and] definitely really rewarding to do… [versus] memorizing a bunch of information". These math problems therefore effectively function as proxies for Tungsten's assessment of her learning. Tungsten adds that "I get excited… looking at a problem… being able to work through it and get an answer… I like [doing] the math". Thus, actualizing her desire to master a "difficult" subject like chemistry confers Tungsten a sense of gratifying accomplishment.

According to Tungsten, the most "difficult", hence "frustrating" aspect of learning chemistry pertains to the abstract nature of certain "hard" concepts that "I don't get… [because] I can't actually see [them]… [despite the] many times [they] get explained to me". Ultimately, Tungsten expresses uncertainty as to whether successfully learning the course material is a consequence of "some people just hav[ing] the brain for it, or if some people just didn't work as hard [as others]".

Tungsten characterizes gatekeeping in undergraduate general chemistry as "very unfortunate" and "frustrating for someone who wants to have a career in science". She argues that the “whole purpose” of gatekeeping is to “discourage students… and get people to drop [the course]… like [the instructors] almost don’t want you to do well”. Tungsten contends that freshman chemistry being a “weed-out” class dramatically “changes peoples' lives”. She laments that “some people have to change majors because they can't get through the course… [and even though] there are people that might really struggle with [the course]… that doesn't mean that they shouldn't be a part of the science world”.

Social Self

In the process of taking introductory college-level chemistry, Tungsten has had to navigate the influence of a “negative [peer] consensus” towards the purportedly “impossible” course. Her daunting perception of the “scary” course was no doubt reinforced by stories of “bad” experiences within her peer group. She recalls, “I know people who started out with science majors who just heard about how hard it was… and change[d] [their majors]… someone on my team did that, and I know two people that went to the first day of chemistry, already heard about how bad it was, felt overwhelmed the first day, and dropped out the next day”. Although she admits to being initially “very, very nervous” at the beginning of the course, she eventually found the course to be “very doable” in contrast to what she “was told” by her peers. Tungsten notes being better prepared due to the peer “negativity” such that “I generated my schedule so [chemistry] was my main class to focus on”.

For Tungsten, what markedly solidified her drive to succeed in the course was a “cautionary tale” of her “three friends who failed… [and] became ineligible to compete on our team that semester… if you're failing, you're not allowed to compete… or [even] practice… that's the worst thing that could happen to one of us”. Tungsten states that her teammates’ experiences “help[ed]” her cultivate a mindset of determination, “an attitude coming in where I have to work really hard…[since] I wanted to do animal science [so] I just have to get through it”.

Familial Self

Although both of Tungsten’s parents have had long careers in STEM, she reports that her choosing a STEM career “was pretty much my own … no one specifically in my family made me want to major in science”. Tungsten states that both of her parents are very “supportive” of her career choice, with the condition that she “get[s] good grades”. Per Tungsten, her mother has “had an enormous influence on me to want to do well, so that I can take care of myself… and not have to rely on someone [else]… that’s how my mom was raised and how independent she is [now]… that's my motivation every day to work hard.” Tungsten feels “pressure” to “have my own job… [and] my own money” like her mother, who she says “makes all the money in our family”.

Tungsten also indicates that it is “definitely motivating” to her in an academic sense that several of her relatives have “gotten through hard undergrad science classes… like [general] chemistry and organic chemistry… that definitely showed me that they work hard and are happy, so I can do it, too”.

Epistemic Beliefs

Tungsten expresses doubt as to whether science alone can be employed to explain everything. Rather, she suggests that a combination of knowledge from various domains, together, can provide an explanation for all things. She discloses, “I guess everything can be explained… I just don't know if everything can be explained in science terms… [it’s] the same thing as [asking] if everything [can] be explained [only] by math or finance, and I just feel like… not really… I think everything has its own place [and explanatory purpose]".

