# EMBRYOLOGY IN MEDICAL EDUCATION: A MIXED METHODS STUDY AND PHENOMENOLOGY OF FACULTY AND FIRST YEAR MEDICAL STUDENTS

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# DEDICATION

This dissertation is dedicated to my teachers and mentors – past and present, near and far, formal or informal – whose support and guidance helped to nurture within me an indefatigable curiosity, steadfast motivation, and joyous enthusiasm for learning.

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EMBRYOLOGY IN MEDICAL EDUCATION: A MIXED METHODS STUDY AND PHENOMENOLOGY OF FACULTY AND FIRST YEAR MEDICAL STUDENTS

The anatomical sciences are experiencing a notable decrease in the time and resources devoted to embryology in North American medical education. With more changes assured, it is necessary to investigate the current trends in curriculum, pedagogy, and related experiences of embryology teachers and learners. To address these concerns, the researcher developed two online mixed methods surveys: one for current anatomy and embryology faculty and another for first year medical students. The faculty survey was followed by interviews with volunteers from that cohort. The researcher used a grounded theory methodology to analyze the qualitative components of the surveys, and descriptive statistics to analyze the quantitative components of the surveys. Both the faculty and student surveys illuminated the vast differences between the explicit, implicit, and null curricular components found in the numerous medical education programs represented. A combined grounded theory methodology and phenomenological approach was used to analyze the interviews with faculty. This generated a lived experience narrative of the phenomenon of teaching embryological content to medical students in the modern world, which led to a better understanding of the needs and challenges that face this subject matter and those who teach it. In this fluid era of medical education reform and integration, the perceptions and experiences of anatomy and embryology faculty and first year medical students are invaluable to assessing the curriculum and pedagogy of

this foundational anatomical science and formulating evidence-based recommendations for the future.

Valerie Dean O'Loughlin, PhD, Chair

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## LIST OF ABBREVIATIONS

UME: Undergraduate medical education

GME: Graduate medical education

CME: Continuing medical education

BCS: Beginning of course student (survey)

ECS: End of course student (survey)

# CHAPTER 1: INTRODUCTION

Medical schools in the United States and Canada vary widely in faculty and student populations, resources available, and role in the history of medical education. Thus, their individual medical curricula vary considerably in specific objectives and missions. The sheer range of educational methods that shape our future physicians is staggering when one considers that all physicians have to pass virtually the same board and licensure exams. Furthermore, despite dispersing similar content, institutional styles of teaching and learning as well as the emphasis placed on different topics means that there is no true standard curriculum in modern medical education (Calman, 2007). In the 2010 book *Educating Physicians*, authors Cooke, Irby, and O'Brien assert,

> Yet during the past century, along with enormous societal changes, the practice of medicine and its scientific, pharmacological, and technological foundations have been transformed. Now medical education in the United States is at a crossroads: those who teach medical students and residents must choose whether to continue in the direction established more than a hundred years ago or take a fundamentally different course, guided by contemporary innovation and new understanding about how people learn. (p. 1).

Many governing bodies monitor and assess the climate of medical education, ask questions about the caliber of education that students receive, and ensure that programs maintain accreditation and standards. The main organizations involved in evaluating medical schools and their curricula include the Liaison Committee on Medical Education (LCME), American Medical Association (AMA), Association of American Medical Colleges (AAMC), Accreditation Council for Graduate Medical Education (ACGME), Accreditation Council for Continuing Medical Education (ACCME), Federation of State Medical Boards (FSMB), National Board of Medical Examiners (NBME), Commission on Osteopathic College Accreditation (COCA), and specialty board societies (Cooke et al., 2010; Association of American Medical Colleges, 2013).

In the United States and Canada, a student in **undergraduate medical education (UME)** typically completes four years of post-baccalaureate training. The first one to two years primarily consist of coursework and the second two+ years consist of clerkships or rotations in various specialties. Students then graduate with a medical doctor (M.D.) degree or a doctor of osteopathic medicine (D.O.) degree, which are comparable and may both practice medicine after licensure exams (Federation of State Medical Boards & National Board of Medical Examiners, 2016; National Board of Osteopathic Medical Examiners, 2016).

The four years of undergraduate medical education are followed by **graduate medical education (GME)**. GME consists a clinical residency that usually last between three and seven years (depending on the specialty), and potentially followed by a one or two year fellowship in a subspecialty. For the remainder of their careers, physicians must complete **continuing medical education (CME)** to maintain competence and learn about new and developing areas of their field. This research focuses most directly on the first two years of undergraduate medical education and the experiences and perceptions of those most directly affected by changes to the curriculum, faculty and medical students.

During the first and second years in undergraduate medical education, students enroll in coursework that includes some combination of the four anatomical subdisciplines: gross anatomy, microscopic anatomy (or histology), neuroanatomy, and embryology (Prentice, 2013). As of 2015 at the Indiana University School of Medicine in Bloomington, the home campus of the researcher of this dissertation, the first two years of UME consists of the following courses seen in Table 1.1, which is posted to the university website. Medical students learn about all four of the anatomical subdisciplines during the first year. Embryology is not noted in this table because it is integrated into the gross human anatomy course that spans the entire academic year (Indiana University, 2015).

Table 1.1: Example of traditional UME coursework in Years 1 and 2

| | |
|---|---|
| **Year 1** | |
| *Fall Semester* | *Spring Semester* |
| Introduction to Clinical Medicine I | |
| Cell & Molecular Biology | Medical Biochemistry |
| Cell Biology & Histology | |
| Gross Human Anatomy | |
| Microbiology & Immunology | Medical Neuroscience |
| Medical Physiology | |
| **Year 2** | |
| *Fall Semester* | *Spring Semester* |
| Introduction to Clinical Medicine II | |
| Pathologic Basis of Disease | |
| Principles of Pharmacology I & II | |
| Human Genetics & Development | |
| EBM & Biostatistics | |

(Indiana University, 2015)

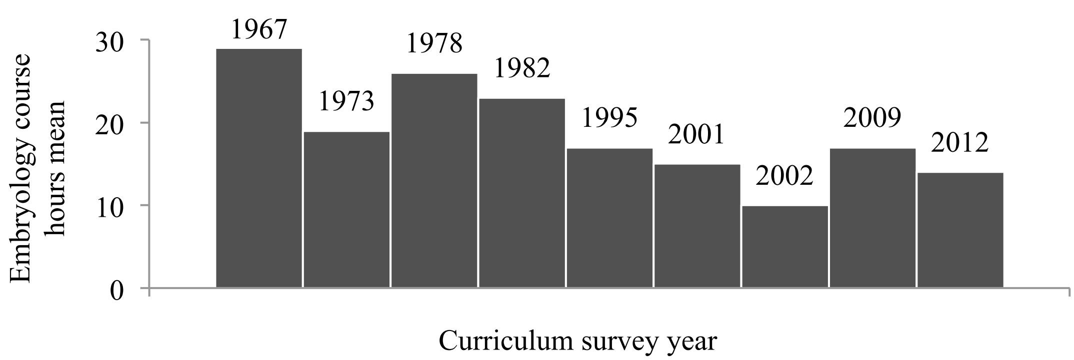
In recent years, both the number of course hours and departmental resources allocated to the anatomical sciences have fallen drastically (Drake, Lowrie, & Prewitt, 2002; Drake, McBride, Lachman, & Pawlina, 2009; Drake, McBride, & Pawlina, 2014). The specific surveys and statistical data providing evidence for this claim will be discussed in chapter 2 of this research. The reduction in time devoted to the anatomical sciences may be attributed to a myriad of factors: increasing costs of dissection laboratories and similar resources, reduction in the availability of cadavers, decline in the perception of anatomy as a lucrative research science, and increased emphasis on interpersonal skills (e.g., communication, teamwork in undergraduate medical curricula) (Ahmed et al., 2010; Gartner, 2003; Prentice, 2013; Drake et al., 2009).

The anatomical subdiscipline of most interest to this dissertation research is **embryology**. There are variations on this subject, which include clinically oriented embryology and developmental anatomy. **Clinically oriented embryology** is the study of the prenatal development of embryos, fetuses, and neonates (infants one month or younger). **Developmental anatomy** is the study of the structural changes of the human form from fertilization to adulthood (Moore, Persaud, & Torchia, 2016). In this research, the term embryology is defined to most closely align with the definition for clinically oriented embryology.

Massive medical, research, and technological advances in recent years have led to more potential embryology content.  Despite the increased knowledge discovered for this subdiscipline, embryology receives less hours in UME and may be perceived as less important than other topics in the anatomical sciences or in medical education overall. Faculty and medical students may observe this treatment of the subject and interpret it – whether accurately or not – as a marginalization of the subject. The integration of embryology into other courses is the norm in modern medical schools, as confirmed in national surveys to course directors reported by Gartner (2003) for 1967-2001 and by the American Association of Anatomists (AAA) for 2001-2014 (Drake et al., 2002; Drake et al., 2009; Drake et al., 2014).

In all the years of these surveys, most institutions integrated embryology content into other courses, usually gross anatomy. Figure 1.1 shows data from these four publications regarding the mean number of course hours devoted to embryology in UME, illustrating a marked overall decrease in course hours devoted to the subject in the past 50 years (Gartner, 2003; Drake et al., 2002; Drake et al., 2009; Drake et al., 2014). In the range of years covered by Gartner's research, there was a 50% decrease in course hours devoted to embryology in UME, changing from a mean of 28.5 and range of 5-96 hours in 1967 to a mean of 14.8 and range of 0-34 hours in 2001 (Gartner, 2003). In the 2002 AAA survey, embryology course hours ranged from 3-65, with most schools having 6-10 hours devoted to the subject (Drake et al., 2002). In the 2009 AAA survey, embryology course hours averaged 17, with a range of 0-68 hours (Drake et al., 2009). In the 2014 AAA survey, embryology course hours averaged 16, with a range of 0-30 hours (Drake et al., 2014). The average number of hours for embryology has stayed just below 20 for the past 3 decades, which may be significant by representing a minimum amount of time that is required for conveying the fundamental embryological knowledge (Drake et al., 2009). No laboratory experiences for embryology were reported from 69 respondents in 2002, only 3 out of 43 programs in 2009 said that they included a laboratory component in embryology, and 3 out of 31 programs in 2014 reported a laboratory learning experience in embryology (Drake et al., 2002; Drake et al., 2009; Drake et al., 2014).

Figure 1.1: Hours devoted to embryology in the undergraduate medical curriculum



While there are fewer course hours devoted to all the basic sciences in UME when compared to years past, the AAA surveys quantified a disproportionally large decrease in embryology content. Based on these survey findings, it is evident that embryology is becoming less of a priority in both U.S. and Canada UME. The shift in emphasis and perceived importance of embryology may be due to a natural evolution of the medical profession and training of future physicians. As medical education strives to provide the most effective, efficient, and appropriate experiences to its students, decisions are made regarding inclusions and exclusions to the coursework in the first two years of the medical curriculum.

The constantly evolving world of healthcare means that medical education must adapt in order to provide society with the caliber of physicians needed. This requires constant evaluations and improvements – not always smoothly adopted or well received – by administration, faculty in both basic sciences and clinical experiences, and laboratory directors. Confounding this task is the difficulty in establishing a common frame of reference when referring to the curriculum of a medical institution, for as was previously stated, no true standard exists in UME curricula in the U.S. and Canada. In order to conduct productive conversations regarding reform in medical education, one must first understand definitively what a curriculum is and how to describe the current climate of a curriculum. The following sections begin with a discussion of the challenges to defining the word "curriculum," then relay how these struggles can stymie or inhibit reformation efforts. Then a theoretical framework with which to organize curricular components will be introduced, with examples given from the anatomical subdiscipline of embryology.

This chapter will conclude with an overview of the research purpose, research questions, and methodology, and then transition to a review of the literature.

**Curriculum Definitions and Theoretical Framework**

The very nature of curriculum is complex and does not lend itself well to simple, dictionary-style definitions. In a study by Burton and McDonald (2001) surveying medical educators with a range of teaching experience and responsibilities, the majority of respondents viewed the term "curriculum" in two-dimensional terms, tending to equate it to "syllabus," an oversimplification that may have significant implications for curricular reform. Flinders, Noddings, and Thornton (1986) stated, "It is not uncommon for two curriculum specialists to discuss their field at great length before discovering that each is using the term 'curriculum' to mean something quite different" (p. 33). The varied ways to perceive and interact with a curriculum can lead to issues when striving for examination or improvements.

In an attempt to clarify the components that make up a curriculum, Eliot Eisner (1985) defined three facets of a curriculum itself that frame and theoretically underpin the overall idea: **explicit** (also known as the formal) **curriculum**, **implicit** (also known as the hidden) **curriculum**, and **null curriculum**. Sometimes the implicit and hidden curricula are grouped together and referred to as the informal curriculum. Table 1.2 defines these three concepts and provides examples from undergraduate medical education, specifically in the anatomical subdiscipline of embryology.

Table 1.2: Three curricular components and embryology examples

| Curricular component | Definition | Example from embryology in UME |
|---|---|---|
| *Explicit curriculum* | Publicly announced programs of study; What the school advertises it is | The required textbook and atlas for use in studying embryology: These resources are tangible objects cited in the syllabus that |

| | | |
|---|---|---|
| | prepared to provide (e.g., handbooks, syllabi) | the instructor refers to during lectures. Students are able to clearly see that these resources are part of the embryology UME curriculum. |
| *Implicit curriculum* | Values, expectations, and behaviors learned by students as part of their school experience | The norms regarding respect between physicians and hypothetical patients: When discussing human birth defects in embryology courses, the classroom environment fostered by the faculty creates a sense of respect for individuals with the defect and their families. Training medical students in the development of compassion and empathy is often implicit, although some schools now include aspects of this concept in their course or program UME objectives. |
| *Null curriculum* | What schools do not teach, whether purposeful or inadvertent; Very ambiguous and sometimes controversial | The ethical and legal issues involved in abortion procedures: In most embryology courses, concepts tangential to the actual mechanisms of abortion are not discussed (see chapter 5 for details about this from faculty interviews in this research). However, these concepts will probably arise during the clinical experiences of UME. So medical students will often think about these tangential issues on their own and depending on faculty reactions to questions, will form their own opinions. That student is thinking about the material at a higher-level, but the school is not explicitly or implicitly teaching this formation of thought. This may not occur for all students at the same time or in the same way. |

(Eisner, 1985; Flinders et al., 1986)

The issues related to embryology within the medical curriculum may be examined via the framework of the explicit, implicit, and null curricula. The use of this categorization schema is appealing because, as John Dewey (1938) said, “Perhaps the greatest of all pedagogical fallacies is the notion that a person learns only the particular thing he is studying at the time” (p. 48). By this, Dewey meant that students may be in a classroom fulfilling specific learning objectives, but they are taking in much more than the explicitly given course information. They are also subconsciously gathering information about how to act, implicit expectations of behavior from the teacher, and other informal aspects of the curriculum they are experiencing.

Investigation of issues directly associated with and also tangential to the education of future physicians is a weighty task. Patterns and potential solutions are of value to medical education policymakers, administrators, educators, and future and present students and physicians. In the book *Medical Education: Past, Present and Future*, Calman (2007) states,

> The curriculum is determined by defining both the role of the doctor and the competencies required. The curriculum is related to the selection of students and their background knowledge and experience. The curriculum is often seen at the heart of the process of medical education, but it is in fact the delivery system for the roles and competencies that have been defined. It is the endpoint, the effector arm, rather than the driver (p. 428).

By this, Calman emphasizes the principles regarding the various interpretations of the word "curriculum" as seen earlier in this chapter. Although the curriculum in UME is often seen in the purely explicit curriculum sense, one must understand that a curriculum is much more than its explicit parts. The curriculum is the mode of delivery rather than merely the load of knowledge being brought to the medical students, which means that much more should be understood about this mechanism than is currently in the literature.

**Research Purpose and Questions**

To address this gap in the literature, the purpose of this research was to investigate and describe the experiences and perceptions of medical school faculty and first-year medical students regarding embryology within undergraduate medical education coursework in the United States and Canada. This research addressed the following questions:

1. What is the current status (e.g., placement, course hours, faculty cohort, content, materials, pedagogy) of embryology in medical education curricula as reported by faculty?
2. What experiences and perceptions do faculty and first year medical students have in regards to the teaching and learning of embryology in medical education, including word associations, most interesting and most confusing aspects of teaching or learning embryology?
3. What suggestions do faculty and first-year medical students have for the improvement of teaching and learning embryology in medical education?

The first question addresses the explicit curriculum, while the second and third questions have the capacity to illuminate aspects of all three components of the curriculum: explicit, implicit, and null. Although the null curriculum is ambiguous, less tangible, and often a more difficult issue to identify and study, it is expected that with rigorous data collection and analyses about the explicit and implicit curricula, factors relating to the null curricula will organically be revealed.

The following section provides an overview of the mixed methods research methodology. In this type of research one does not formulate rigid research questions or hypotheses. Instead, the researcher forms broad questions and then lets the collected and analyzed data provide answers to the research inquiries.

**Overview of Research Methodology**

This mixed methods research design uses both surveys and interviews to examine the experiences with and perceptions of embryology faculty who teach embryology or embryological content and the experiences with and perceptions of embryology of first-year medical students. The data was analyzed using a dual approach of grounded theory and phenomenology, utilizing NVivo qualitative data analysis software. Both grounded theory and phenomenology are approaches used with qualitative data. **Grounded theory** generates original theories based on the patterns and themes found in the data, while **phenomenology** allows the researcher to write a short narrative about the particular phenomenon being studied, which in this research will focus on the experience of teaching embryology in modern UME. More detailed definitions regarding these concepts and the data analyses are in chapter 3 of this research.