Tungsten offers that she is a "very open-minded… Christian [who] believes in a lot of different things… I am very spiritual, but then I'm also very logical… I definitely think there's [a] conflict… [nevertheless] that's a subject that I personally wouldn't want to touch… [because] some people… believe very strongly in one [over the other]". Speaking to how she personally reconciles these admittedly disparate systems of thought, she proclaims that "I don't think we need an answer to all of that… [but] I lean more towards the science side and being logical, but the other part of me just likes to… have faith and have something to believe in, like a higher power. So, I just try not to combine the two and make sense of it".

Overall Case Findings (Tungsten)

Figure 9 shown below illustrates the selective codes generated for each input type as well as epistemic beliefs.

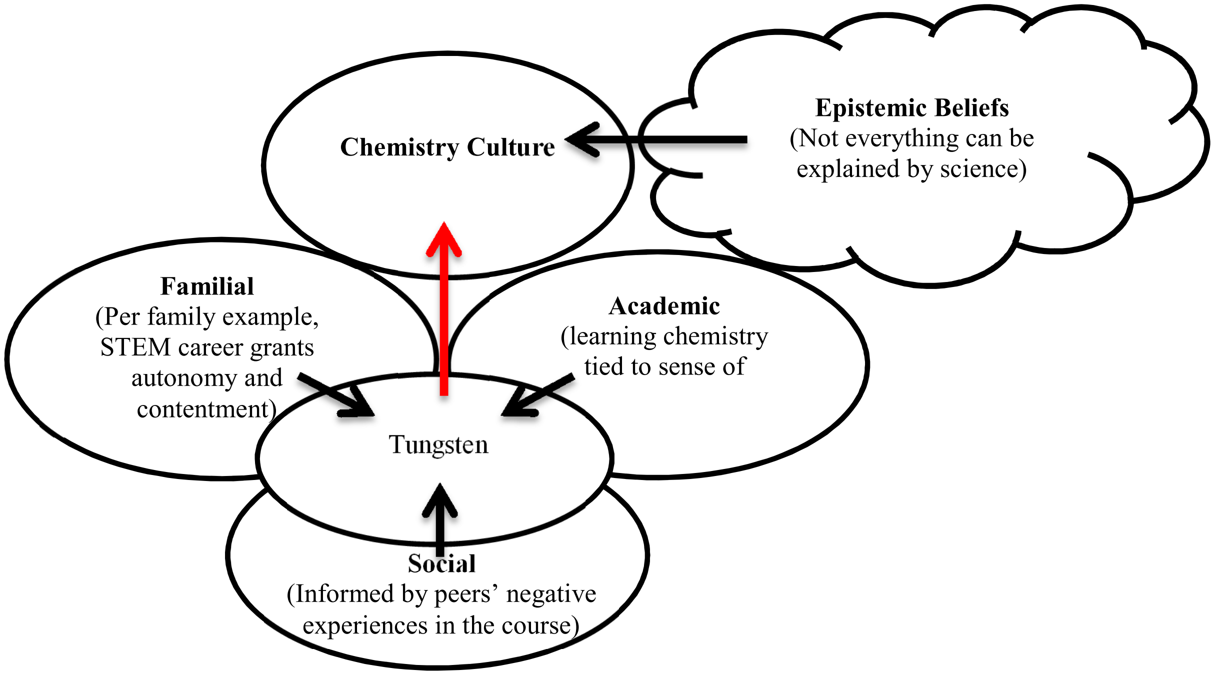

Figure 9. Representation of findings related to Tungsten's case.

Case 8: Scandium

Scandium is a first-year undergraduate student majoring in genetics and is planning on attending medical school. She is taking this chemistry course for the first time and did not take AP chemistry in high school. Her experience in high school chemistry is described as "unfavorable/negative". She also reports she is "very much" interested in the subject of chemistry outside of an academic context owing to her prior academic experiences.