### Organization of the Dissertation

This dissertation research contains 7 chapters. This first chapter introduces the research topic, clarifies the research purpose and questions, and outlines the remainder of the manuscript. The second chapter is a review of the relevant literature regarding curricular reform movements throughout medical education in the United States and Canada. It places embryology within the context of the explicit, implicit, and null curricula. The third chapter explains the methodology of this dissertation research in greater detail, including theoretical explanations of the grounded theory and phenomenology data analysis approaches, and how the data collection of surveys from faculty and first year medical students and the interviews with faculty were synthesized. The fourth chapter is an explanatory and reflective section, describing the design and implementation of an undergraduate embryology course by the researcher. The fifth and sixth chapters contain the findings and analyses of the data collected. Chapter 5 examines data from the faculty survey using grounded theory analysis and the faculty interview using phenomenological analysis. Chapter 6 finishes the data analysis with the student surveys using grounded theory analysis. The seventh and final chapter of this dissertation synthesizes all of the previous components of the research study and forms evidence-based recommendations for the future of embryology in medical education.

# CHAPTER 2: REVIEW OF THE LITERATURE

The issues regarding embryology in the UME explained in the previous chapter bring to mind an appropriate adage: You can't know where you are going until you know where you've been. A continuous and permanent improvement of medical education requires the individuals involved to research and remember the historical aspects of medical education reform in the U.S. and Canada. Careful examination of the literature relating to medical education reform in the past several hundred years illustrates a clear trajectory of reform movements all appropriate to the era during which they were developed. In addition, since the popularization of careful record keeping of curricula and establishment of medical institutions, one is able to trace the reforms throughout their inception to the present day. Being cognizant of the successes, failures, and ongoing areas for improvement in medical education reform efforts serves to better prepare researchers and individuals enacting change in modern medical training.

This chapter will begin with an introduction to the problems facing reformation of medical education today, including reports that have been completed and the involvement of medical education governing bodies. Then, the chapter will provide a summary of the history of medical education reform in the U.S. and Canada from the mid-18$^{th}$ century to the present day of the early-21$^{st}$ century. There have been 5 major curricular reform movements so far and each will be described in detail within their historical contexts. Next, the chapter will describe the challenges to the modern medical curriculum and its three components (explicit, implicit, null) as they relate to embryology. This chapter of the research will conclude with a justification for the participants of this research

## Medical Education Reform

The knowledge available to teach in undergraduate medical education is constantly increasing in waves with scientific and technological breakthroughs. Ideally, the enacted changes are based upon evidence formed by rigorous evaluations and assessments of current programs of study. At medical schools in the U.S. and Canada, curricular change is only justified if "the desired reform will actually improve students' future performance as physicians – and, ultimately, the health of those they serve" (Salmon, Williams, & Rhee, 2015, p. 136). This doctrine should be at the forefront of the minds of individuals forming and implementing these revisions. A well designed UME curriculum includes topics and issues that align with the intended learning outcomes and medical skills which serve the needs of society, patients, content experts, and students (Kusurkar, Croiset, Mann, Custers, & Cate, 2012; Carlson, 2002).

**Change without difference.** Despite the many intended alterations in UME occurring in the U.S. and Canada throughout history and the massive amounts of available and necessary knowledge for future physicians, the actual teaching of medical students has changed little over the past several decades (Guze, 1995). The unfortunate but popular metaphor of this "paradox of change without difference" seen in undergraduate medical education is that of a carousel going around and around, eternally circling in the same pattern with medical educators "regularly returning with fresh and un-remembering minds, to the same concerns" (Matson, Davis, & Stephens, 2013, p. 581; Lempp & Seale, 2004; Whitehead, Hodges, & Austin, 2013; Woodbury & Gess-Newsome, 2002). Bloom (1988) hypothesized that the lack of major change is due to the evolution of medical schools from locations for learning into complex social organizations, in which education (perhaps inadvertently, perhaps not) takes a backseat to the operational needs of research and the clinical missions of medical centers (Enarson & Burg, 1992). There is generally a feeling of concern about the limited lasting impact of recent medical education reform attempts despite the large scale of resources devoted to them (Hopkins, Pratt, Bowen, & Regehr, 2015).

There are differing opinions about the effects and true expansiveness of medical education reform in the past several centuries. Some individuals have stated that the medical education literature illustrates that the overall assessment of the medical curriculum is rarely rigorous or expansive enough to satisfy the demands placed upon it by external or internal forces (Anderson & Kanter, 2010). Others state that after examining quantitative and qualitative analyses, claims that little has changed are clearly inaccurate and "The cry of three decades ago that 'medical education is in a state of crisis' and that 'the lessons of the past have been ignored too long' (Beecher & Altschule, 1977) is certainly not a fair assessment of the current state of affairs" (Putnam, 2006, p. 233). There exists in the current climate of UME reform a large continuum of agreement, with some individuals of the extreme former opinion, some on the extreme latter, and many somewhere amongst the middle of these two schools of thought.

These varying views bring to mind what curriculum scholars, and not necessarily those who solely study medical education curricula, call the **implementation problem** (McLaughlin, 1987). This term was first used in the 1970s to describe the failure of many reforms started in the 1960s with federal funds. Many of these reforms were not seen to full fruition for various reasons, and blunted implementation success has been a fairly common problem at many levels of education because it arises and unfolds in a very fluid setting (McLaughlin, 1987). Implementation problems are never fully solved, because there are always new issues, requirements, and considerations to address (McLaughlin, 1987). Therefore, careful monitoring and constant analysis of the UME curriculum is essential if change is to be not only enacted, but also long-lasting and effective in the dynamic fields of medical education and practice.

**Reports on medical education curricular reform.** In the last two centuries, many reforms of varying sizes and scopes have been proposed for the organization, content, and pedagogy of teaching future physicians (Salmon et al., 2015). Impetus for the reforms were varied and stemmed from global (e.g., world wars), to national (e.g., financial crises), to technological breakthroughs (e.g., increased availability of medical imaging). The reforms have included various foci such as: fewer lectures, more case-based learning, earlier introduction to patient interactions, use of simulations, and increased instruction in the social sciences and palliative care. But "neither the rate nor magnitude of actual progress suggests that reform is anywhere near completion" (Salmon et al., 2015, p. 136). Curricular reform reiterates many of the same challenges the field has had for over half a century: divided structure of medical curriculum, perceived lack of relevance of basic science material as currently delivered, and lack of student retention and application of the basic sciences in clinical practice (Hopkins et al., 2015).

There have been at least twenty-five major reports in the past two centuries regarding UME reform in the U.S. and Canada and each report, regardless of historical era, illustrated a similar set of issues and reaffirmed core values within the curriculum (Christakis, 1995). Christakis (1995) found that the majority of these reports dealt with strikingly similar problems perceived within medical education, but often went unnoticed or unheeded. Nishiyama and Oberman (1970) investigated to what extent the reforms calling for standardization of the curricula actually resulted in a lasting improvement of the medical curriculum since the 1960s. Fifteen years after that, several other groups of researchers identified superficial modifications and adjustments that kept training current with advancements in medical science and technology, but this was widely considered to be “curricular tinkering” in small increments rather than fundamental and lasting changes (Ludmerer, 1985). Most recently, Skochelak (2010) reviewed recommendations of fifteen reports between 2000 and 2010 performed by national professional organizations, foundations, and advocacy groups in the U.S. and Canada. Each report found deficits and called for significant changes in medical education. There was much congruence between these fifteen reports in the early-21$^{st}$ century, indicating that most contemporary researchers and scholars agree on the broad categories of what is needed to improve medical education.

It has even been argued that undergraduate medical education (UME) needs another **Flexner Report** (Flexner, 1910). The Flexner Report, a comprehensive survey and analysis of all medical schools in the U.S. and Canada published in 1910, will be discussed in great detail later in this chapter. The Flexner Report is often seen as one of the major factors in the reform of medical education in the early-20th century. Those who call for another undertaking similar to the Flexner Report desire a comprehensive and thorough study that focuses on areas not yet closely examined in contemporary medical education, such as entrance requirements and specific studies in the first and fourth years of UME (Emanuel, 2006). Although exactly who or what group can and should take responsibility for this type of action is a bit more complicated than it was in 1910 because there are more medical schools, more stakeholders involved, and more content knowledge available to consider.

**Medical education governing bodies.** The medical education governing bodies that could enact such a study strive to maintain strict standards for the accreditation of medical schools granting these equal degrees. The Liaison Committee on Medical Education (LCME) is sponsored by the Association of American Medical Colleges (AAMC) and the American Medical Association (AMA). It governs 134 allopathic medical schools in the U.S. as well as four in Puerto Rico and 17 in Canada (Liaison Committee on Medical Education, 2015). The Commission on Osteopathic College Accreditation (COCA) is sponsored by the American Osteopathic Association (AOA) and controls the 31 osteopathic medical schools in the U.S. (American Osteopathic Association, 2016). Medical schools must meet all of the specific standards determined by either the LCME or the COCA in order to maintain accreditation standing (Skochelak, 2010). Any reform efforts must comply with the regulations set out by these governing bodies, residing in hundreds of pages of detailed legalese that can be found on the websites of both the LCME and the COCA (Liaison Committee on Medical Education, 2015; American Osteopathic Association, 2016).

**Recognition of the history of UME reform is necessary for successful future reforms.** The development of undergraduate medical education in the U.S. and Canada is a complex process that spans regions, occurs over centuries, and is a constantly evolving phenomenon. For as society and the available medical and scientific knowledge evolves, so too should educational forums. Lasting and significant curricular reform is neither simple nor easy, but the real challenge is not defining the appropriate content but rather incorporating it into the existing curriculum in a manner that emphasizes its importance relative to and in sync with the traditional biomedical content, and then preparing faculty to teach this revised curriculum (Cooke et al., 2010). One must no longer have to ask what to do but how to get there in order to implement sustainable and lasting improvements to medical education (Skochelak, 2010). The goal for UME reform should not be to have the subjectively "best" method but to have the most appropriate and effective approach for that particular institution, faculty, and student populations. In order to achieve success, one must understand the significance of curricular reform in terms of the format of the explicit, implicit, and null curricula and how subjects such as embryology are placed within that framework. The next section of this chapter details the history of the past several centuries of medical education reform in the U.S. and Canada.

**History of Medical Education Reform in the U.S. and Canada**

Since the mid-18$^{th}$ century and the keeping of consistent written accounts regarding medical education, there have been 5 major movements that catalyzed medical education reform in the U.S. and Canada. These movements were named for the fundamental frameworks upon which their learning experiences are based: apprenticeship model, discipline-based model, organ system-based model, problem based-learning model, and clinical presentation-based model (Papa & Harasym, 1999). Table 2.1 provides the approximate dates and descriptions for each major reform movement model (Hecker & Violato, 2009). For several of the later models there are not closing dates because they are still implemented to some extent at various medical schools. Therefore, each of the models that are still in use in some part of the U.S or Canada is noted as continuing to the present day.

Table 2.1: Five major curriculum reform movements in the U.S. and Canada

| **Approximate dates of implementation** | **Reform movement models** | **Brief description** |
|---|---|---|
| unknown - 1900 | *Apprenticeship model* | Physicians in training shadowed current physicians; variable training and no external accountability |
| 1900 - present | *Discipline-based model* | Medical schools established curricula and entrance/progression requirements; included research, laboratory, and clerkship training experiences |
| 1952 - present | *Organ system-based model* | Continuous curriculum that integrated basic and clinical sciences |
| 1969 - present | *Problem based-learning (PBL) model* | Information presented as clinical problems or cases; relied on the foundation of student knowledge |
| 1991 - present | *Clinical presentation-based model* | Built upon the PBL model by situating the experience as if the medical school was a clinic and patients were entering |

(Hecker & Violato, 2009)

Each of these movements has the underlying theme of increasing focus and understanding of the differences between medical experts and novices. Improvements in medical education occurred as each model grew upon the strengths of those previous and attempted to identify and overcome weaknesses (Papa & Harasym, 1999; Kusurkar et al., 2012). After all, the elements of physician training that are fundamental yet may be difficult to execute for a myriad of reasons must be revisited periodically to make these elements relevant to the social and historical context (Whitehead et al., 2013). It is prudent to note that the historical facts to follow are not uniform across all medical institutions, populations, or regions, and "within agreed-on standards of quality, each medical school follows its own philosophy and mission and integrates the changes that are suitable for its ideology and context" (Kusurkar et al., 2012, p. 737). Each of these UME reform movement models and their origins, successes, and downfalls are described in greater detail in the remainder of this chapter.

**The apprenticeship model of medical education.** The late colonial and early national independent periods in North America starting in the mid-18th century saw medical professionals with training traditions similar to tradesmen in a semiformal medical apprenticeship system. This first of the 5 reform movements was essentially a shadowing situation and quality was dependent upon the practitioner under whom the apprentice obtained training. Apprenticeships were extremely variable in length, instruction, and quality and were not regulated by any authorities (Kusurkar et al., 2012).

***The first medical school in the U.S. and Canada.*** After the 1749 foundation of the first medical school in North America, the Medical School of the College of Philadelphia, anatomy lectures and demonstrations began and the college setting became a center of medical interest. The apprenticeship system was still in place, but society began to be more interested in formalizing the training of future physicians. In 1765 the Medical School of the College of Philadelphia established a professorship in medical theory and practice and through association with the local Pennsylvania Hospital created the first collaborative medical school and hospital system in the U.S. and Canada (Zelenka, 2008). Within 50 years, approximately 40 medical schools were operating, a number that increased tenfold by the end of the 19th century. But unlike the Medical School of the College of Philadelphia, these institutions were typically freestanding with no close ties to either institutions of higher learning or public hospitals, and they were unregulated and often profit-driven (Papa & Harasym, 1999). Despite the prevalence of medical schools at this time, the apprenticeship model was not yet set aside and many practitioners and future physicians still clung to this familiar method of teaching and learning.

***Proprietary medical schools.*** During this advent of formal medical schools forming across the country, the physicians who had been training the next generation of healthcare providers grew concerned that their input was being diminished. A compromise of sorts was made in the development of independent commercial medical schools, also known as proprietary medical schools. The first proprietary medical school was 100 miles south from Philadelphia, at the College of Medicine in Maryland, now named the University of Maryland School of Medicine (Zelenka, 2008). At these institutions, private citizens who were often practicing physicians were paid to train future physicians (Ludmerer, 1985; Zelenka, 2008). This became a profitable business and proprietary medical schools flourished, claiming loose but tenuous ties to universities across the eastern part of the continent. While more formal than the apprenticeship model, proprietary medical schools were not regulated or overseen by any widespread, formal governing body. These institutions were originally intended to be only a supplement to the traditional apprenticeship system, but within 50 years it was realized that the proprietary schools could more readily provide systematic teaching. This realization, combined with the westward expansion in the nineteenth century and subsequent population rise, increased demand for the number of physicians and led to a scarcity of apprenticeships. Therefore, in the early-19$^{th}$ century, less than 50 years after the establishment of the Medical School of the College of Philadelphia, there were 148 proprietary medical schools in the U.S. and Canada (Ludmerer, 1985; Zelenka, 2008).

*Entrance requirements of proprietary medical schools.* There were typically vague or no entrance requirements and a lack of academic standards or competencies for these proprietary medical schools, and many were eventually suppressed due to fraud and malpractice. Out of the 148 existing institutions, less than 50 required entrance standards proportional to graduation from high school; less than 24 required any sort of prior college education. The remaining 74 schools paid lip service to the high school education standard based on a written competency exam, which often became an informal after-dinner conversation with admission committees (Barr, 2010; Zelenka, 2008). Oftentimes the only limiting factor to becoming a medical student was one's ability to pay the tuition. This wide accessibility of medical education led to a discrepancy in the knowledge, skill set, and experience between medical students and the newly minted physicians they would become. This led to an overabundance of medical school students and graduates, and a lower general quality of practicing physicians (Anderson, 2011). The intention was to provide structure and perhaps some standardization to the undergraduate medical education curriculum and experience. Instead, the actual outcome from the proliferation of proprietary medical schools brings to mind the phrase "quality or quackery," demonstrating the extremes that existed on the healthcare provider continuum due to the varying experiences in medical education (Zelenka, 2008).

*Curricula of proprietary medical schools.* An example of a proprietary medical school curriculum was 2 4-month terms of classroom lectures, totaling about 500 hours per semester. Instructors were physicians with experience in general medicine, and taught courses each semester in anatomy, physiology, pathology, chemistry, surgery, medicine, pharmacology, obstetrics and gynecology, and pediatrics (Papa & Harasym, 1999; Ludmerer, 1985). Instruction was almost purely didactic, consisting of brief and sometimes public lectures in crowded lecture halls or amphitheaters. There was no gradation of studies or written exams, no hospital or clinical practicums, no research opportunities, and often no laboratory experiences to supplement the coursework. One exception at the more prestigious and financially comfortable schools was the opportunity to observe anatomy instructors performing a dissection on a cadaveric specimen (Ludmerer, 1985; Zelenka, 2008). After 8 months of coursework, students chose a private practitioner with whom to perform a 1 to 3 year apprenticeship before graduating. This mentoring relationship was essentially a shadowing exercise, and the quality once again depended entirely on the mentors' resources and variable experience (Papa & Harasym, 1999). Earning a degree as a doctor of medicine meant the student passed a set of casual, perfunctory oral questions, oftentimes regardless of their academic or clinical performances. Once an individual had a medical school diploma in hand, they had the legal ability to practice medicine as licensure by state did not yet exist (Ludmerer, 1985; Papa & Harasym, 1999).

***Professional medical education organizations instigate reform (1850 – present).*** The aforementioned laxity in the medical schools' curricula and standards were noted by medical leaders, and led to the formation of professional organizations to provide structure, delineate standards, and instigate reform in the training of future physicians (Barr, 2010; Association of American Medical Colleges, 2013). The first organization was the American Academy of Medicine (now the American Medical Association (AMA)) whose primary objective was to improve medical education programs and assess physician competencies (Papa & Harasym, 1999). The shift to a more standardized medical educational plan began in the mid- to late-1800s with the formation of both the AMA and the American Medical College Association (now the Association of American Medical Colleges (AAMC)). These organizations' attempts to enact changes immediately after their formation failed, thanks in part to political traditions and to a lack of public conviction – despite expert testimony to reaffirm – that the current medical education system was not working. The AMA-based editors of the *Journal of the American Medical Association* (*JAMA*) declared that only the most fit medical schools should survive, which when reading between the lines meant only the ones who complied with the changes proposed by the AMA (Beck, 2004). By the mid-19th century, standards were starting to be enforced and investigatory committees formed by the AMA and AAMC. But the American Civil War put a temporary halt to these discussions between 1861 and 1865 (Papa & Harasym, 1999).

***Reform, not revolution.*** Post-American Civil War, the AMA reinvigorated their early efforts at reform and picked up where they left off saying, "It is reform, not revolution, that is contemplated" (Ludmerer, 1985, p. 20). By stating this, the AMA was making clear that they did not desire a complete overhaul of the current medical education format, but rather a fine-tuning of the areas with issues. One of the chief concerns was a perceived decline in status of the medical profession that the AMA attributed to defective medical education and lower quality of emerging physicians (Ludmerer, 1985). The AMA's proposed changes included: lengthened period of formal instruction (from 4 months to 6 months each), requirement of adequate preliminary education to meet new entrance standards, and completion of apprenticeships with qualified preceptors. The organization also wanted to be certain that medical instructors were fully invested in the education of future physicians and that there were high quality resources available to institutions nationwide (Ludmerer, 1985).

*Medical instructors as trained educators versus practicing physicians.* The medical school instructors at this time were not trained educators, but instead practicing physicians who viewed teaching as a part-time endeavor. But with increasing educational regulations and responsibilities being placed upon the institutions, these individuals started to have to decide whether they were going to be medical professors and scholars or focus on being practitioners of medicine. A full-time commitment in either direction began to be forced on this group of educators (Ludmerer, 1985). This full-time commitment was, and still is, a controversial reform component. Many medical schools in the 21st century have faculty members who are also practicing physicians, and so this aspect of reform in the late-19th century did not quite come to fruition. Another prominent concern was with the pedagogical methods – or lack thereof – at many medical schools. Many thought there should be at least an introduction to laboratory and hospital work, and that students should be made more responsible for their education by being active participants and fostering critical thinking rather than fact memorization (Ludmerer, 1985).

*Medical textbook development.* Medical textbooks began to be published and mass-produced in the 1850s and significantly advanced the quality of medical education. These text resources were able to offer an organized, peer-reviewed set of information rather than relying on faculty members' memories. Textbooks also encouraged students to be more self-reliant and take greater responsibility for their educational outcomes (Papa & Harasym, 1999). The caveat to this development was that not all that was known about medicine could fit into a textbook, or even into the entire medical curriculum. The proliferation of scientific discoveries in the mid-nineteenth century meant that medical knowledge was no longer seen as a fixed body of dogma but as a constantly growing and evolving entity. The existing medical schools' faculty members and administration began to make decisions, with the oversight of the AMA, about what was taught, in what order, and in what relation to other topics. The only curricular constant at this time was that anatomy was the only scientific subject consistently taught in detail, often with laboratory experiences (Ludmerer, 1985). The debates regarding the content and its order and emphasis in UE curricula are ongoing today.

***Four preeminent U.S. medical schools led medical education reform efforts.*** Medical education reform gained allies and speed in the 1870s and 1880s and spread "in almost seismic fashion" after 1910 (Ludmerer, 1985, p. 29). During this period, 4 U.S. medical schools served as exemplary institutions in terms of their curricular and professional innovations, basing many of their decisions on medical schools in Europe, particularly Germany. The medical schools within Harvard, Pennsylvania, Michigan, and Johns Hopkins universities became models for all subsequent medical education reform efforts in the U.S. These schools established rigorous curricula that included heightened entrance requirements, compulsory written and oral exams, increased total length of undergraduate medical education to 4 years, and lengthened academic years from 6 month to 9 months (Ludmerer, 1985). The coursework was arranged with the basic science subjects (e.g., anatomy, pathology) preceding clinical sciences, and new subjects were added to stay abreast of contemporary scientific, medical, and technological discoveries. But perhaps the most paradigm-shifting change in this time was the improved pedagogical methods. Students were encouraged and began to be trained to change from passive observers into more active participants, and the wholly lecture- and demonstration-driven classrooms began to be supplemented with laboratory and clerkship experiences. It was at this time that medical research found its place in medical education, becoming known as **academic medicine** because of the synthesis of focused scientific research, sound pedagogical methods, and clinically relevant medical training. Thus, the most common and traditional format of the medical school in the U.S. and Canada was born (Ludmerer, 1985).

**Development of the discipline-based model of medical education.** Seeing the success and accolades lavished upon the medical schools at Harvard, Pennsylvania, Michigan, and Johns Hopkins, other institutions began to emulate their practices. This process was first gradual and almost hesitant, but accelerated after 1900 into a powerful and unstoppable movement. Other medical schools also began to house themselves within universities that split faculty into discipline-specific departments (e.g., anatomy, chemistry) and also lengthened the formal coursework expected from their students. Faculty taught in both the lecture hall and the clinic, creating new clinical application opportunities for the basic sciences. In the previous apprenticeship model, memorization of specific cases and practical experiences led to student success. With this new discipline-based method of teaching and learning, students had to begin to think critically, problem solve, find new information, and keep up with scientific advancements. For the first time in U.S. and Canada UE, students were “thinkers” rather than “memorizers” (Papa & Harasym, 1999). Thus, in approximately 1900, the second of the 5 major reform movements, the discipline-based model, was born.

But conditions and the degree to which schools across the continent bought into the discipline-based model varied and still some proprietary medical schools continued to operate and grant medical degrees. In the 1890s, some states began to require additional licensing exams in an attempt to regulate practicing physician standards and to flush out the remaining proprietary medical schools. The reform of medical education became a true national movement in the 1890s because of better-trained educators, more and more schools emulating successful programs, and the ongoing efforts of the AAMC and AMA (Ludmerer, 1985).

***Academic medicine rises in the 20th century.*** As with most reforms and revolutions, "…changes in medicine and medical education occur within a social and political context" (Calman, 2007, p. 221). As academic medicine rose to power, basic scientist researchers were perceived to start to overtake schools from private practitioners. This dichotomous struggle for control of the training of future physicians continues today, with practitioners often on the losing side against research and revenue-producing basic scientist researchers (Ludmerer, 1985). The two most conspicuous features of the development of U.S. medical education were the movement into established universities and the rise of medical research (Ludmerer, 1985). But despite the many positive changes that occurred in a relatively short time period, there was still a general feeling that medical education standards were subpar and the quality of new physicians was lacking (Calman, 2007).

***A call for intensive curricular research.*** In an attempt to investigate and assess the declining quality of medical education and the physicians it was producing, the AMA's Council on Medical Education conducted a survey regarding medical school requirements and format, and found many still lacking in the most basic areas of the reform such as standardized entrance requirements and rigorous curricular design.

Therefore, in 1908 the AMA asked the newly founded Carnegie Foundation for the Advancement of Teaching to perform a comprehensive survey of all medical schools in North America. The resulting document, "Medical Education in the United States and Canada: A Report to the Carnegie Foundation for the Advancement of Teaching," garnered attention and gained fame as the eponymous Flexner Report, named for the lead researcher of this undertaking (Zelenka, 2008; Hiatt & Stockton, 2003). The foundation for a massive medical education reform was already laid, as the AMA had for decades past proclaimed plans and goals that paralleled issues to be evaluated in the Flexner Report. But the next several years proved that "if the Report and the earlier work of the Council on Medical Education were collectively the anvil on which reform was to be forged, Flexner himself was certainly the hammer" (Chapman, 1974, p. 110). The Flexner Report therefore served to publicize the reform process that was already an internal struggle to those in the field of medical education (Barr, 2010; Calman, 2007).

*Flexner's background and reputation.* Higher education expert Abraham Flexner was hired by the Carnegie Foundation for the Advancement of Teaching to conduct visits to the 155 undergraduate and 12 graduate medical schools in the U.S. and Canada to evaluate their institutional design and educational programs. He already had a reputation as being the "master of the survey," a meticulous and brutally honest researcher (Zelenka, 2008, p. 17). Flexner felt that scientifically based medicine was possible as long as the basic sciences served as a fundamental knowledge base for medical education, practice, and research, and that scientific reasoning was used in the clinics to solve medical problems. He vehemently opposed any patient contact or clinical experience within the first two years of medical school (Papa & Harasym, 1999).

*Flexner identifies his standards for medical education.* Flexner's data collection for the AMA study took 18 months of non-stop travel to complete. Though there was no concrete methodology, Flexner evaluated each school in five principal areas: entrance requirements, size and training of faculty, size of endowment and tuition, quality of laboratories and laboratory instructors, and availability of a teaching hospital with physicians and surgeons serving as clinical instructors (Anderson, 2011; Barr, 2010; Hiatt & Stockton, 2003). In preparation for the study and to identify benchmarks of a high functioning and effective medical education system, Flexner visited Johns Hopkins School of Medicine. Flexner's brother studied medicine at Johns Hopkins before becoming the first director of the Rockefeller Institute for Medical Research. Flexner spoke with leading physicians there who had very strong views on what a medical school should be. He took these physicians' convictions and the established respect for and reputation of the institution and used Johns Hopkins as the prototype to which he compared the other 167 institutions. As the first major, comprehensive survey of U.S. and Canada medical schools Flexner had both the onus and honor of deciding what he thought an adequate medical education experience would be. There was no one in an unbiased position of power to argue otherwise with Flexner, and so the details of his model were solely in his control (Zelenka, 2008).

The general model Flexner decided on was that of a university-based medical institution that placed an emphasis on both science and the humanities, offered advanced laboratory facilities, and in the later years required student experiences in clinics and hospitals (Zelenka, 2008). Other proposed standards of quality included the entrance requirement of a bachelor's degree in science, and the medical curriculum consisting of two years in the basic sciences followed by two years of practical clinical education involving close contact with patients (Kusurkar et al., 2012). For Flexner, medical school was about trying to make a "personally expert sovereign physician" (Lucey, 2013, p. 1639). This study was conducted in the era of the predominantly discipline-based model of medical education, where basic scientists were thought to have a mindset appropriate for new scientific clinician: an intellectual ability to critically challenge the views of others, to continually and independently conduct research, and to deal with the unknown using the scientific reasoning process (Papa & Harasym, 1999).

*The Flexner Report.* After survey data collection and analysis, the 346-page Flexner Report consisted of two major sections: a narrative report on the current state of early twentieth century medical education and the complete survey data describing each of the 167 medical schools (Flexner, 1910; Zelenka, 2008; Hiatt & Stockton, 2003). The first part of the report discussed the recent history and traditions of medical education, compared what Flexner decided its proper basis versus the actual basis, discussed financial aspects, and proposed a plan for the reconstruction of medical education and a recommended curriculum (Flexner, 1910). The first part of the report also commented on medical sectarianism (i.e., alternative medical treatments of the time that focused on nature's healing power instead of scientific research), state boards of licensure, postgraduate education, and educating women and minority populations (Flexner, 1910; Buchanon, 1854; Hiatt & Stockton, 2003).

The overarching idea conveyed by the Flexner Report was that medical schools should be university-based with a sound scientific basis, and the beginning of medical school should take place primarily in the classroom, where students learn basic scientific knowledge. But these recommendations of what medical education should be were so far removed from what actually was happening in the field at this time. Therefore, these prescriptions as a whole are referred to as the Flexnerian paradigm (Boelen, 2002). Varughese and Shin (2010) discussed the Flexner report and emphasized that:

> Educational reform in America did not come in one fell swoop. Rather, the report publicized and galvanized financial and philanthropic support for developments in medical education already under way at some medical schools. In this regard, the Flexner report was less a singular force of reform than a well-publicized statement of what many medical reformers already desired (p. 149).

The Flexner Report observed that some schools were already implementing the desired four year curriculum in which the first two years were devoted to basic sciences coursework and the next two years to clinical training, using the knowledge gleaned to assist in treating patients. Within ten years of the report's publication, almost all remaining schools had converted to this system (Chapman, 1974; Zelenka, 2008). An enormous continuum of quality in teaching was found amongst medical schools during Flexner's study. He observed this continuum and reported that in order to best use resources and standardize medical education, policymakers needed to stop wasting time on schools deemed inadequate by either closing or assimilating them into more qualified institutions (Barr, 2010). The recommendation to consolidate or close schools in order to raise overall standards was a common refrain from Flexner. He called for a severe cut in the number of medical schools and enrolled medical students, recommending the reduction of the number of institutions from 155 to 31 and the number of graduates from these by more than half (Zelenka, 2008).

*Results of the Flexner Report.* The changes that were enacted were dramatic, but not nearly to the level Flexner desired. Within ten years post-Flexner Report, the number of medical schools decreased to 85 and the number of enrolled students by more than half, from 28,142 to 13,798 (Varughese & Shin, 2010). Within two decades of the publication, over half of the original U.S. and Canada medical schools either closed or merged with another (Varughese & Shin, 2010). The percentage of schools requiring two years of college for admission rose from 3 to 92 (Hiatt & Stockton, 2003). The report raised the quality of medical education by changing standards and reducing the overall number of schools by closing or merging those lacking with those with adequate standards. This reduction left some areas of the U.S. and Canada without a ready supply of physicians and unintentionally introduced a greater extent of professional elitism. Flexner also advocated for a "more uniformly arduous and expensive medical education," the latter which in retrospect foreshadows the beginning of classism and elitism in the medical profession (Beck, 2004). Increased tuition costs added to this and made it extremely difficult if not impossible for the lower socioeconomic classes to pursue careers in the medical profession (Barr, 2010).

One of the most striking revelations of the Flexner Report was the extreme heterogeneity in U.S. and Canada medical schools. After completion of his data collection and observations, Flexner determined that the ideal medical school should have a discipline-based model of curriculum with three major characteristics:

(1) *High caliber equipment and resources*. This took the form of modern laboratories for each curricular subject, control of teaching hospitals, and adequate funds to purchase land, erect and maintain buildings, and pay salaries.

(2) *Admittance of only academically qualified students.* Flexner maintained that the study of medicine is science at a secondary and not primary

stage. Therefore, to succeed students must enter with a minimum of two years of college training in a science discipline (e.g., physics, chemistry, biology).

(3) *Production of original research by faculty*. Flexner opined that scientific and medical researchers made the best teachers because it served to animate their teaching. He claimed this was because the inclusion of contemporary developments and real-world experiences would serve to make the abstract more real to students (Ludmerer, 1985).

The massive production of 15,000 copies of the Flexner Report circulated, gaining headlines and newspaper exposure. But despite the attention given to this publication at the time, many of Flexner's more detailed recommendations for medical education remained unrealized (Hiatt & Stockton, 2003). The overall results of the Flexner Report were superficially what he envisioned and recommended, but outside of the number of institutions and students, the extent of change is difficult to quantify. Unfortunately many physicians lapsed back into the traditional, apprenticeship frame of mind after graduating medical school. They had paid their dues to the system and while the newly minted physicians were more modernized, those who had been practicing typically did not immediately buy into the revised UME curriculum. Despite being one of the most influential documents in the early-20$^{th}$ century regarding higher education in the U.S. and Canada, the Flexner Report also attracted controversy, criticism, libel lawsuits against Flexner, and even the publication of violent letters of protest (Chapman, 1974).

The Flexner Report influenced not only the U.S. and Canada, but also Asia and parts of Europe where medical licensure then became the norm (Frenk, Chen, & Bhutta, 2010; Gwee, Samarasekera, & Chay-Hoon, 2010). After this foray into medical education research Flexner left this work behind and moved on to the General Education Board where he became the country's most influential manager of foundational philanthropy (Ludmerer, 1985). A tribute to Abraham Flexner in *The New York Times* after his death in 1959 was "Dr. Flexner was an implacable critic of education…he was equally brilliant at finding fault and creating right" (Bodreau and Cassell, 2010, p. 378). The pivotal question that must be addressed in contemporary medical education is if the observations that Flexner made regarding issues in the early twentieth century are still relevant, and if the methods currently used are still adequately preparing individuals to respond to the requirements of the modern healthcare system and society (Boelen, 2002).

***Medical curriculum is driven by research (1920 – present).*** The 1920s saw the maturation of medical education in the U.S. in terms of Flexner's recommended standards and a desire to monitor and continually improve the system (Ludmerer, 1985). After international disruption by World War II and the subsequent establishment of the National Institutes of Health, research once again became a priority in medical education (Chapman, 1974; Zelenka, 2008). In the 1930s and 1940s, the discipline-based model was subjected to intense scrutiny in view of its segregated topics, adversity to early patient contact, and arguably high level of content detail. A new model in which the amount of unconnected, discipline-specific information was reduced and made into a more coordinated format became desired by medical education faculty and administration.

**The organ systems-based model developed in 1952.** To this end, the very first integrated type of curriculum and also the third of five major reform movements in the

U.S. and Canada, the organ system-based model, was created in 1952 at Case Western Reserve University. In this system, curricular content was overseen by faculty on topic committees and rather than discrete departments there were overlapping groups of educators agreeing to a consensus for the overall coursework framework (Papa & Harasym, 1999). Case Western Reserve University organized lectures from different content areas using a single organ system (e.g., cardiovascular, urinary, respiratory) as the focal point, incorporating clinical correlations from visiting physicians. The central themes of the organ system-based model included teaching based on problem solving, students accepting responsibility for their own education, faculty topic committees rather than departments, designing the curriculum as a continuum, interdisciplinary teaching, and integrating basic and clinical sciences (Papa & Harasym, 1999; Kusurkar et al., 2012; Hopkins et al., 2015). The organ system-based model was the most drastic and well known of many curricular changes of the time, as a result of medical specialization and addressing complaints about fragmentation of the curriculum.