Academic Self

Scandium perceives learning chemistry as difficult to learn relative to other subjects. She characterizes chemistry as being "all abstract", replete with "things we can't see… [that] no one can relate to" in their "own personal life". This is contrasted with a "much easier to learn" subject like "history… [that] people can wrap their mind around… [it] goes in a [comprehensible] sequence… you can form the picture of events in your head… [which] lots of people view [as] pertain[ing] to them personally".

Scandium expresses frustration with learning chemistry, citing a disconnect between her efforts made to succeed in the course, and her grades in the course. She describes her efforts to learn as a "stressful kind of study", wherein she "stud[ies] for long amounts of time… [and doesn't] see the result [she] expect[s] to". She shares that "I should be doing well in the class… [I] study for hours every day… prepare for tests weeks before… but [have yet] to get an A on a test… I feel like I'm never learning it".

Scandium views the gatekeeping nature of the course, with its attendant "high stakes" pressure to perform, as additionally problematic to learning. Per Scandium, "the whole weed out class thing… is set up for the majority of people to fail… it makes it more difficult to learn chemistry… I don't have the chance to sit down and simply enjoy [learning]… [since] the biggest focus [is] to not fail the test… [and] get the grade that I need to go on with what I actually want to do". She argues that the gatekeeping is "very overdone", lamenting that "you can't really afford a C as pre-med or pre-vet or pre-pharmacy… this one class can ruin your GPA… lower[ing] your GPA enough [to] where you couldn't recover from it".

Social Self

Scandium's drive to pursue a career in STEM is strongly tied to her veneration of science and scientists, which she speaks of as "very cool". She elaborates, "I view [science] as [something] that's going to help [people]… [an] improvement… when I hear about a [scientific] breakthrough, it's exciting… [it's] going to affect the world". In contrast, Scandium thinks that “science is not seen as important” to society-at-large. Instead, “people in general… view it [as] just work… not fun… not interesting… boring… dorky… just people in lab coats… [they] are more worried about other things… [like] the newest movie… celebrity… or actor”.

Amongst her peers, Scandium has met with similar negative attitudes regarding her academic endeavors in science. She remarks that “[it’s] kind of sad… when I tell someone I'm a genetics major or I'm pre-med, usually their response[s] are: ‘Your life is going to suck… that sounds awful.’, ‘That sounds like a lot of work.’, [and] ‘That doesn’t sound fun, it just sounds bad’”.

As it pertains to female participation within STEM careers, Scandium implicates the influence of “popular media” as largely culpable for making it more difficult for women to do such. Per Scandium, said media has deified feminine beauty to such an extent that “many people feel like I’m supposed to think my first priority is to look pretty… and perfect at all moments of the day… so a guy will like me and then I can get married and all these things”. Moreover, Scandium reports that she herself has been inculcated to feel as though “it's a bigger insult for someone to say I'm ugly [versus] someone say[ing] I'm stupid”. According to Scandium, “the emphasis on beauty… and the importance of looking good”, result in females often being solely assessed on their looks and perceived as having little else to contribute to society. Scandium concludes that “a very small percentage of women actually go into [STEM] careers… [because of] feel[ing] underestimated by multiple people, mostly men… underestimat[ing] someone simply because they are a woman… like [they’re not] capable of understanding or handl[ing] something”.

Familial Self

Scandium attributes the influence of her scientist parents as the impetus toward her pursuit of a career in STEM. Scandium reveals that her parents, who “studied the genetic side of agriculture”, introduced her to science at a young age, presenting it as “the next big thing” and the “future”. Scandium fondly recalls how she eventually “ran with it” and became “very interested” in biochemistry, biology and genetics. She explains that “[because] my parents always made [science] seem very interesting… I always wanted to pursue a science major… I wouldn’t have been interested enough to learn more, if they hadn’t told me about it or what they learned”.