Other schools followed suit and developed programs based around the organ systems, some of which resulted in better integration of laboratory and clinical teaching, greater emphasis on the medical humanities, and more elective time (Ludmerer, 1985). But students in these curricula, perhaps the most discerning critics with the most to gain or lose in the evolving medical education arena, often found the information to learn disjointed and integration of clinical presentations challenging. In the last two years of medical school while on clinical rotations, many students had trouble generalizing concepts and applying these concepts to new situations. They were also generally deficient in forming differential diagnoses because their scientific reasoning and deductive skills were sorely lacking which they – rightly or wrongly – ascribed to the organ system-based organization (Papa & Harasym, 1999). In the 1960s and 1970s research began using cognitive science-derived theories as the basis for solutions to inadequacies in medical education (Papa & Harasym, 1999). Also at this time, offices of medical education were established at some medical schools to help support evaluation and development of faculty and continuous curricular improvement (Zelenka, 2008). It is important to note that although the organ system-based model was used by many schools, others still used the discipline based model as their main mode of teaching future physicians. Each of the five major reform movements were gradual changes in the climate of UME, often blending with one another for decades, rather than happening in all medical schools in the U.S. and Canada simultaneously.

**The problem-based learning (PBL) model originated in 1969.** In 1969, it was realized that educators needed to set an appropriate context for students in which to learn new content. The organ systems-based model theoretically increased understanding and retention, but made it difficult to establish differential diagnoses and select treatments from the many that were available. In efforts to rectify the deficits found within this model of medical education curricula, the problem-based learning (PBL) model arose at McMasters University (Kusurkar et al., 2012). The PBL model was based on the Flexnerian assumption that problem-solving skills form the basis of being a good diagnostician and health care provider. This was the fourth of five major reform movements in medical education, and like the previous model was also a form of integration. At the schools that adopted the PBL model, information was presented in the form of clinical cases and relied on the foundation of previous student knowledge which was extremely varied depending on the previous curriculum. After being presented with cases, students worked in small groups to delve into the relevant information from the basic, clinical, and social aspects of the patient's case and connect this information with their existing knowledge. This model promoted self-directed learning and often encouraged instructors to move from a traditional disseminating role into a facilitating role. Problem-based learning brought clinical relevance directly into the first two years of medical school and improved clinical reasoning and retention of information because it integrated the basic and clinical sciences into the context of interesting clinical problems (Kusurkar et al., 2012; Zelenka, 2008; Papa & Harasym, 1999; Hopkins et al., 2015).

**The clinical presentation model evolved from the PBL model in 1991.** The fifth and most recent major curricular reform movement occurred in 1991, when the University of Calgary Faculty of Medicine took the problem-based curriculum and altered it to create the clinical presentation model (Kusurkar et al., 2012). This involved taking problem-based learning situations but staging them as if the patient was first presenting to a clinic with specific signs and symptoms. When the learning experiences were repeated with different patients and scenarios, the clinical presentation model mimicked a day in the life of a physician. It is not drastically different from the PBL model, but the clinical presentation model has the advantage of a roleplaying exercise which encourages medical students to make rapid and more realistic decisions in regards to patient care and treatment (Kusurkar et al., 2012). The clinical presentation model incorporated problem solving schema to enable students to apply the principles learned in other contexts, which is what distinguished it from the problem-based model: being structured-knowledge and process-specific (Papa & Harasym, 1999). Interestingly, the clinical presentation model almost seems to bring the UME curriculum full circle in that it mimics the apprenticeship model. In the apprenticeship model, physicians in training would shadow and assist practicing physicians; in the clinical presentation model, the only major difference pedagogically is that the patients are simulated.

By the turn of the millennium, medical education in the U.S. and Canada looked vastly different that it had in its apprenticeship days. After progressing through a myriad of reports, research studies, and reform movements, medical training became more humanized and left behind much of the commercialism, inadequate or hasty training, and public deception that dominated the profit-driven approach to medical training by proprietary schools in the late nineteenth century (Anderson, 2011). Medical education became more tied to evidence-based clinical practice and research, social accountability, and educational patriotism, which is the moral obligation of a school to do their utmost to serve the public interest (Boelen, 2002). The first two reform movement models, apprenticeship and discipline-based, can be set into discrete categories as they were two of the larger paradigm-shifting changes to medical education in their time. But the latter three reform movement models, organ systems-based, problem-based learning, and clinical presentation-based, were all pointing medical education toward the same basic idea:  integration. These models approach learning about the human body and medicine not by placing each piece of new information in a separate cognitive box, but rather by making connections and links between all pieces of information as a physician ideally does. Different schools have different levels of implementation, and many have some combination of the three latter models. The integrated methods of teaching and learning were established with the aim of placing each discipline and its subject matter in the context of all other disciplines or in the broader context of medical education. The following section of this chapter discusses the recent push for UME to integrate the entire four year curriculum into one cohesive unit of learning rather than continuing on a Flexnerian model.

**Curricular Integration**

While there are clearly several ways to approach integrated learning, there is no one universal definition for **curricular integration**. In contemporary undergraduate medical education, integration typically refers to four years of interdisciplinary block courses that bring together basic, clinical and social sciences into one cohesive learning experience or weaves curricular themes (e.g., ethics, cancer) across the four year undergraduate medical curriculum (Muller, Jain, Loeser, & Irby, 2008). Integration aims to bring together the basic sciences whose subject areas contribute to fundamental medical knowledge and the clinical sciences as the practical application of medical knowledge. The goal is to increase student retention, improve transfer of knowledge in clinical settings, and maintain student interest by allowing them to see the relevance of basic sciences in clinical practice (Kulasegaram, Martimianakis, Mylopoulos, Whitehead, & Woods, 2013).

An ever-present struggle in medical education is finding a balance between generalization and specialization (Whitehead et al., 2013). The integration of medical education is an attempt – sometimes well-coordinated and sometimes not – to unify all aspects of the four years of training given to future physicians into one well-oiled and efficient machine of knowledge transfer and skill practice. In general, the basic scientific knowledge foundation of medicine is not well integrated with acquiring experiential knowledge over the course of one's medical education. This lack of integration often results in first- and second-year medical students failing to appreciate the relevance of their classroom information for the clinical setting. Reciprocally, as advanced students in a clinical environment, students may struggle to recognize the relationships between what they were taught in the classroom and the problems with which patients present, and so they feel they have to learn everything all over again. In a study that looked at learning facts disassociated from patients, the results were a 30 to 50 percent loss in knowledge by the time students reached the clinical setting (Zelenka, 2008).

The following scenario is an example of an integrated curriculum: Students begin with two years of classroom- and laboratory-based coursework that serve as the foundation of formal medical knowledge on which all clinical practices are based. Most medical schools offer these two years in integrated units or blocks organized in discrete time blocks around organ systems (e.g., urinary, skeletal) or clinical topics (e.g., genetics, cancer). This foundational coursework is followed by two years of clinical practice, organized into specialty blocks called clerkships. During the third year, students rotate through a series of clerkships in the core specialties of family medicine, internal medicine, neurology, obstetrics and gynecology, pediatrics, psychiatry, and surgery. Following the required clerkships, the fourth year is primarily advanced electives or clerkships. Some medical schools offer specialized tracks early on within their curricula, allowing students to alter their coursework trajectory and pursue areas of interest such as biotechnology, clinical and translational research, molecular medicine, and global health (Zelenka, 2008; Liaison Committee on Medical Education, 2015; American Osteopathic Association, 2016).

As was illustrated earlier in this chapter, integration has been continually revisited throughout the history of medical curriculum in the form of the organ system-based, problem-based learning, and clinical presentation-based models, leading to "incremental change but no meaningful transformation" (Hopkins et al., 2015, p. 149) There is a constant struggle of recommendations being made but not effectively put in to action and followed through (Hopkins et al., 2015). Many allopathic and osteopathic medical schools are currently integrated to some extent, though the exact layout of the UME curriculum varies by institution.

**Challenges to the present medical curriculum (2000 – present).** In the 2010 book *Educating Physicians*, authors Cooke, Irby, and O'Brien claim that the major challenge in modern medical education is how to most effectively and efficiently train students to face the needs of a constantly evolving society. Medical curricula undergo continual evaluation and updates as new scientific information becomes available, health care priorities change, and innovative instructional techniques are introduced (Anderson and Kanter, 2010). Mennin (2010) speaks of medical education as a very complex system through the expression of its curriculum, and the interactions, exchanges, and learning that take place within and surrounding it. In this setting, learning and knowing become adaptive responses to continuously evolving circumstances – an accurate description of the medical field when dealing with individual patients and illnesses. The medical curriculum is an ever changing system and

> How we respond to and frame the issues of learning and understanding that challenge contemporary medicine and, by extension, medical education, in a complex and rapidly changing world can have profound effects on the preparedness of tomorrow's health professionals and their impact on society (Mennin, 2010, p. 20).

The professional identity of the physician that was successful in the acute disease era of the 20th century will not be effective in the complex chronic disease era of the 21st; but unfortunately UME as a whole seems to want to continue to develop this type of physician and way of thinking rather than refining the old way to be more appropriate for the contemporary world (Lucey, 2013). Patients' expectations of physician expertise is no longer limited to the sciences but may also include prowess in communication, bioethics, statistics, health care finance, health law, management sciences, and alternative or holistic healing methods (Emanuel, 2006). The CanMEDS 2000 Project, an initiative seeking to define a competency framework of physician skills for the new millennium, identified the multiple roles that must be fulfilled simultaneously and enthusiastically by physicians today: expert, communicator, collaborator, manager, health advocate, scholar, and professional (Gregory, Lachman, Camp, Chen, & Pawlina, 2009). These are lofty roles to expect newly qualified physicians to be able to fulfill by the end of their medical training, but their patients seem to believe that with great power comes great responsibility. Regardless of society's demands, the dynamic nature of learning calls for greater long-term connections of knowledge to be made during UME (Zelenka, 2008). To this end, the purpose of medical education should be "to transmit knowledge, impart skills, and indoctrinate into students the values of the profession in an appropriately balanced and integrated manner" (Cooke, Irby, Sullivan, & Ludmerer, 2006, p. 1341).

Irby, Cooke, and O'Brien (2010) report that some medical education researchers claim that the Flexnerian model of medical education which served well for much of the 20th century must be transformed to promote excellence in the 21st century. Now the question is how to analyze, assess, and ultimately alter the medical education system to fit these needs when the requirements of society are so fluid and the existing curricula so varied. The major national organizations that oversee medical education were previously listed in this chapter. They include the Liaison Committee on Medical Education, American Medical Association, American Association of Medical Colleges, Accreditation Council for Graduate Medical Education, Accreditation Council for Continuing Medical Education, Federation of State Medical Boards, National Board of Medical Examiners, Commission on Osteopathic College Accreditation, and specialty board societies (Cooke et al., 2010; Liaison Committee on Medical Education, 2015; American Osteopathic Association, 2016). But no single governing body or group has absolute power, though the LCME and AOA do perform general oversight of allopathic and osteopathic medical schools, respectively, via site visits and accreditation. The characteristics of successful UME curricular change that these governing bodies should consider in modern reform are:  strong leadership, faculty development programs, a formal curriculum change process, awards to acknowledge efforts of curricular development, and high quality processes for assessment of student learning (Cuff & Vanselow, 2004). Successful curriculum changes have followed a model that includes needs assessment, specification of learning objectives, selection of content and teaching methods, and evaluation of the changes made. Now we need to incorporate systems-based practice and interprofessional teamwork, as well as a clear understanding of what the term curriculum means in all its nuances and implications (Cuff & Vanselow, 2004). The remainder of this chapter will discuss the meanings of all aspects of a curriculum, and provide examples from the anatomical subdiscipline that is pertinent to this research, embryology.

**Definition and Types of Curricula**

The word "curriculum" is Latin for a racecourse or the race itself, a place of action or a series of active events (Oxford University Press, 2016). A curriculum can therefore be defined in two ways: 1) the entire range of directed and undirected experiences concerned with uncovering the abilities of the students, 2) the series of consciously directed training experiences that the schools use for tapping into students' potential (Bobbitt, 1918). As mentioned in chapter one, curriculum scholars Flinders, Noddings, and Thornton (1986) stated, "It is not uncommon for two curriculum specialists to discuss their field at great length before discovering that each is using the term 'curriculum' to mean something quite different" (p. 33). The word "curriculum" has many interpretations including something that is moving and changing, a range of subjects or content, the means through which the content is delivered and assessed, the aims and objectives of a program, the strategies of teaching and learning, a reflection of the needs and interests of society, and many more (Flinders et al., 1986). Calman (2007) was of the opinion that the curriculum in medical education was not the "what" but rather the "how and maybe sometimes even the "why" of an institution. The recurring theme in medical education of what Bloom (1988) calls "reform without change" may be partially due to a lack of a common language and understanding of the nature of curriculum to underpin the debate (Burton & McDonald, 2001). In order to have productive conversations regarding curricula, it is essential to have some sort of structure to provide a frame of reference.

As introduced in the first chapter of this research, Eisner (1985) explains that the curriculum is composed of three facets that frame the overall idea: explicit, implicit (also known as hidden), and null curricula. The **explicit curriculum** is sometimes called the formal curriculum, whereas the **implicit** and **null curricula** are sometimes collectively referred to as the informal curriculum. Before delving into an analysis of these three components, it is important to acknowledge that it is still ill-advised to bestow rigid labels to settings, situations, and roles because all three of these components can exist in any place of a curriculum and at any time. Sometimes they occur simultaneously and convey very different messages, as will be seen later in this section with the example of the white coat ceremony at the beginning of medical school (Veatch, 2002). However, while it is organizationally pleasing to attempt to place aspects of the medical school experience into neat blocks and sort them accordingly, this method does not work for all parts of the curriculum and doing this may collapse important subtleties into a single category, thus limiting our understanding of this complex system (Hafferty & Castellani, 2009). The trifold framework of the explicit, implicit, and null curricula is especially useful because it allows one to identify and more easily assess areas of success and areas in need of improvement. With medical education currently undergoing another wave of reform, this method of organizing components of a curriculum may prove extremely useful to those involved in enacting change.

When considering the five major curricular reform movements described earlier in this chapter, one can see that the latter four models (discipline-based, organ system-based, problem based-learning, and clinical presentation-based) each have a distinct correlation with one or more of the explicit, implicit, and null curricula. Each of these four curricular models provide distinct assumptions about the implicit curriculum, about what learning anatomy, including embryology, means. The discipline- and organ-system based models imply that anatomy is a science in which students must learn facts and structures. The problem based-learning and clinical presentation-based models imply that anatomy is an applied science in which students must use the knowledge gained to form connections between other coursework and experiences. From this perspective, each model can also suggest explicit and, with further analysis and thought, null curricula.

The following sections define and describe the explicit, implicit, and null curricula in terms of the anatomical sciences subdiscipline embryology. Particular focus will be placed on how embryology has fared thus far in the explicit, implicit, and null curricula in the current climate of curricular reform in UME.

**The anatomical sciences subdiscipline embryology and the three curricular components.** Anatomy has traditionally been a major foundational component of the basic sciences in UME. The four subdisciplines of the anatomical sciences (gross anatomy, microscopic anatomy or histology, neuroanatomy, and embryology) are time- and content- intensive courses. Anatomy is often complemented by evolution (incorporating comparative anatomy) and interfaces naturally with physiology and pathology. The field of anatomy is pertinent to many clinical disciplines, particularly surgery, radiology and emergency medicine (Louw, Eizenberg, & Carmichael, 2009).

Establishing adequate comprehension of anatomy is usually regarded as a necessary step before commencing to the later years of UME studies. The prevalence and perceived importance of the anatomical sciences can pose practical issues for curricular reform and integration, as each subdiscipline is able to justify strongly why they require no decrease in course hours and resources. But the relevance of anatomy is under scrutiny as medical education is once again being reevaluated in the face of reducing course hours and the shifting emphases of medical training (Drake, 2002; Drake et al., 2002; Drake et al., 2009; Drake et al., 2014).

Until recently, anatomy occupied a significant portion of the first year of UME, and included formal lectures and laboratory dissection of the entire body. But with more information becoming discovered about other basic sciences (e.g., molecular biology), the basic science curriculum has become more crowded and the time for anatomy has become compressed to accommodate the new content for other disciplines. In particular, time for studying in the laboratory and for cadaveric dissection has been shortened (Louw et al., 2009; Drake, 2002; Drake et al., 2002; Drake et al., 2009; Drake et al., 2014). In recent years, many medical educators have recognized a need to redesign the medical curriculum to reduce the emphasis on ever-increasing amounts of details as well as to approach topics from a more conceptual and integrated point of view (Vidic & Weitlauf, 2002).

The anatomical subdiscipline that has seen some of the most dramatic curricular changes is embryology. Embryology, more than any other basic science in the medical curriculum, has faced difficulties trying to find a curricular niche (Carlson, 2002). Extensive medical and technological advances lead to more potential embryology content, and with an overall reduction in medical school contact hours and the addition of other essential content, the presence of embryology is slowly but surely decreasing in UME. The integration of embryology into other courses is the norm in modern medical schools, as is its disproportionate decrease in course hours and allocated resource (Gartner, 2003; Drake et al., 2002; Drake et al., 2009; Drake et al., 2014). The details gathered by the 1967-2014 surveys may be found in chapter one of this research, in Table

1.1. The surveys show that there are fewer hours devoted to the anatomical sciences in general, yet there is a disproportionate decrease in hours for embryology (Gartner, 2003; Drake et al., 2002; Drake et al., 2009; Drake et al., 2014).

The remainder of this chapter will provide details and examples of embryology within the explicit, implicit, and null curricula, and conclude with the reasons why this mixed methods research is needed for the improvement of UME in the U.S. and Canada.

There are various methods used to teach embryology, but trends observed since the Flexner Report and on the heels of scientific and technological advances include the following generalities. Embryology is typically integrated into another course, most often gross anatomy, but sometimes or additionally into either the anatomical subdisciplines of microscopic anatomy or neuroanatomy. The majority of embryology lectures are interspersed through the course into which embryology is integrated. The course hours and laboratory hours (if any) devoted to embryology are steadily declining and now average just seventeen hours (Drake et al.,2002; Drake et al., 2009; Drake et al., 2014). This is a significant number as it may represent the minimum amount of time necessary to provide a fundamental level of knowledge in the subject (Drake et al., 2009).

Embryology content provides unique challenges to both faculty and medical students in UME. One reason for this is some experts feel that both the descriptive developmental anatomy and the molecular signaling and pathways must be taught in order for students to have a complete understanding of the topic. In addition, the dramatic explosion of advances in molecular imaging and signaling has led to a period of unprecedented change in embryology’s knowledge base. Embryology is no longer a teaching and learning situation of descriptive anatomical development at static stages, but instead now also incorporates information from biochemistry, microscopic anatomy, genetics, and other fields for a clearer understanding. This molecular metamorphosis of embryology has long reaching implications for UME and curricular reform, as has been described earlier in this chapter (Tavares, 2004). While exciting and scientifically gratifying, this creates a dilemma of how much new molecular knowledge versus how much traditional developmental anatomy structural knowledge should be learned in UME (Carlson, 2002).

When asked what sciences constitute the foundation for medical practice, the majority of educators surveyed by the International Association of Medical Science Educators (IAMSE) replied that embryology was of some importance, but it should be integrated in other disciplines or taken as a premedical undergraduate course (Finnerty et al., 2010; International Association of Medical Science Educators, 2016). However, premedical (not UME) undergraduate embryology courses for students pursuing bachelor's degrees are extremely rare, especially those focusing on the human organism. Chapter 4 of this research will describe the development and implementation of a premedical undergraduate embryology course that focused on student learning objectives on human embryological development and human birth defects.

Traditionally, most UME institutions currently teach embryology within gross anatomy, integrating embryology content in an organ systems-based format, wherein the embryological development of organ systems are studied one at a time (sometimes with the appropriate molecular information) when the relevant gross anatomy is learned (Carlson, 2002; Drake et al., 2014). The problem with this pedagogical approach is that the embryological content often appears disorganized to the medical students and sometimes to the faculty as well. A major pedagogical conundrum is that it is difficult to lecture about embryology without students knowing the final gross anatomical structures and morphology, but conversely, it is problematic to teach embryology solely at the end of the gross anatomy content because in this case embryology may be seen as an afterthought in the UME curriculum. These issues and other aspects related to embryology within the UME curriculum may be examined via the framework of the explicit, implicit, and null curricula.

**Embryology's place in the explicit curriculum.** The explicit, or formal, curriculum is the specifically stated component of medical education (Eisner, 1985). In chapter one, Table 1.2, the explicit curriculum was defined as the publicly announced programs of study or what the school advertises it will provide, such as handbook or syllabi. The explicit curriculum is usually easily identifiable, even by individuals who are unfamiliar with an institution's particular curriculum. Many options exist for how to disperse embryology content, and UME utilized many of these techniques: lectures, textbooks that blend anatomical and molecular approaches, web-based models, computerized animations, case studies, instructor- and student-constructed models, drawing, embryonic autopsies, laboratory exercises, and problem-based learning (Nnodim, 1988; Carlson, 2002; Nieder, Parmelee, Stolfi, & Hudes, 2005; Vasan, DeFouw, & Holland, 2008; Nachiket Shankar, 2009; Versi-Farreira et al., 2012, Chan, 2010; McLachlan, 2000; Fraser & Harland, 2000; Moraes, Reis, Mello, & Pereira, 2004; Smith, 1975; Dinsmore, Paul, & Sweet, 1993; Evans, 2011; Rao, 2012; Ginani, Vasconcelos, & Barboza, 2012; Azkue, 2013; Kakusho et al., 2002; Pierce, 1985; Watt, McDonald, & Watt, 1996). While administrators and faculty control the decisions made in conveying the explicit curricular component of medical education, they have limited access to student subcultures and student assumptions about how the institution truly functions. At times there is a disturbing discordance between what the explicit curriculum intends to teach and what students perceive they should learn.

The integrated nature of embryology is sometimes interpreted by faculty and students as a marginalization of the subject. Evidence supporting this was described earlier in chapter one and this chapter, citing the surveys by Gartner (2003) and Drake et al. (2002; 2009; 2014). It is unknown how faculty and students perceive and interpret the explicit curriculum relating to embryology, a gap in the literature about UME. This dissertation research strives to answer this question. Knowledge gaps also exist about embryology's place in the next curricular component, the implicit curriculum, even more so than for the explicit curriculum.

**Embryology's place in the implicit curriculum.** The implicit curriculum is also known as the hidden curriculum for its often veiled nature (Eisner, 1985). It encompasses curricular aspects not included in the explicit curriculum but learned informally by students as part of their school experience (Eisner, 1985). The implicit curriculum usually deals with attitudes, values, beliefs, and behavior, and consists of often subtle messages communicated by the school apart from its official or public statements (Hafferty & Castellani, 2009; Burton & McDonald, 2001). Some medical educators claim that the concepts that are most noticeable by their absence are those of the implicit curriculum (Burton & McDonald, 2001). In educational curriculum studies research it is largely accepted that "a great deal of what is taught – and most of what is learned – in medical school takes place not within formal course offerings but within medicine's 'hidden curriculum'" (Hafferty, 1998, p. 403). This component is not generally included in standard course materials or evaluations, despite the implications of its influence on teaching and learning, because its analysis is far from straightforward (Mossop, Dennick, Hammond, & Robbe, 2013). The majority of research investigating the implicit curriculum in medical schools relates to professionalism and professional socialization of student doctors, loss of idealism, emotional socialization and mental health, ethical integrity, power dynamics, or the concept of a worthy patient (Cribb & Bignold, 1999; Higashi, Tillack, Steinman, Johnston, & Harper, 2013; Michalec, 2011; Lempp & Seale, 2004).

One of the LCME's new accreditation standards frames the implicit curriculum, referred to as "learning environments," solely in terms of professionalism (Liaison Committee on Medical Education, 2015). Unfortunately for medical educators, this specificity limits the applicability of the trifold curricular components to the broader issues in medical training (Hafferty & Castellani, 2009; Liaison Committee on Medical Education, 2015). Additionally, the very act of the LCME framing the implicit curriculum solely in terms of professionalism places the concept of professionalism simultaneously in both the explicit and implicit curricula. This may assist in analysis or it may serve to further confound study of the three curricula in UME. It is only through careful and rigorous evaluation of the UME curriculum using the framework of the explicit, implicit, and null curricula that the overlaps between components will be evaluated. There have been several attempts to analyze the implicit curriculum within institutions, but without an established methodology, this has proven to be extremely difficult (Mossop et al., 2013).

Another area of overlap between the explicit, implicit, and null curricula is that it is common for embryology courses to teach human birth defects to solidify the content in students' future careers as healthcare providers (Marino, 2010; Carlson, 2002). Social responsibility, the duty of physicians to consider all aspects of patients' life and health, is another aspect of the embryology curriculum to be considered (Gilbert & Fausto-Sterling, 2003). This is mainly because of the importance of pertinent social topics such as abortion and reproductive health debates that are often not formally included in the UME curriculum (Gilbert & Fausto-Sterling, 2003). Anecdotally, when medical students ask about these issues in relation to the embryology content, they are often told to form their own opinions using their personal experiences and beliefs. No research is available regarding the affective experience of teaching and learning these aspects of embryology, the dearth of which may indicate something in and of itself about the curriculum and the need for further inquiry. If social topics relating to embryology are completely left out of the explicit curriculum and student questions are left unanswered, then this would no longer be considered an implicit curriculum. Instead, that situation would bring the researcher to examine the final component in the trifold framework, the null curriculum.

**Embryology's place in the null curriculum.** The null curriculum is what schools do not teach, whether on purpose or unintentionally (Flinders et al., 1986; Eisner, 1985). It is more difficult to identify and is known to involve rather ambiguous and at times controversial concepts. Eisner argues that "what is not taught may be as educationally significant as what is taught" (Flinders et al., 1986, p. 34; Eisner, 1985). A study by Lempp and Seale (2004) found the main themes in the null curriculum of medical education were personal encouragement, haphazard teaching, the importance of hierarchy, and getting ahead by being competitive. Haphazard teaching referred to class attendance and rescheduling of classes, which reflects upon the enthusiasm and the importance placed on those subjects or lessons by the faculty and institution. As the basic science educational side of medical school is still fairly separated from the clinical side of medical school, medical education has largely escaped from the public quality control rigors imposed on clinical practice post-graduation (Lempp & Seale, 2004). This means that certain lessons, courses (e.g,. embryology), and class activities may be pushed to the side with no acknowledgment or rectification of the problem. This apathy and lack of acknowledgment in conjunction with the survey data cited several times in this chapter regarding decreasing course hours and allocated resources, it may stand to reason that certain aspects of embryology are being removed from the explicit and implicit curricula and into the null curriculum, what UME does not teach despite the fact that knowledge of embryology is essential for the understanding of birth defects and a variety of diseases and growth processes clinically.

One final example of overlap between the curricular components is the white coat ceremony at the beginning of medical school. At this formal event, medical students are presented with their white clinical laboratory coats, a symbol of the profession, in a ceremony full of pomp, circumstance, and gravitas. The ceremony was originally expected to symbolize the students' sense of compassion and humility with an implicit and sometimes explicit curriculum, but sometimes instead conveys a social hierarchy and privilege via the implicit or even null curriculum (Murakami, Kawabata, & Maezawa, 2009). The white coat ceremony is usually described in the former terms and not the latter, though both aspects of the UME curriculum represent. This conflict of interpretation, even amongst experts, necessitates further understanding of the matter by asking the primary populations involved: faculty and medical students.

**Voices of the Medical Faculty and Students**

In medical education, the hierarchical levels of stakeholders are: individual student and educators (basic scientist or clinical instructor), departmental or faculty cohorts, medical school, university and teaching hospitals, provincial or state educational and health care systems (Fullan, 2007). When any one of these levels is working at cross-purposes to the rest, then change is likely to be extremely challenging or even fail (Fullan, 2007). Curriculum researchers largely agree that any attempt to significantly change an educational program must start with the educators and continue to hold them at the center (Bailey, 2000; Southerland, Sowell, Blanchard, & Granger, 2011). But the existing literature tends to focus on the level of curricular structure rather than planning. This is evidenced by the given descriptions of UME curricula being about courses, blocks and their relationships to one another, curricular design features, and content areas and themes. Wherein this description the voices of individual educators and basic scientists are lost (Wilkerson, Stevens, & Krasne, 2009).

Despite or perhaps due to faculty voices often being muted or missing from discussion regarding curricular reform, one challenge of implementation is resistance from faculty. They are generally accused of having negative attitudes and are unwilling, and when forced to integrate display “anxiety, antipathy, lack of cooperation, and general mistrust” (Muller et al., 2008; Schmidt, 1998; Sweeny, 1999). It has been noted there is considerable fragmentation and contradiction among the messages from course work, supervisory conferences, and classroom interactions with cooperating teachers; in other words, recommended practice of how to teach in the classroom is often completely at odds with observed practice (Clift & Brady, 2005). To this end, one must better understand the experiences of the educators and even the students involved who are at different points along the process of UME reform, to better anticipate and address tensions arising (Fullan, 2007). In fact, some medical education researchers say that lasting educational change depends on what teachers do and think, stating it is as simple and complex as that (Fullan, 2007).

The rich history of UME is complex, multi-faceted, and worthy of careful and rigorous study. In contemporary medical schools in the U.S. and Canada, curriculum reform and integration are theoretically constantly mobile in an attempt to meet the needs of society. The flux of knowledge base and pedagogical methods means that the courses and their contents are always changing or, in the case of embryology, decreasing. Conducting this type of research study entails investigating perceptions of the medical curriculum by faculty and medical students in relation to topics such as embryology. Hopkins and colleagues (2015) suggest that due to the complex and collaborative nature of educational reform,

> We suggest delving *beneath* the models of curricular structure that dominate current conversations, and developing an understanding of what those curricular changes mean to those who are asked to live them and carry them out. Focusing not only on what we are integrating but also on *who* we are integrating may be the key to moving beyond change without difference, and enacting change that is both successful and meaningful (p. 152).

The gradual decline in time and effort devoted to subjects like embryology must be thoroughly researched and the analysis placed into a commonly accepted curricular framework, so that medical educators, administrators, and policymakers are able to instigate UME reform with the appropriate and necessary facts with which to make these significant decisions.

This dissertation research addresses the call to action presented in the previous paragraph about embryology's place in the UME curriculum. The following chapter begins by describing the methodology of this research in detail. In order to pursue the collection and analysis of several forms of data pertaining to the experiences with and perceptions of embryology by faculty and students in UME, a mixed methods research design was utilized. Chapter three describes the rationale for using a mixed methods design and the blended approach of grounded theory and phenomenology. It continues with the research setting and context and explains the pilot studies performed prior to official data collection of this research. Then, chapter three describes the research sample and data collection in the two phases of the study, and concludes with the methods of data analysis along with the limitations and delimitations of this research.

# CHAPTER 3: METHODOLOGY

The central aim of this study was to summarize involvement with and perceptions of embryology experienced by faculty and first-year medical students within medical education in the United States and Canada. The research addressed the following questions:

1. What is the current status (e.g., placement, course hours, faculty cohort, content, materials, pedagogy) of embryology in medical education curricula as reported by faculty?
2. What experiences and perceptions do faculty and first-year medical students have in regards to the teaching and learning of embryology in medical education, including word associations, most interesting, and most confusing aspects of teaching or learning embryology?
3. What suggestions do faculty and first-year medical students have for the improvement of teaching and learning embryology in medical education?

The overall inquiry was subdivided into two components, focusing on a) individuals with experience teaching embryology and b) individuals currently learning embryology as first-year medical students. In this study, the scope of status includes curricular placement, content, pedagogical methods, and experiences by all involved. This research assessed patterns of the treatment of embryology in the medical curriculum's explicit, implicit, and null components, evaluated patterns and themes, and formulated evidence-based recommendations for improvement to the contemporary status of embryology in medical education.

Investigation of how embryology is approached in UME curricula currently will facilitate the formation of the best practices by way of evidence-based recommendations. Evidence-based medicine as seen in both academia and clinics is "the conscientious, explicit, and judicious use of current best evidence in making decisions" (Sackett et al., 1996, p. 71). Van Der Vleuten and colleagues (2000) claim that medical education should use data derived from this type of framework to determine best practices, just as is optimally done in any other professional area. The authors stated that being an effective educator of future physicians requires more than expert content knowledge, but also the familiarity, use, and formulation of educational evidence and theory.

The remainder of this chapter explains the methods of data collection and analysis. This study utilized a two-phase, sequential explanatory mixed methods research design that blended grounded theory and phenomenological approaches (Creswell, 2012; Starks & Trinidad, 2007). Grounded theory results in the generation of explanatory theories of the processes being studied, while phenomenology is finalized with a product that shows how participants make meaning of a lived experience. Both approaches will be described and compared in detail later in this chapter. The selection of these two approaches was based upon both logistics of the research schedule and the goal of answering the research questions by accurately portraying all facets of embryology in medical education. The blended approach combining grounded theory and phenomenological methodologies converges well during the last stages of data analysis. The resulting theories generated about the status of embryology from faculty and student experiences and the essence of faculty participant experiences complement one another, serving to enrich understanding of the explicit, implicit, and null curricula of embryology in medical education.

Data collection consisted of two phases conducted between October 2014 and October 2015. Phase one consisted of surveys with faculty and different surveys with first year medical students at medical schools in the United States and Canada. Phase two consisted of follow-up interviews with faculty who completed the survey and volunteered to take part in the secondary stage of research. More details on the methodology of the data collection will be explained later in this chapter. Participant safety and confidentiality rights were protected at all stages of the study, which was approved as exempt research by the Indiana University Institutional Review Board (#1303010942).

**Rationale for a Mixed Method Research Design**

The research focus of this study was to ascertain individuals' experiences with the teaching and learning of embryology in medical education. Many problems in medical education are complex and multifaceted, and research studies addressing these problems should give practical consideration to the multiple involved entities and causes, timing, short and long term effects, potential multiple locations (e.g., various clinics in addition to the institution), and a plethora of societal assumptions (O'Leary, 2005). Therefore, a medical education researcher's job is to supplement the current body of knowledge and to add illumination where needed in order to address the research problem. This may require collecting and analyzing the data with diverse, collaborative, or creative research methodologies.

There is an interactive continuum of research design that exists, with quantitative traditions on one end and qualitative traditions on the other end (Ridenour & Newman, 2008). This is not a dichotomous relationship, an important distinction which leads to the ability to combine these two research methods at some point in the middle of the spectrum and incorporate a "holistic conceptualization of research" in their practice (Ridenour & Newman, 2008, p. 9). The result, **mixed methods** research design, is the combination of at least one qualitative component and at least one quantitative element into a single research project (Brewer & Hunter, 1989; Bergman, 2008; Creswell & Plano Clark, 2011).

Conventionally in educational research, quantitative studies are useful to describe trends about a large number of subjects or artifacts, while qualitative studies have the ability to offer new perspectives and provide a more complex picture of the situation. Qualitative research has been used in medical education to elucidate answers to questions regarding complex conditions such as awareness of death affecting patient attitudes and the care delivered by healthcare providers or the connections between student metacognitive strategies and remediation trends in anatomical education (Glaser & Strauss, 1967; Schutte, 2013). Quantitative and qualitative approaches have very different sets of assumptions and paradigms shared by their respective proponents in the scientific community. But in an appropriately defined and deliberate combination, a dual quantitative and qualitative research design provides a greater breadth and depth to the understanding of the research problem and questions. The merging of these two methods and the resulting consideration of numerous research perspectives results in a more comprehensive view than either method could produce in solitary use (Creswell, 2012; Mayoh & Onwuegbuzie, 2013). Furthermore, when both quantitative and qualitative methods are used in the same study, they often lead to greater insights because the researcher is able to build on the strengths of each type (Creswell, 2012). Using a mixed methods research design can provide a more detailed understanding of the factors associated with embryology in medical education because it provides the opportunity to address different facets of the research questions and leads to a more comprehensive understanding of the phenomenon being investigated.