As it relates specifically to her career goal of becoming a medical doctor, Scandium has experienced some push back owing to her family’s cultural norms. Scandium explicates that as a woman in her “traditional” Colombian family, it is expected that she would prioritize getting married and having children over the development of her career. According to Scandium, her mother, in particular, has expressed concern with “the whole investment of time [it takes] to become a doctor and specialize”, asking her questions like “when are you going to get married?” and “when are you going to stop to have kids?”. Despite this, Scandium ultimately concludes that although her family “would rather me go into research or something else… my family [has] always supported me for everything”.

Epistemic Beliefs

Scandium sees science as capable of “explain[ing] most things… [such that] everything I see in daily life makes sense… why the lights are on, why there's glass, why my cup keeps my coffee warm, all those things”. She further asserts that science, however advanced, cannot elucidate answers for “why we’re here” and “where we go when we’re dead”. To further illustrate the “limitations” of science, Scandium notes that answering such “religious” questions about “God’s plan” is “beyond our capabilities… [and] not in our power to understand… even with all of the science and all of the math and all the equations, I don't think we can ever know”. In Scandium’s view, the explanations derived from her religious beliefs come closer to answering those questions left unanswered by science alone. But, as she points out, belief in those “religious” elucidations requires a “leap of faith”, with the understanding that one will “never be able to see … [or have] a concrete explanation”.

As a Catholic, Scandium seems to rely heavily on her faith to provide solace in the face of existential dubiety. She divulges, “I think a lot of it for me is the comfort of knowing a reason as to why [I’m] here … [and] I have a purpose… that I'm here for”. Likewise, she believes that her “faith” in God confers meaning to her life, which would otherwise seem “random” and “point[less]”. As Scandium explains it, “I feel like I would walk around with no purpose” if life was “all random” and without any divine orchestration.

Overall Case Findings (Scandium)

Figure 10 shown below illustrates the selective codes generated for each input type as well as epistemic beliefs.