There are several reasons why a mixed methods research design may be preferred to the quantitative or qualitative research designs at either extreme of the interactive continuum. This combined methodology may be required by the research purpose if there is not enough information available in the background literature and thus there is a need for exploratory or explanatory research. The use of qualitative in addition to quantitative data collection and analysis, when implemented carefully and methodically, often illuminates aspects of the research questions that would otherwise be difficult to address (Kennedy & Lingard, 2006). The status of embryology within medical education, and particularly from the points of view of those currently teaching and learning the subject, has not been the subject of much inquiry. The most recent investigation related to this was the national survey of course directors by the American Association of Anatomists, which did not delve into perceptions or opinions but focused on course hours and allocation of resources in the anatomical sciences at medical schools (Drake et al., 2002; Drake et al., 2009; Drake et al., 2014).

Another reason to utilize a mixed method research design is that the resources available often govern what type of research is performed. If one has adequate time, funding, and access to the desired populations, then mixed methods research may be possible. In addition, the stakeholders interested in the research study may want detailed coverage in both the extent of (typically found via quantitative data) and nature of (typically found in qualitative data) the problem and the interaction between both practices (Andrew & Halcomb, 2009). One major benefit of using a mixed methods research design is the ability to perform **data triangulation**, the comparison of findings about the same research questions using different inquiry methods (Boet, Sharma, Goldman, & Reeves, 2012). Data triangulation is one way to increase the validity of a study, and will be discussed in greater detail near the end of this chapter.

The review of background literature, pilot studies, and quantitative data collection and analyses provided a general picture of the problem, but more data collection and analyses via qualitative methods was needed to refine the individual perceptions of embryology in medical education. The procedure used and shown in table 3.1 was two-phased and performed sequentially, in which quantitative and qualitative data collection was followed by a purely qualitative data collection, with the findings and analyses based upon an integration of both data sets (Andrew & Halcomb, 2009). Here, the first phase was distribution of national surveys and the second phase was follow-up interviews. This study assigned more weight to the qualitative data found in both the surveys and interviews than the quantitative data found only in the surveys because the latter was mainly demographics of participants and descriptions of curricula.

Table 3.1: Phases of data collection of this mixed methods research

| | **Data collection method** | **Type of data collected** |
|---|---|---|
| *Phase 1* | Surveys to faculty | Quantitative and Qualitative |
| | Surveys to first year medical students | Quantitative and Qualitative |
| | Interpretation of quantitative data from surveys<br>Interpretation of qualitative data from surveys | |
| *Phase 2* | Interviews with faculty | Qualitative |
| | Interpretation of qualitative data from surveys<br>Generation of a phenomenology regarding modern medical embryology education | |

The grounded theory and phenomenological methodologies used to evaluate the data were intended to result in detailed views of the individual experience of teaching or learning embryology in a medical school (Starks & Trinidad, 2007). The qualitative component of the surveys and the entirety of the follow-up interviews served to extend, elaborate on, and explain the quantitative foundations of this research (Creswell, 2012). The mixed method inquiry design includes the use of **induction**, the discovery of patterns; **deduction**, the testing of theories; and **abduction**, uncovering and relying on the best of a set of explanations for understanding one's results. The researcher must reformulate the research questions at the end of the study, since the research questions inform and drive the methodology. The inductive form of mixed methods research used in this study was intentionally theory-generating rather than theory-testing (Onwuegbuzie & Leech, 2005). The inductive form is appropriate in this research because there are no formal hypotheses being tested; the research questions focus on the generation of theories by finding patterns and themes related to embryology in UME.

**Types of descriptive research, including phenomenology and grounded theory**

**Descriptive research** is designed primarily to chronicle what exists in relation to the research questions. It describes specific characteristics of individuals, groups, situations, or events by summarizing the commonalities found in discrete observations and stating these in descriptions. Descriptive research is needed when there is nothing or very little known about the subject or phenomenon in question, as in embryology in UME (Fawcett & Downs, 1992). Descriptive research is different from other types of more traditional research, such as that of testing formal hypotheses, because with descriptive methods the impetus is to find out as much as possible about the subject(s) being studied rather than a focus on hypotheses (Kennedy & Lingard, 2006).

The **iterative** inquiry tradition in descriptive research involves seeking meaning and developing interpretive explanations through processes of continual feedback during data collection (Grbich, 2007; O'Leary, 2005). A series of data collections are repeated until the accumulated findings indicate that nothing new is likely to emerge, and the research question has been answered. Only after this point can thematic analyses occur (Grbich, 2007).

The types of descriptive research studies vary widely and encompass case studies, grounded theory, ethnographies, phenomenologies, and surveys (Fawcett & Downs, 1992). This research combined two of these methodologies, grounded theory and phenomenology, in an effort to both form a theory with which to form evidence-based educational and curricular recommendations and describe the first person experience of teaching embryology (O'Leary, 2005).

Health sciences educational researchers in 2013 described a specialized research design, **mixed methods phenomenological research (MMPR)**, that combines phenomenology with another method (either quantitative or qualitative) grounded in an a different paradigm, such as grounded theory, within a single study (Mayoh & Onwuegbuzie, 2012; Mayoh & Onwuegbuzie, 2013). The aim of this philosophy is to develop the subjective data "to describe or to interpret human experience as lived by the experiencer in a way that can be used as a source of qualitative evidence" (Mayoh & Onwuegbuzie, 2013, p. 92). The MMPR model used in part for the faculty participants in this research study was first quantitative and phenomenological, then qualitative and phenomenological in a concurrent approach. Normally, methods in MMPR have equal priority; however, it is possible to give priority to a single method depending on the overall thrust of the study. This research assigned more weight to the qualitative data than the quantitative data overall because the quantitative data was mainly demographics of participants and descriptions of curricula. Within this research design both grounded theory and phenomenological approaches yielded complementary data that served to cross-validate and confirm findings (Mayoh & Onwuegbuzie, 2013).

The MMPR with grounded theory approach was chosen because grounded theory will result in the generation of theory regarding embryology in medical education, and may be used to formulate evidence-based education practices within the current curriculum. The phenomenology aspect will produce an experiential narrative of the subjects' combined experience, focusing on the affective component and therefore illuminating aspects of the implicit and null curricula. Table 3.2 below compares and contrasts grounded theory and phenomenology. These two approaches are described in greater detail and in relation to this specific research in the following sections of this chapter.

Table 3.2: Comparison of the two types of descriptive research utilized

| **Characteristics of the descriptive research approach** | ***Grounded theory*** | ***Phenomenology*** |
|---|---|---|
| Method of qualitative data analysis | Yes | Yes |
| Uses codes to find patterns and themes in the data | Yes | Yes |
| Is heavily philosophical | No | Yes |
| Result is a theory in various forms (e.g., narrative, diagram) | Yes | No |
| Result is an essence of the phenomenon being studied in narrative form | No | Yes |

**Grounded theory.** Grounded theory is an inquiry method that looks systematically at primarily qualitative data, aiming at the generation of an argument that accounts for a pattern of behavior that is relevant and problematic for those involved (Artinian, Giske, & Cone, 2009; Grbich, 2007; Starks & Trinidad, 2007). Grounded theory allows the researcher to identify the main concern of a group of subjects and the behaviors used to resolve this main concern. This approach was developed by Glaser and Strauss in the 1960s in order to generate theory from observations in real life (Glaser & Strauss, 1967). It is useful when the microcosm of social interaction is the focus of the research question because it locates the phenomena of human experiences within the world of social interaction where reality is constructed and shifting (Glaser and Strauss, 1967; Glaser, 1994; Strauss & Corbin, 1998; Grbich, 2007; Corbin & Strauss, 2008). The aim of grounded theory is to generate theoretical constructs about a social phenomenon from the joint collection, coding, and analysis of qualitative data. Grounded theory is not intended to test or verify existing theory, but to generate a theory regarding the situation addressed in the research question (Kennedy & Lingard, 2006; Corbin & Strauss, 2008).

Grounded theory is used in this research because it connects theory generation with testing, links theory and practice, and links descriptions with understandings (Glaser & Strauss, 1967). Researchers then express this understanding in a theory named by a carefully chosen word or phrase that captures the subjects' experience. Often, the components of these theories are expressed as codes and subcodes (Grbich, 2007). Medical education research is seeing the benefits of this research approach, saying,

> The emphasis on pragmatic theory generation inherent in grounded theory research also has implications for medical education research. Recently, medical education researchers have called for an increase in programmatic research and in research that is based on relevant theory. In our opinion, grounded theory research is uniquely suited to form the basis of research programmes that arise from theory grounded in the medical education experience, and then build toward implementation of practical educational innovations (Grbich, 2007, p. 106).

The type of theory to be generated must be both analytic and sensitizing. An analytic construct is sufficiently generalized to identify characteristics of participants' experiences, not the participants themselves. Sensitizing constructs yield a purposeful picture, and enable the researcher and readers to grasp the reference in terms of one's subjective experience (Tavakol, Torabi, & Zeinaloo, 2006).

Researchers cannot avoid approaching the research questions with a set of disciplinary interests and background assumptions, but *a priori* hypotheses are not developed; the theory is grounded and developed from the data as it is collected and analyzed. Grounded theory is developed by constant comparison of incident with incident, and its main strength is the ability to move data from the descriptive level to the conceptual level (Glaser & Strauss, 1967; Grbich, 2007). This constant comparative analysis that is a major portion of grounded theory designs generates theory more systematically and accurately than one lump analysis (Strauss & Corbin, 1998; Mayoh & Onwuegbuzie, 2013). The other approach used in this blended method of research is phenomenology, described in the next section of this chapter.

**Phenomenology.** Phenomenology is the study of experiences as they present themselves in individuals' direct awareness, with an emphasis on understanding individuals' subjective perceptions and the effect of those perceptions on behavior. Rather than inspecting definitions or causes, phenomenology explores the lived experience of participants and attempts to describe this so well that the reader is able to imagine and share in the event (Starks & Trinidad, 2007; O'Leary, 2005). Phenomenology is a descriptive research approach that attempts to understand the hidden meanings and the essence of an experience or phenomenon (e.g., teaching embryology) together with how participants make sense of the experiences. ***Essences*** are objects that do not necessarily exist in time and space like facts do, but can be known through essential or imaginative intuition involving interaction between the researcher and respondents (Grbich, 2007). Husserl envisioned phenomenology as the science of the essence of consciousness, in which the focus is on first person experiences and the trait of intentionality, the direction of experiences towards things in the world (Husserl, 1913).

Phenomenology involves the researcher in intensive sampling of a small group and detailed exploration of particular life experiences over time, without preconceived expectations (Grbich, 2007; Starks & Trinidad, 2007). Phenomenology may use observations, interviews, and written documents to gain insight into subjects' life experiences. Phenomenological analyses assist in disclosing the researcher's hidden paradigms through its inherent reflective methods, and performing phenomenological research requires a paradigm shift because the researcher has to open a new window to see the world with new eyes (Boet et al., 2012). This descriptive research approach is used when the essence of peoples' experiences of a phenomenon are to be explored, described, communicated, and interpreted. Phenomena about which there are few in depth data are suitable areas of study because phenomenologies produce rich descriptive data about the lived experience, which can be beneficial to both the beginning of a study and to solidify results, as it was used in this research (Grbich, 2007; Starks & Trinidad, 2007).

There are two main forms of phenomenological research:  descriptive and interpretive. This phenomenological research is in the descriptive format because it focuses on the depiction of participants' individual experiences. Therefore, both the grounded theory and phenomenological approaches of this research are descriptive. Each lived experience, such as the teaching of embryology in medical education, has a descriptive emphasis, or features that define the phenomenon most generally and "by focusing on a specific lived experience in a number of variations, it is possible to identify insights that are common throughout experiences in order to emphasize the universal themes held within the lived experiences" (Boet et al., 2012, p. 94). The steps to take during a phenomenological approach are to first identify a phenomenon or object. Then, identify a recent experience of one's own of this phenomenon in terms of how it appeared to the individual. The research must then take certain features of this personal experience, form theoretical brackets around the individual experiences, and then delete these potential biases from the formation of the essence of the phenomenon being studied. The researcher must continue this process by deleting areas of participant bias until arriving at the essence or essential features of the experience shared by all the participants (Boet et al., 2012).

**Research Setting and Context**

This research involved medical schools across the United States and Canada, the institutions responsible for the basic sciences education of undergraduate medical students. The researcher in this study performed a **stakeholder analysis**, which involves identifying all of the individuals who can affect or will be affected by changed in the curriculum of a medical school. In the book *Researching Real-World Problems*, O'Leary (2005) said,

> It doesn't matter how legitimate your research findings and recommendations are if they're not meeting the needs of those facing the problems you have identified. Sustainable change is often dependent on making sure that what an expert deems as a problem is actually identified and prioritized as a problem by stakeholders themselves. In short, listening to, and identifying the needs of stakeholders is paramount (p. 26).

The stakeholder analysis part of this study estimated the number of individuals and organizations likely to be affected by any issues associated with embryology education. The first part of the stakeholder analysis involved identifying medical schools in the U.S. and Canada. The Association of American Medical Colleges (2016), American Association of Colleges of Osteopathic Medicine (2016), and American Medical Association (2016) listed 144 allopathic medical schools in the U.S., 31 osteopathic medical schools in the U.S., and 17 medical schools in Canada. Next, the researcher investigated whether the status and perception of embryology within medical education was seen as an issue by two of the identified stakeholder groups for this research, faculty and first-year medical students. It is important to note that even within a body of stakeholders who are proportionally very similar to each other in many ways, there still is the potential for a diversity of attitudes and opinions (O'Leary, 2005). While exploring the range of perspectives held by stakeholders, the researcher kept in mind not only the stakeholder's opinions but also the general impetus of medical schools to produce individuals with the foundational knowledge to obtain a medical degree and continue in their careers.

Prior to performing the dissertation research, pilot studies were conducted in two research settings with three different participant cohorts in order to assess the research methodology and refine the original instruments designed for this research (Cassidy, 2013; Cassidy, 2015). The following section provides an overview of the goals, procedure, and changes implemented to the dissertation research based upon the results and analyses of these pilot studies.

**Pilot Studies Prior to Dissertation Research**

The impetus for the pilot studies was as described in chapters one and two of this research: a decline in perceived emphasis of embryology in UME. The decision was made to undergo pilot studies in order to assess whether a full dissertation research study was necessary and possible regarding the challenges to embryology as seen from individuals being directly affected, as students. Three iterations of surveys related to medical student study approaches, attitudes, and beliefs regarding human embryology were performed before the formal data collection of this research. The goal for these pilot studies was to distribute the original survey instruments, a pre-course survey and a post-course survey, to first-year medical students in courses with embryological content and use the process to revise the instruments if needed. The last pilot study also included a focus group of first-year medical students to follow-up to the questions in the post-course survey. The locations of the pilot studies were the Indiana University School of Medicine-Bloomington (IUSM-B) and the University of Minnesota Medical School (UMN), and took place at IUSM-B in spring 2013 (n = 36) and spring 2014 (n = 40), and at UMN in fall 2013 (n = 36) (see table 3.3). The study was granted exempt status by the Indiana University Bloomington Institutional Board Review, # 1303010942, on the basis of voluntary participation, anonymity, and minimal risk to participants.

Table 3. 3: Locations and dates of pilot studies for this research

| Location | Date | Number of participants |
|---|---|---|
| Indiana University School of Medicine-Bloomington | Spring 2013 | 36 |
| University of Minnesota Medical School | Fall 2013 | 36 |
| Indiana University School of Medicine-Bloomington | Spring 2014 | 40 |
| Indiana University School of Medicine-Bloomington (focus group) | Spring 2014 | 6 |

For each pilot study, the researcher and the co-researcher at each institution distributed informed consent and a pre-course survey to the first-year medical students at the beginning of their studies regarding embryology for the semester, and a post-course study after the exam for the embryological content was complete. At the IUSM-B campus, this was done during the second semester of gross anatomy so students had already encountered embryological content in the fall semester. The surveys at IUSM-B were distributed surrounding the head and neck units of gross anatomy in the spring semester. At the UMN campus in the fall, students had not yet had embryological content. The focus groups (n = 6) were conducted at IUSM-B in the spring of 2014 after completion of the surveys.

The results of these pilot studies were analyzed and reported on in several settings in 2014. Most notably, the researcher was an active member of a graduate student learning community (GSLC) ran by the Indiana University Center for Innovative Teaching and Learning (CITL). As part of this group, members were able to conduct research in the scholarship of teaching and learning, present their raw data, analyses, and conclusions to the group in an informal and supporting setting, and receive feedback about their research design and future directions from like-minded individuals. The pilot study performed at IUSM-B in spring 2013 was the first iteration of the research and benefitted from this process. The surveys underwent minor revisions in the wording of questions for students before being administered to UMN participants in fall 2013, and more minor revisions before the final pilot study at IUSM-B in spring 2014. The researcher presented the IUSM-B spring 2013 student data and analyses as a poster presentation at the Human Anatomy and Physiology Society (HAPS) annual conference and the aggregate faculty data and analyses as a poster presentation at the American Association of Anatomists (AAA) annual conference, and received feedback and suggestions for improvement from fellow members through both formal and informal discussions (Cassidy, 2013; Cassidy, 2015)

These pilot studies provided one way to validate the original survey instruments, through three pilot studies at two different medical institutions and three different first-year medical student cohorts. Using the knowledge gained by these pilot studies and feedback from multiple sources, the researcher decided to make several changes and improvements to the research, as explained in table 3.4 below.

Table 3.4: Changes to the research based upon the pilot studies

| Change | Reasoning |
| --- | --- |
| Revisions to the survey questions to include more inquiry about institutions and to improve participant understanding of what was being asked in the surveys | Clarification of what was being asked, as well as adding the important data about the particular medical schools involved in this research |
| Expand the scope of the research to include faculty experiences and perceptions regarding embryology in UME using both surveys and individual interviews | Faculty typically have many more years of experience in the field of UME than medical students, and their experiences with and perceptions of embryology in UME needed to be heard in order for the research to include the relevant stakeholders |
| Expand the scope of the research to all medical schools in the U.S. and Canada | Since all medical institutions vary in many ways, as described in chapter one, it was essential to hear from as many regions and schools as possible in order to be able to reach saturation (described later in this chapter with desired sample sizes) |
| No longer include student focus groups in the dissertation research | Valuable data was collected and survey questions were indirectly revised due to the knowledge gleaned from the focus groups at IUSM-B. However, the researcher had to consider the logistics of performing focus groups with the medical student population spread across the U.S. and Canada. It was decided that continuation of focus groups was not feasible. |

The use of the above three pilot studies was invaluable in the continued development and improvement of this research, and data collection started in fall 2014 after data analysis and reflections about the pilot studies was complete. In the remainder of this chapter, the research sample and data sources will be explained as well as the phases of data collection, data analyses via grounded theory and phenomenology, and issues of trustworthiness, limitations, and delimitations of this research.

**Research Sample and Data Sources**

When the purpose of a study is to find solutions, researchers must work toward a result that reflects the needs, desires, and goals of relevant stakeholders by first assessing needs, and then strive for sustainable change by envisioning the future (O'Leary, 2005). After identifying the stakeholders and conducting several iterations of pilot studies, the two target populations were identified, recruitment began, and then data collection commenced. To that end, the two research samples in this study derive from two related expert populations: 1) faculty at medical schools in the U.S. and Canada and 2) first-year medical students at the same types of institutions. During the one year of data collection between October 2014 through October 2015, no medical schools in Canada responded, so from now on in this dissertation the research should be assumed to only include data from the U.S. This study describes and analyzes the phenomenon of embryology education in medical education from the perspectives of faculty and first-year medical students. Sampling for proportionality was not the primary concern, but rather gathering a rich set of data from which themes could be elucidated.

The procedure for recruitment started with the researcher compiling a list of approximately twenty-five personal contacts, faculty in anatomy departments and programs, at both allopathic and osteopathic medical schools. Calls for participants were sent out via several professional organizational electronic mailing lists and online forums, such as that of the American Association of Anatomists (AAA), Human Anatomy and Physiology Society (HAPS), and DR-ED, an electronic discussion group for medical educators sponsored by The Office of Medical Education Research and Development at the Michigan State University College of Human Medicine. Recipients of these calls for participants were encouraged to forward the information to any faculty in their departments or at other schools with experience in embryology within medical education. The sample size used for the analysis for the single faculty survey was 44 participants. The sample size for first-year medical students was 127 participants for the pre-survey and 143 participants for the post-survey. Enrollment in these online surveys will be open at least through 2020 so data will continue to be collected for a future longitudinal study.

The sample size desired for research using a partially qualitative analysis is typically smaller because the goal is for the sample to be large enough to obtain information for most or all perceptions regarding the research questions. Once **saturation** is reached (i.e., the point at which adding more participants would not result in additional perspectives), then the appropriate sample size for a partially qualitative study has been reached (Glaser & Strauss, 1967; Glaser, 1994; Strauss & Corbin, 1998; Corbin & Strauss, 2008). For grounded theory studies, Morse (1994) recommended between 30-50 participants, while Creswell (1998) preferred 20-30 participants. For phenomenological studies, Morse (1994) said that at least 6 participants should be used and Creswell (1998) recommended 5-25 participants. This research was completed with 34 faculty survey participants, 13 faculty who also consented to the interview portion of the study, and 114 students in each of the student surveys. However, there are no solid or specific rules for determining an ideal sample size in qualitative data collection. Oftentimes the sample is best determined by careful consideration of both the time and resources available to the researcher and the research purpose and questions (Morse, 1994).

This **purposive nonprobability expert sampling** targeted these two specific populations because the researcher desired to reach a set of individuals with known or demonstrable experience with and interest in either the teaching or the learning of embryology (O'Leary, 2005; Tavakol et al., 2006). *Purposive* (meaning 'on purpose,' ) *nonprobability* (meaning 'not random') *sampling* occurs when there is a target population already in mind. These study participants have a strong interest in the main topic of the study and have expert knowledge of the phenomenon under inquiry. *Expert sampling*, in which individuals with expertise in the area being studied are targeted as possible participants, was the best way to elicit their views and provides evidence for validity because the theory construction has experts to back the researcher (Artinian et al., 2009). From a grounded theory perspective, the population of participants was targeted purposefully for their ability to provide data that could confirm, challenge, or expand upon the researcher's theories regarding embryology. Recruitment continued until saturation was achieved (O'Leary, 2005).

The study was granted exempt status by the Indiana University Bloomington Institutional Board Review, #1303010942, on the basis of voluntary participation, anonymity, and minimal risk to participants. Detailed information regarding the purpose and procedures in the study was distributed at the time of recruitment via study information sheets, one specifically for faculty, and another for first year medical students. The surveys for faculty and two surveys for first-year medical students were developed by the researcher and distributed via SurveyMonkey, an online cloud-based survey development website (SurveyMonkey Inc., 2015). Potential faculty participants were sent an email with the links to the surveys via SurveyMonkey and the relevant study information sheets. Any individuals in possession of the link were able to access the surveys. The study information sheets were distributed electronically with the call for participants in 2014-2015 and then as an online document within the first page of the survey link in 2015.

**Data Collection**

In grounded theory, data collection takes an iterative approach in which cycles of data collection and analysis continually inform the next cycle of collection and analysis. The cycles allow analytical considerations to inform decisions for improvement of research schedules, recruitment, instruments, or even the entire data collection of the study. The cycles of data collection and analysis are a major source of the effectiveness of the grounded theory approach, that the researcher is continually able to refine, expand, and challenge the emerging theory. Overall, the objective of data collection in grounded theory is to obtain an appropriately broad range of perspectives and experience relevant to the research question (Glaser & Strauss, 1967; Glaser, 1994; Strauss & Corbin, 1998; Grbich, 2007; Corbin & Strauss, 2008; Kennedy & Lingard, 2006; Starks & Trinidad, 2007). In contrast, the phenomenological intention is to delve into the perspectives and experiences to extract the essence of the situations experienced by the participants. In this research, phase one consisted of separate surveys for faculty/instructors and for first year medical students with both quantitative and qualitative questions, while phase two consisted of follow-up interviews with faculty volunteers from the survey phase.

**Phase one: Surveys.** A survey is a method of data collection that asks a range of individuals the same questions related to their characteristics, attributes, experiences, or opinions (O'Leary, 2005). While one of the major benefits of survey research is that they are inexpensive and relatively convenient, it is challenging to design a survey that is valid, has careful and deliberate question phrasing, and whose impact advances the field (Boet et al., 2012). A high quality survey instrument "must be custom made to address a specific set of research goals" (Fowler, 1995, p. 78). Thus, the faculty survey and the first-year medical student pre- and post-surveys were all original instruments developed for this research. The researcher sought feedback and revised the surveys during the aforementioned graduate student learning community (GSLC) feedback process and the subsequent pilot studies with feedback from fellow GSLC participants and facilitators.

The faculty survey (See Appendix A: Faculty Survey) collected demographic data on both the faculty and their institutions; quantitative data on the faculty's confidence level when teaching embryology and opinions on the use of educational resources; and qualitative data about word associations with embryology, what faculty find most interesting and most confusing about embryology, as well as any suggestions for the improvement of the teaching and learning of embryology in medical education. The self-identified demographic data included: gender; whether participant was currently or had ever taught embryology; highest level and field of degree completed; current college or university affiliation and information about the type of institution, primary and secondary learner populations, anatomy curriculum format; years of experience teaching;

years of experience teaching embryology; all the anatomy courses the participant commonly teaches in an academic year; the reason for their assignment of teaching embryology; and any previous experiences with embryology.

Participants from the first-year medical student cohort were recruited by asking faculty to send the SurveyMonkey student survey link to their students. One of the limitations to this study is that medical schools often have self-imposed restrictions on the number of research studies they will make available to students, in order to not overload students with outside work that may distract them from their studies. The student surveys have two components: a pre-survey to be taken before starting the embryology course and a post-survey for once the embryology content is complete. The intention was to compare any change between the beginning and the end of the course. This approach, in which data is collected shortly before and after a learning opportunity, enables the researcher to detect changes resulting from an experience more accurately (Boet et al., 2012). Also, pairing and linking the two sets of survey data permits the use of more powerful statistical tests than in the case of unpaired data alone.

The first year medical student surveys (See Appendix B: Student Beginning of Course Student Survey & Appendix C: Student End of Course Student Survey) also collected demographic, quantitative, and qualitative data. First, students created a seven-digit identifier, suggested as their phone number without area code, so their two surveys could be linked after completion of their embryology course or course with an embryology component. In the beginning-of-course survey, the self-identified demographic data included: gender; current college or university affiliation and information about the type of institution; and any previous experiences with embryology. The quantitative medical student survey data collected included:

- the percentage of time that students predicted they would spend learning by themselves, with partners, or in a group;
- the resources they anticipated using to study for embryology; the clinical specialties (for medical students) or field (other students) in which they were most interested in pursuing; and
- twelve Likert type items that addressed the utility of the subject of embryology as it relates to gross anatomy education, modern medicine, and curricular format.

The qualitative medical student survey data included three components. First, the first-year medical student participants were asked to list ten words they associate with embryology, as the faculty survey did. Then there were two open-ended questions that asked participants to describe what they find most challenging or most confusing about embryology. The end-of-course medical student survey was intended to be used to compare the individuals' predicted study habits and opinions of embryology in medical education from the beginning to the end of their courses. This survey was therefore shorter, but collected the same information in the past tense. Students were asked to re-enter their seven digit identifier code in order to the surveys and the questions on the end-of-course survey mirrored that of the beginning-of-course survey with the questions written in the past tense. The exceptions to this were that the majority of the demographic data for both the individual and the institution were omitted since that did not change during the course of the study. Also, one final qualitative question was added to the student end-of-course survey, asking if they had any suggestions for how to improve the teaching and/or learning of human embryology at their particular institution. All data were analyzed, even if a student participant only completed one of the surveys.

**Phase two: Faculty interviews.** The goal of the individual interviews with volunteer faculty from the survey participants was to follow-up from the surveys and expand upon the explanation of trends seen in the survey data as well as to gain insight into individual opinions and perceptions. The researcher performed thirteen follow-up telephone interviews during the summer of 2015 with faculty who had previously completed the faculty survey and indicated a willingness in the survey to take part in a follow-up interview. Data collected from these interviews allowed the researcher to delve deeper and have meaningful conversations regarding personal experiences and perceptions about embryology that may not have been communicated in the survey data. The interviews were semi-structured, which means the researcher had a list of questions and an interview schedule to maintain focus of the interview, but allowed for some flexibility in the flow of conversation (O'Leary, 2005). The interviews were audio recorded on a personal, password protected device and transcribed in totality.

The thirteen faculty participants that volunteered to sit for the 30 to 60 minute telephone interviews responded to questions regarding their institution's general medical and specifically anatomical curriculum; departmental dynamics; typical day in the embryology classroom; rationale for content included; and importance placed upon embryology by their institution, department, and the medical profession as a whole. (See Appendix D: Faculty Interview Questions). Both surveys and interviews had the same goal: to analyze the experiences and perceptions of faculty and first-year medical students with embryology in medical education. Table 3.5, below, illustrates the types of data collected from both samples and the type of analysis performed on the data.

The following section of this chapter outlines and describes how the data was analyzed using a blended grounded theory and phenomenological approach in order to describe the explicit, implicit, and null curricular components of embryology in medical education.

Table 3.5: End products of data collected and the focus of analyses

| Type of data | Faculty | First year medical students | Type of analysis |
|---|---|---|---|
| *Quantitative (via surveys)* | • Demographics<br>• Institutional demographics<br>• Level of confidence<br>• Course resources information<br>• Likert items | • Demographics<br>• Course resources and study group information<br>• Likert items | Descriptive statistics |
| *Qualitative (via surveys)* | • Word association lists<br>• Open-ended questions | • Word association lists<br>• Open-ended questions | Grounded theory |
| *Qualitative (via faculty interviews)* | • Transcriptions | N/A | Phenomenological |

**Data Analysis**

Data collected via the surveys and interviews were integrated during data analysis, to remain true to the blended grounded theory and phenomenological approaches (Creswell, 2012). In this mixed methods research integrated analysis model, the researcher described, compared, and related ideas embedded in multiple data sources (i.e., surveys and interviews) or derived through multiple analytical strategies, and interprets these in the light of the data as a whole (Andrew & Halcomb, 2009). The quantitative data from the surveys was directly imported into and evaluated with the statistical software package IBM Statistical Package for the Social Sciences (SPSS) Statistics Version 23 (IBM Corp., 2013). The qualitative data from both surveys and interviews was examined first using grounded theory data analysis. The codes and theories generated from the grounded theory analysis were then examined using applied phenomenological data analysis to emerge with the essences of what it means to teach and learn embryology in modern medical education. These theories (from the grounded theory analysis) and essences (from the phenomenological analysis) were utilized in forming inferences about the explicit, implicit, and null curricula and finally, evidence-based recommendations for best practices for embryology in medical education.

**Quantitative data.** The researcher ran descriptive data analyses via SPSS to analyze by various measures of central tendency and variability for select questions, primarily demographics. The data was analyzed in its entirety (i.e., U.S. medical schools) for each sample (i.e., faculty or first-year medical students) and then described by using figures to demonstrate relationships. These figures and text explaining the analyses are in chapter five of this research.

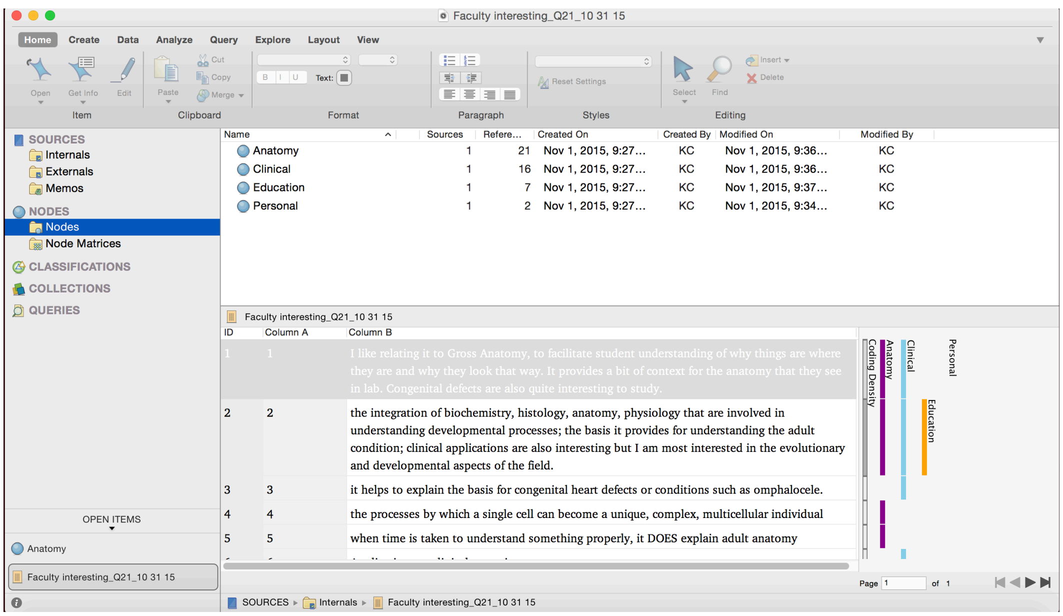
**Qualitative data.** Qualitative data from both surveys and interviews was evaluated with QSR International's NVivo 10 qualitative data analysis software (QSR International Pty. Ltd., 2014). When combining grounded theory and phenomenological approaches, there are distinct steps of the analysis process that must be taken into consideration to retain the richness of the data and emerging theory and essence (Glaser & Strauss, 1967). With both grounded theory and phenomenology, the researcher starts with data immersion which is placing oneself within the data and completely focusing on the data itself in order to become familiar with as many nuances as possible. Once the researcher is saturated with information and sources, then he or she is able to uncover raw themes and look at implications of those themes relative to the research questions and purpose (Boet et al., 2012). The figures and text explaining the analyses are in chapter six of this research.

The qualitative questions in the faculty and medical student surveys were treated separately from that of the interviews. For the list of ten words that come to mind when thinking about embryology, the researcher first coded all the words into positive, negative, or neutral (i.e., vocabulary) connotations. The word lists were then *quantitized*, which is when qualitative coding is converted into numerical form for statistical analysis, to form three distinct categories of positive, negative, and neutral connotations (Andrew & Halcomb, 2009). The open-ended survey questions were treated in the same way that the interviews were, by both grounded theory and phenomenological analyses.

**NVivo qualitative data analysis software**. The NVivo software package is designed for use when working with text-based or multimedia qualitative information, where deep and multiple levels of analysis are required. The capabilities of this software allow the researcher to “classify, sort, and arrange information; examine relationships in the data; and combine analysis with linking, shaping, searching, and modeling” (QSR International Pty. Ltd., 2014). After the data is organized, the software can be used to test theories, identify trends (as is being done in this research), and cross-examine information by using various engines and functions within the system. The use of NVivo in qualitative research makes clarifying observations and building evidence to support a case or project more efficient.

For the text-based qualitative data from both faculty and student surveys, as well as the faculty interviews, the capabilities of NVivo were utilized to import Microsoft Excel files or transcripts in portable document format (.pdf) that contained the relevant data from SurveyMonkey into NVivo. Figure 3.1 provides an example (via a screen capture) of an imported data file (bottom), the codes that were used to identify themes within the file (top), navigation panels and commands (left and top), and coding stripes (bottom right) which are colored bars that enable one to see the coding and attributes as one scrolls through a data source. The tools existing within NVivo enabled an efficient coding and subcoding process for the textual data, and an effective identification of the emerging themes and theories for a survey question or interview transcript.

Figure 3.1: Screen capture of qualitative survey data being coded using NVivo




**Grounded theory data analysis**. The central principle in grounded theory is constant comparison and assessment of data for similarities and differences (Glaser & Strauss, 1967; Kennedy & Lingard, 2006; Startks & Trinidad, 2007). Grounded theory is an emergent design because the theory unfolds in the course of the study as the researcher makes ongoing decisions reflecting what has already been learned (Tavakol et al., 2009). In this study, the researcher designed the faculty interview questions in order to be more easily understood and to enable expansion upon previous answers.