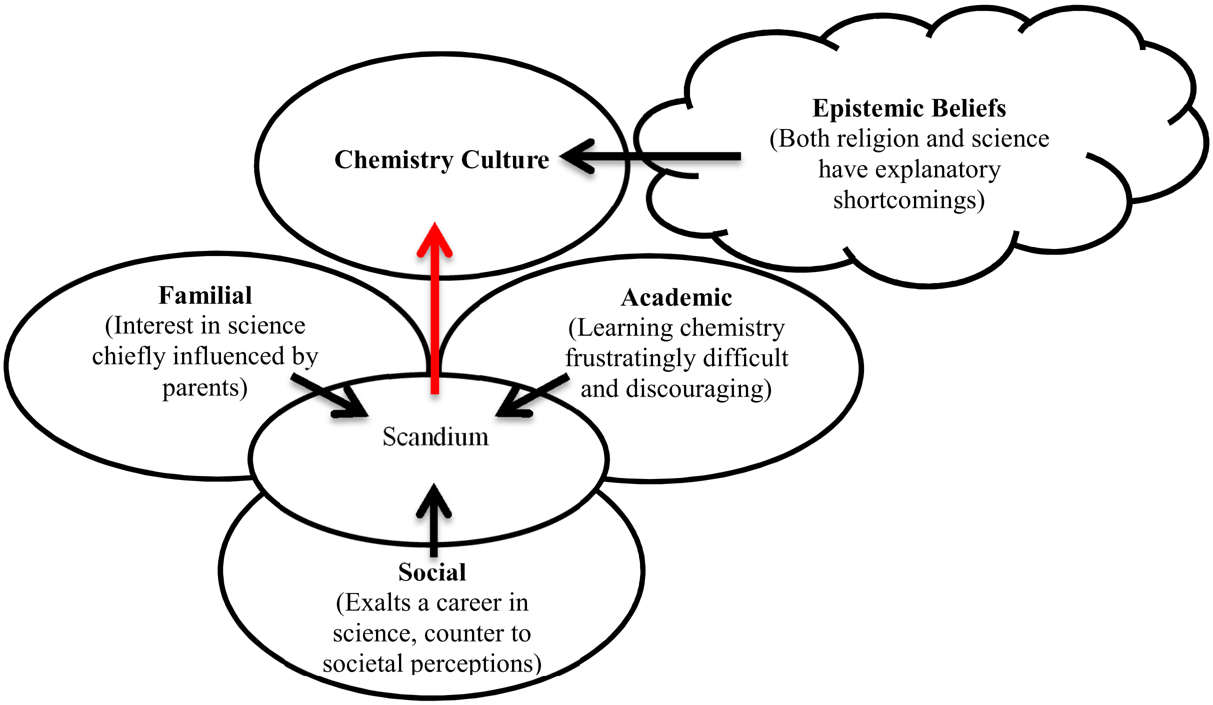

Figure 10. Representation of findings related to Scandium's case.

Summary of Findings

Cross-case analysis of the data set was performed to answer the following research questions:

1.) How do female undergraduate students develop an interest in learning chemistry?

2.) How do female undergraduate students' beliefs about the gatekeeping function of introductory chemistry influence their pursuit of a scientific career?

Findings for Research Question #1

Data pertinent to this question are the cases' key familial, social and academic selves affecting their interest in learning chemistry. Table 1 below summarizes these experientially-based factors and epistemic beliefs for each case.

Table 1: Summary of influences on case chemistry learning interest.

	Familial Self	**Social Self**	**Academic Self**	**Epistemic Beliefs**
Case 1- Antimony	No direct influence, but very supportive	Chemistry underappreciated by peers	Intrinsic interest to learn chemistry	Not everything can be explained by science
Case 2- Hydrogen	STEM career as family duty	Career focus supersedes peer notions about chemistry	Chemistry a hurdle to desired career	Not everything can be explained by science
Case 3- Phosphorus	Strong family ties to STEM careers	Embraces challenge of learning chemistry, unlike her peers	Chemistry develops critical thinking skills	Science is only means of explanation
Case 4- Mendelevium	No direct influence; Gender roles reinforced by her family	Defies gender stereotype as a chemistry major	Positive experiences with learning chemistry	Technological advances may eventually explain everything
Case 5- Xenon	Inspired by family member to pursue science	Positive influence by friends who valued science knowledge	Learning chemistry is its own reward	Not everything can be explained by science
Case 6- Magnesium	Strongly influenced by family member to pursue career in STEM	STEM career pursuit at odds with prevailing gender roles	Inspired by high school teacher to appreciate chemistry	Religious beliefs and science are synergistic
Case 7- Tungsten	Per family example, STEM career grants autonomy and contentment	Informed by peers' negative experiences in the course	Learning chemistry tied to sense of achievement	Not everything can be explained by science
Case 8- Scandium	Interest in science chiefly influenced by parents	Exalts a career in science, counter to societal perceptions	Learning chemistry frustratingly difficult and discouraging	Both religion and science have explanatory shortcomings

Familial Selves

A collective analysis of familial selves reveals the strong impact of family on cases' choice of a career in STEM. Common to all of the cases is having parental support of their chosen STEM career. Moreover, all but two of the cases reported having been directly influenced by a family member to pursue science, wherein this "influential" family member served as a role model or took an active role in cultivating the case's interest in learning science, ostensibly including chemistry.

Social Selves

A prevalent theme concerning their social selves is that all of the cases have reported their peers sharing negative perceptions about science and/or careers in STEM. Nevertheless, the data indicates that case interest in learning chemistry and pursuing a STEM career, are not affected in any meaningful way by such social "discouragement".

Academic Selves

Analysis of academic selves shows that for six of the cases, interest in learning chemistry is associated with some prior positive experience or sentiment within the learning process. For the other two cases, one has more of a neutral view, seeing chemistry as merely a "hurdle" to get past while the other case expresses discontentment in relation to learning "frustrating difficult" chemistry.

Epistemic Beliefs

Analysis of the cases did not reveal any discernable influence of epistemic beliefs upon case interest in learning chemistry. To varying degrees, all of the cases believe science to be a valid means of explanation.

Findings for Research Question #2

Case perspectives on gatekeeping were analyzed according to the case-defined function of gatekeeping and that function's corresponding influence on the student. Table 2 below summarizes case data pertaining to gatekeeping.

Table 2. Summary of case beliefs regarding gatekeeping.

	Function	Influence on student
Case 1-Antimony	"[exclude] people who aren't willing to put the effort into it"	"you have no business in the courses if you don't love science"
Case 2-Hydrogen	"filter for things like intelligence, effort, and ambition"	"[without gatekeeping] anybody could be a doctor… a vet... it's being certain to make sure we have good doctors and good vets"
Case 3-Phosphorus	"[the course covers] the basics to everything else you're going to learn"	"[it's a] good idea… to gatekeep science majors using that course"
Case 4-Mendelevium	"if you don't do well… [it makes you] rethink what you're doing and find something that suits you better"	"if you're not going to do good in chemistry and you can't get the hang of it, then you're not going to be able to do well in your higher-level major classes"
Case 5-Xenon	"[the course] is a culture shock… a big reality check…it gets people ready for college"	"people can be lazy and not want to put a lot of effort in… [so it] really helps you to see if your major matches your interests"
Case 6-Magnesium	"being forced… to have that chemistry background… is a good thing [for my career] "	"If you don't have that basic understanding of chemistry, the other stuff is going to be hard for you"
Case 7-Tungsten	"[the] whole purpose… [is to] discourage students… and get people to drop [the course]"	"[it's] very unfortunate… changes peoples' lives… some people have to change majors"
Case 8-Scandium	"[It's a] very overdone… high stakes… weed out class… set up for the majority of people to fail"	"It makes it more difficult to learn chemistry…. this one class can ruin your GPA… [to] where you couldn't recover from it"

The Function of Gatekeeping and Its Influence on Students

Pertaining to the research question, case notions about gatekeeping function of the chemistry course helps them to better understand and prepare for the rigor innate to the pursuit of a STEM career. A major theme is that the cases view gatekeeping to be a necessary and useful facet of the course since it is purported to keep “unqualified” students from being able to pursue a STEM career.

CHAPTER 5: DISCUSSION OF THE RESULTS

The purpose of this study was to investigate undergraduate female students' epistemic beliefs and worldviews as they relate to the subject of introductory college chemistry. The ultimate goal of this study was to more closely understand female undergraduate student (academic) experiences in the context of an introductory college chemistry course to gain insight related to retaining more female students in STEM programs and careers, ideally leading to a greater inclusion of women within STEM fields.

This study employed an interpretive case study methodology involving 8 female undergraduate students enrolled in introductory chemistry, including both chemistry majors and non-majors. The primary data generated in this study are from case interviews, which were also audio-recorded and transcribed by the researcher. The data were analyzed using the Constant Comparative Method [CCM] to render "core" findings (Glaser and Strauss, 1967). The resultant "core" findings were then considered to provide answers to the following research questions:

1.) How do female undergraduate students develop an interest in learning chemistry?

2.) How do female undergraduate students' beliefs about the gatekeeping function of introductory chemistry influence their pursuit of a scientific career?

The remainder of this chapter is divided into two sections. The first discussion section will include a detailed discussion of the importance of findings in reference to previously reviewed literature as well as additional literature. This discussion section will conclude with exposition of the implications of said findings. The last section will describe directions for future research as informed by this study and contemporary research literature.

Discussion

A decided goal of this study was to build upon the research literature reviewed in Chapter 2. Reviewing said literature provided the researcher with an understanding of the then-current state of research on the subject, which elucidated potential avenues of research for this study. The following section explicates this study's findings in relation to the literature reviewed earlier, as well as literature published since then or newly identified as particularly relevant.

Findings for Research Question #1:

How do female undergraduate students develop an interest in learning chemistry?

Familial Selves

Analysis of the cases' familial selves shows the great extent to which pursuing a STEM career is influenced by family. In a recent study, Mujtaba (2018) similarly found that "family encouragement… [and] shared engagement with extra-curricular science activities" is "strongly and positively associated with students' (science career) aspirations" (p. 660). This, in itself, is not a surprising result since one's close family members are usually their primary role models. However, the fact that so many of the cases (six) were influenced by their family to pursue a career in STEM is unexpected.

As it relates to the research question, it should be noted that the desire to pursue a STEM career does not necessarily correlate with a specific interest in learning chemistry, but it rather implies a broader interest in learning science. Assuming this to be true, it can thus be said that case interest in learning science is greatly influenced by family.

Social Selves

Cross analysis of the cases' social selves indicates that interest in learning chemistry is not measurably affected by their peers and friends. An important theme however, is that by virtue of their interest in learning chemistry and/or working towards a STEM career, female students encounter "social isolation/loneliness" per Heilbronner (2013) due to their peers, gender stereotypes, or some other societal "norm" (p. 49). Consequently, Hardin (2016) adds that female students in introductory college chemistry tend to have "less self-efficacy for their ability to succeed in STEM classes" and less (social) support in their STEM career, culminating in "lower[ed] interest in obtaining a STEM degree" (p. 237). Based on Heilbronner (2013) and Hardin's (2016) work, it is ultimately surmised that these cases have enough self-efficacy to "go against the grain" in pursuit of a STEM career, braving an environment Watts' (2014) describes as "elitist, masculinist and hierarchical" (p. 132).

Academic Selves

Collective consideration of cases' academic selves indicates interest in learning chemistry is linked to some favorable sentiment or positive outcome experienced in the process of learning chemistry. Of the three "self" categories, a case's chemistry learning interest is most directly influenced by their academic experiences. It stands to reason therefore that high school chemistry plays a prominent role, as it is the first exposure most students have to a chemistry course. Cases reporting difficulty with transitioning from high school chemistry (even AP) to college chemistry, bolsters Popejoy's (2013) statement that college chemistry students are "confronted with a faster pace and higher expectations… without previous support structures” (p. 19). By inference, interest in learning chemistry is encouraged when there is sufficient alignment between high school and college chemistry courses. This is echoed by Cohen (2019) who affirms that “misalignment between student precollege preparation and collegiate academic STEM experiences often results in poor academic performance, dissatisfaction with choice of major, and attrition to other (non-STEM) fields” (p. 5). An additional finding of note is that half of the cases view learning chemistry, in itself, to be a personally worthwhile endeavor. In addition, it is also gleaned from the data that the conceptual challenge of chemistry can actually serve as a motivation to learn it. Given the general view of chemistry amongst many as impossibly difficult, it is theorized that learning chemistry confers some of the cases a boost to their pride or self-esteem.

Epistemic Beliefs

Analysis of epistemic beliefs did not uncover any noticeable impact on the cases’ interest in learning chemistry. Nevertheless, a noteworthy trend is that all but one of the cases expresses some degree of doubt as to the capability of science to explain “everything”. All of the seven cases disclosed an adherence, in some degree, to religious beliefs. They also regard “some” religious beliefs as having equally valid explanatory merit as scientific knowledge. Yet, in light of these beliefs, there is no evidence to indicate any effect upon the cases’ STEM career pursuits.

Findings for Research Question #2:

How do female undergraduate students’ beliefs about the gatekeeping function of introductory chemistry influence their pursuit of a scientific career?

The Function of Gatekeeping and its Influence on Students

Via cross-case analysis, the major theme is that the majority of cases believe the gatekeeping nature of the course to be necessary based on reasonable utilitarian considerations. This finding is markedly surprising as it wholly contradicts the researcher's (anecdotal) conception of student views on gatekeeping. In consideration of the fact that "failure in chemistry… drives students out of… [STEM] fields altogether", it is confounding that these cases, who are themselves subject to gatekeeping, would view it in such a way (Popejoy, 2013, p.19). It appears that the overarching rationale of these cases is that gatekeeping, in spite of the harsh consequences it has on certain students, the function of gatekeeping effects some beneficial influence in the end.

As per these cases, a perceived benefit of gatekeeping by way of an (introductory) chemistry course is that it is seen as functioning to preserve the integrity of STEM fields, such that all "would-be" professionals meet necessary qualifications. Furthermore, it is suggested that the course serves as a properly calibrated metric for estimating student performance in subsequent science courses. This accords with Cohen's (2019) results, since "students who performed better in introductory chemistry were more likely to persist in STEM majors… [with] chemistry performance explain[ing] 58% of the variance in degree change to non-STEM fields" (p. 8).

The other cases in this study however, view said gatekeeping to be altogether problematic. They contend that gatekeeping has a needlessly deleterious impact on student STEM-career aspirations, such that some students are unjustly precluded from pursuing their career goals solely based on performance in the course. Furthermore, owing to the discouragingly excessive “high stakes” gatekeeping, student success in the course is impeded as students are effectively “set up” to fail.

In reference to the research question, there is universal belief amongst the cases that gatekeeping functions to uphold a rigorous standard. The cases further comprehend that gatekeeping in introductory chemistry is a barrier to their desired STEM major and career. Ultimately, the specter of gatekeeping in the chemistry course influences the cases to be cognizant of the rigor and required effort inherent to a career in STEM. In this way, the salient effects of gatekeeping are that it helps students to better assess the personal fit of their career goals, and it also prepares them for subsequent courses in their STEM career pursuit.

Implications of Findings

Given the purportedly jarring transition from high school to college chemistry, an implication of this study’s findings for introductory college chemistry is that there should be collaboration with high school teachers in a joint effort to more closely align instructional strategies between the two levels. Also, based on the unexpected findings in relation to student gatekeeping sentiment, there should be a larger-scale investigation into whether student views on gatekeeping are indeed shifting in a more positive direction and if so, why.

Future Research

Limitations of the Study

As a qualitative study, the indications of findings are strictly limited to each respective case and the time/context in which the data were collected. As such, the findings of the study are not conducive to making generalizations. The reliability of the data could have been enhanced by implementing member checking with the participants to ensure the veracity of the researcher's interpretation of case interview data. Over the course of data collection, the researcher may have also (unintentionally) guided or influenced case responses to certain questions. It is further conceivable that researcher bias, however small, could have impacted the processes of data analysis.

Future Avenues of Exploration

Based on this study's findings relative to chemistry learning interest, doing a similar study to elucidate what sort of factors lead to an intrinsic (i.e. maximal) interest in chemistry seems a fruitful undertaking. The prospective participants would be female undergraduate chemistry majors, as they are assumed to be intrinsically inclined to learn chemistry. From an instructional standpoint, this would potentially provide key insight as to ways of promoting female learning interest in chemistry. In related fashion, it is seemingly useful to examine how student learning interest is impacted by the lab portion of the course. From this study, it also emerged that another topic meriting investigation is the apparent lack in self-efficacy of female students within science courses.

As this study relates to gender equity, it might also prove instructive for future research to consider facets of intersectionality amongst female participants by way of purposeful sampling. Likewise, incorporating "parallel" male participants into a future study might more clearly delineate uniquely female experiences within the course via comparison to their male counterparts.

In light of more recent data showing vastly improved student performance in the course, it would be useful to interview current introductory chemistry instructors to gain insight into how they were able to effect such a drastic change in student grades. Lastly, consideration of their perspectives would also likely render deeper insight into the phenomenon of gatekeeping and what constitutes “chemistry culture”.

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