The steps of grounded theory data analysis are 1) identification, 2) coding (which in itself has several sublevels of analysis), and 3) theory generation (Kennedy & Lingard, 2006). The process of analyzing in a grounded theory manner is to first identify major themes. Major themes were developed in tandem with performing the phenomenological data analysis via block and file and conceptual mapping techniques. Next, coding following the ideographic mode of qualitative data analysis started to explore and define connections between categories. Finally, theoretical formulations produced an understanding or explanation of the phenomenon of teaching embryology in medical education. The corresponding codes were identified during the phenomenological data analysis (Kennedy & Lingard, 2006).

The development of the grounded theory codes for the data involved in this analysis required three sublevels of analysis:

level 1: initial code identification,
level 2: code collapsing (through comparison of initial codes), and
level 3: theoretical construct identification.

The researcher took the qualitative data from open-ended faculty and student survey answers and the interview transcriptions to be analyzed separately. In level one, the text was studied line by line, and words and phrases that all cited particular ideas were grouped and initial codes were identified. These were called substantive or *in vivo* codes because they codified the substance of the data and use participants' actual words. This level generated as many categories as possible and necessary in the data. In level two, the *in vivo* codes are collapsed by constant comparison to one another. This will result in broader categories of substantive codes that can be mutually exclusive. This mutual exclusivity is one major difference between this methodology and that of phenomenology as described later in this chapter. In the third and last level of grounded theory coding, theoretical constructs were identified by collapsing the level two codes even further to aid in identifying major constructs. This final level of coding adds a wider scope to the emerging theory, pulling it past the local meaning of the data and enabling discovery of the basic social psychological processes and emerging core variables (Takavol et al., 2009; Kennedy & Lingard, 2006). To summarize, from raw data come *in vivo* codes, then after collapsing the *in vivo* codes come categories of codes, which are then used to identify the major constructs of core variables in grounded theory. The core variables are then used to explain and generate the theories for the research.

A **core variable** has six features that must be present in order to generate a grounded theory. The core variable must repeat frequently in the data; link various data; be central and explain much of the variation in all the data collected; have implications for a more formal or general theory; become more detailed as the theory moves forward; and permit maximum variation and analyses (Takavol et al., 2009; Kennedy & Lingard, 2006). After these three levels of coding leads to the discovery of a core variable, the researcher is able to move to the third step of using the codes to identify the theoretical constructs of the data in the research. Only then can the research can be moved from the descriptive level of showing data and codes to the theoretical level of using those core variables to construct theories (Kennedy & Lingard, 2006).

This research utilized a blended approach of both grounded theory and phenomenology to produce theories about embryology in UME and the essence of what it means to actually teach embryology in the modern medical curriculum. The following section provides details on the phenomenological data analysis process and shows the connections between this approach and grounded theory as described in the previous section of this chapter.

**Phenomenological data analysis.** The four major steps of a phenomenological data analysis are bracketing (also known as intentionality), description, reduction, and essence (Boet et al., 2012). Each of these steps are defined and elaborated upon in the following paragraphs.

After data collection via faculty interviews, the first step in phenomenological data analysis is to explore commonalties and divergences in the experiences related to the phenomenon itself, here teaching embryology in medical education (O'Leary, 2005; Grbich, 2007). The student experience was not continued with interviews or focus groups, as was done in several of the pilot studies. This was because the faculty data revealed much richer and deeper themes than the student data, and both time and other practical constraints made performing interviews with the student sample prohibitive.

The researcher performs **bracketing** during phenomenological analysis, a uniquely phenomenological reflection, requiring one to undertake "to accept no beliefs involving objective experience and, therefore, also undertake to make not the slightest use of any conclusions derived from Objective experience" (Husserl, 1913, p. 3). To do this, the researcher places theoretical brackets around the objective world and focuses purely on the subjective experiences of the participants. This allows the essence, or the narrative of the lived experience, of the phenomenon to emerge and enables researchers to have the ability to see the structures and truths found in the data (Boet et al., 2012). This approach is very flexible and bracketing may occur to varying degrees depending on whether the essences are seen as harder to separate out from the human generated discourses with potential biases that form them (Grbich, 2007).

The second step in phenomenological analysis is to use **descriptions** to uncover the essence of the phenomenon being studied by identifying and breaking the phenomenon down into its different codes. Meaning lies in the identification of dominant themes within each code (Grbich, 2007). This step is similar to the steps of grounded theory wherein the researcher identifies and collapses *in vivo* codes. Both approaches necessitate immersion in the data and a conscious effort to find the connections between the textual data.

The third step of phenomenological analysis is **reduction**, the phenomenological form of content analysis. The content analysis is used to either sort data into *a priori* categories or into categories that emerge during the analysis. In this study, the content analysis is performed in the latter way since it is being done also with grounded theory. Content analysis may be done either by the block and file process, the conceptual mapping process, or a combination of the two, as was done with the data in this research (Boet et al., 2012; Grbich, 2007; Husserl, 1913). Performing a combination of these two methods of phenomenological analysis assists in data triangulation (Grbich, 2007).

In a **block and file** content analysis, the researcher underlines, italicizes, and color codes sections of text in the transcription. Then, similar segments are grouped together and placed in a table, with headings gradually emerging to categorize the contents. Text is allowed to occur in more than one column to avoid decontextualization. The advantage to block and file is that one can keep fairly large chunks of data intact but a disadvantage is that you end up with huge columns of data which can become unwieldy (Grbich, 2007).

**Conceptual mapping** was developed by Artinian (1977) and is performed by drawing a conceptual diagram of the relationships among the variables (Artinian, 1982a). Conceptual mapping is simpler and more flexible than block and file, but potentially more decontextualixing due to an oversimplication in the generated summaries (Grbich, 2007). After performing both block and file and conceptual mapping techniques, the data is in a form that can be written up by summarizing or representing the essence of the data in a narrative or case study format, which is the fourth step and final display of phenomenological research data analysis (Artinian et al., 2009).

The final step for phenomenological data analysis is **theoretical integration** and **theory formalization** in which the researcher writes the essence of the phenomenon being studied (Andrew & Halcomb, 2009). In this research, theory formalization combined the phenomenological and grounded theory analyses in the final steps of data analysis, articulating the theory grounded in research and the essence of a phenomenon. Here, the analysis was framed by the theoretical framework of the explicit, implicit, and null curricula in forming evidence-based recommendation for the UME curriculum in regards to embryology.

**Issues of Trustworthiness, Limitations, and Delimitations**

The methodology of any mixed methods research study must be consistent, systematic, and designed to account for research subjectivities. It is the responsibility of the researcher to recognize his or her personal bias and worldview, consider how this might affect the research process, and attempt to balance subjectivities to ensure the integrity of the theories and essences being produced. In order to be a self-reflective researcher, one should consider one's own views as they relate to the problem or situation and accept that others may not think or process the world in the same way (O'Leary, 2005). The acknowledgement must be made that within the process of phenomenological and grounded theory data analysis, both the researcher and the participants will construct meaning. But it is the responsibility of the researcher to minimize his or her impact on the setting and any possible overinterpretation of the situation in favor of highlighting the views of those researched (Grbich, 2007).

The quality of the study may be evaluated by looking at the inferences made and their transferability, the degree to which these conclusions may be applied to other specific settings, people, time periods, contexts (Bergman, 2008). In this study, the transferability will likely be low because the goal was to describe the current status and perceptions of embryology within medical education and not to form a theory that is generalizable to many other curricular situations.

Each data collection strategy has its own advantages and disadvantages. Surveys are relatively inexpensive to administer and offer moderate anonymity. There was no interviewer bias because the surveys were self-administered and reached a wider population than face-to-face data collection would have. However, the response rate was lower and there is no opportunity to clarify or address nonresponses. For interviews, the response rate was relatively higher and clarification of responses can be undertaken, but there is the potential for interviewer bias and interviews are relatively expensive to undertake (Andrew & Halcomb, 2009).

**Validity of data collection methods.** Validity, or credibility, is the extent to which a research conclusion is well-founded and generalizable to the real world (Fowler, 1995). Validity is the framework through which one can assess the scientific quality of a research design. To assess the validity of survey questions, there are four forms that may be used: studies of patterns of association; comparison of results from alternative forms of the same question; comparing answers to survey questions with information derived from other sources; and asking the same questions twice of the same respondents and comparing results, or asking the same question of more than one person then comparing the results (Fowler, 1995; Cronback & Meehl, 1955). Technically these last two steps are truly measures of reliability, but unreliable questions also have low validity (Fowler, 1995). The latter three methods of assessing survey validity were used in this research, when similar questions to the open-ended faculty survey questions were asked during the interviews and when students completed both the BSC and ECS surveys about embryology. When surveys are measuring subjective phenomena, the evidence for how well measurement has occurred must be somewhat indirect, and this is called construct validity (Cronback & Meehl, 1955).

Another measure of validity is that prior to embarking upon this research, the researcher was an associate instructor in gross anatomy and embryology courses at two different medical schools. In this role, the researcher was able to gather informal anecdotal data from students that informed the survey development. Also, conversations with the faculty of these courses assisted in developing portions of the survey and the faculty interview questions. The gross anatomy and embryology course director at one of the institutions also reviewed the survey prior to data collection and provided feedback that helped to form the final version of the faculty survey instrument. Another process used to test the validity and reliability of the codebook used while performing the grounded theory analysis was constant comparison between the faculty and student data. The codebook for each question in the qualitative portions of this research was comprised of codes and subcodes that were very similar for both faculty and students (for details see chapters five and six).

One of the major benefits of the mixed methods research design is the opportunity for cross-validation via data triangulation (Bergman, 2008). Triangulation is checking the validity of an interpretation based on a single data source by recourse to at least one other source of a strategically different type, such as the surveys and then the interviews of multiple participants. Including data triangulation in a study can decrease the chance of reaching weak or false conclusions, but it must be noted that data triangulation techniques are investigative strategies that offer evidence, and do not provide guaranteed truth or completeness (Artinian et al., 2009). The researcher is simply able to employ more than one source of data, in order that the insights gained from different perspectives will add to the richness of the understanding of the phenomenon under study (Kennedy & Lingard, 2006).

**Reliability of data collection methods.** Reliability, or dependability, is the overall consistency of a measure or the ability to produce similar results under consistent conditions. It is found when thematic categories are constantly verified while forming a theory, and new data or changing conditions require modification of the thematic categories as research continues. Confirmability is found when conceptualization and not description is the goal, and when conceptual patterns stand on their own new data extend and modify the theory (Andrew & Halcomb, 2009). For the qualitative portion of the study, reliability is usually not a major concern. For the quantitative portion, there may be biases of selection, sampling, and randomization. These potential issues include the *Halo effect,* when the researchers put every participant into one category, while the *Hawthorne effect* happens when the researcher's presence influences the interviews or even the surveys (Artinian et al, 2009). Both the Halo and Hawthorne effects have the potential to skew the reliability of a study. This research demonstrated reliability in the measures within both samples, faculty and first-year medical students, because clear patterns and themes emerged during the data analysis. Since some of the data collection was in the form of individual interviews, the Hawthorne effect may play a role in this research. However, the richness of the data gathered in conducting faculty interviews outweighs the potential Hawthorne effect in this research.

**Limitations.** Some of the limitations in this study relate to the methods of sampling and recruitment, and attribution of change in first year medical students' pre- and post-surveys. This research study performed nonprobability sampling on a voluntary basis, in which a specific group was targeted and participants were volunteers, so the sample may not be representative of the population. Nonprobability sampling can overweight subgroups in the population that are more readily accessible and subscribe to the professional organization electronic mailing lists through which the surveys were advertised. Some medical schools, for various reasons, don't allow or limit the number of surveys forwarded to their medical students. Despite using a pre-course and post-course survey for the medical students, this part of the study is still limited in providing a rigorous understanding of any change because the researcher cannot state accurately whether the change was attributable to learning the embryological content or other influences. One also cannot ascertain whether positive or negative change is sustained over time (Boet et al., 2012). See Chapter six for details on this aspect of the student surveys.

**Delimitations.** Delimitations are conditions or parameters that the researcher intentionally imposes in order to limit the scope of a study (e.g., using participants of certain groups; conducting the research in a single setting). In this research, the delimitations include: limiting data collection to one year, limiting the faculty sample to those who are currently or have taught embryology, and limiting the student sample to first-year medical students enrolled in a course with embryology content at the time of participation. These were chosen because the scope of the study was modern medical education in the U.S. and Canada, and therefore the individuals who are directly involved in this environment (i.e., faculty and students) and have the most direct experiences with and perspectives pertaining to embryology were the ideal participants. Although the data collection reported in this research was restricted to one year, the online surveys remain open to participants. In the six months after data collection for this dissertation research ended, the faculty participants rose to over 80 and the student participants to almost 200. The surveys will remain open until at least the year 2020 and data will continue to be collected for a longitudinal study about embryology in the UME curriculum.

## Summary of the Methodology Used in this Research

The two-phase sequential explanatory mixed methods research design, with a blended grounded theory and phenomenology approach, of this study explored experiences with and perceptions of embryology by faculty and first-year medical students within medical education in the United States and Canada. It addressed the overarching research questions regarding the present status of embryology in medical education by surveying faculty and first-year medical students in phase one, then using follow-up interviews with faculty in phase two to triangulate some of the data obtained in the first phase.

The purpose of this research was twofold: to assess patterns of the treatment of embryology in the medical curriculum's explicit, implicit, and null components, and to formulate evidence-based recommendations to improve the status of embryology in medical education. Data analysis was driven by both grounded theory and phenomenological approaches, and proceeded through multiple levels of description, coding, and reduction to arrive at the two final products: theories generated about the status of embryology in medical education and narratives about the essence of the experience of teaching and learning embryology. These results were then applied to the theoretical framework of the explicit, implicit, and null curricula to complete the scholarly view of this subject.

The next chapter in this research deviates from the traditional research report format. Chapter four is a reflective section that describes the design and implementation by the researcher of a premedical, bachelor's degree-level, undergraduate human embryology course, MSCI M300: Topics in Medical Sciences: "Human Embryology." This chapter is written in a first-person narrative format to facilitate communication of the researcher's thought process while designing the course. Chapters five and six of this research return to the traditional reporting format and both contain the findings and analyses for the research introduced in chapters one and two and described in greater detail in this chapter three. Chapter five will include the faculty survey and interview data findings and analyses, while chapter six will provide the student survey data findings and analyses. Within chapter six, at each major section where comparison with the faculty data is appropriate, there will be a subsection to discuss the similarities, differences, and importance of major theories between the faculty and first-year medical student participants.

# CHAPTER 4: DEVELOPMENT OF A PREMEDICAL UNDERGRADUATE EMBRYOLOGY COURSE

Medical students come from varied educational backgrounds, but even those experienced in the biological sciences often do not acquire many educational or research experiences related to the subject of human embryology. After matriculating to undergraduate medical education, these first-year medical students are often shocked by the complexity and lack of perceived relevance of this topic to their studies and continued academic successes. After observing these concerns at two different medical schools, the idea arose that there may be enough interest from the undergraduate pre-medical student population to offer an embryology course through the Medical Sciences minor field of study at Indiana University School of Medicine in Bloomington.

I developed, proposed, and have taught for the past three fall semesters an upper-level undergraduate course about human embryology. This process was started by a course proposal in the fall semester of 2012, and the course was taught for the past three fall semesters in 2013, 2014, and 2015. The course MSCI M300, "Topics in Medical Sciences: Human Embryology," (hereafter referred to as MSCI M300) was worth three credits and counted toward the medical sciences minor degree. It focused on development from an organ-based and not molecular viewpoint.

This chapter describes several aspects of the development and implementation of this course. This chapter will be written in the first person narrative format, as it functions partially as a description of the course MSCI M300 and partially as a reflective piece on the experience of course development. First, I will explain the background and need for the course as well as my expectations as the instructor. Then I will describe the development of the course using backward course design and provide an overview of the course goals. This chapter concludes with reflections on the lessons learned and future directions with undergraduate premedical embryology coursework.

**Medical Student Struggles with Embryology Led to Development of a Premedical Preparatory Embryology Course**

I have attended two medical schools, one allopathic and one osteopathic, as a graduate student in the anatomical sciences in pursuit of my master's and doctorate degrees. During my time at each institution, I heard both faculty and medical students complain about the subject of embryology. Their objections ranged from the difficulty of the material, to the lack of perceived relevance seen in relation to medical practice, to the dearth of quality resources for teaching and learning the subject matter. I willingly admit that when I was first introduced to the topic of embryology, I shared these concerns. Why should I devote time and effort to learning this material, when it was clear that even some of my instructors did not find it particularly useful or relevant to graduate or medical student studies? So I enrolled in a required course for my master's program, human embryology, in the summer of 2010 and found the small class size much more conducive to my learning than the lecture hall of hundreds of students. I began to see the relevance of embryology to learning gross anatomy, and came to appreciate the complexity of the processes that must occur in order for the human body to correctly develop. I also admit that I took pride in excelling in a mode of coursework deemed extremely difficult by many who cross its path, and was thereafter a proponent of this anatomical subdiscipline.

Fast-forward three years later to the middle of my doctorate program, while discussing degree progression with my advisor. We began a conversation about the difficulties that medical students have learning embryology in UME, and how it is unfortunate that more students do not enter medical school with at least the basic background of vocabulary and the conceptual framework of development. The need for a shift in the negative medical student paradigm regarding embryology was obvious to us both. And so I began to design an undergraduate course that would provide this background knowledge to premedical undergraduate students at Indiana University. I was to design a syllabus, write a course proposal, and submit the materials to the Medical Sciences Undergraduate Education Committee. They would convene and discuss my proposal at a meeting with me present to answer any questions, provide feedback, and if the course was approved, then I would teach it the following year. In the next six months this process was completed and the course was on the books for fall of 2013. See Appendix E:  MSCI M300 Course Proposal for a summary of the course proposal document.

**Embryology is not a medical school prerequisite.** Currently, embryology is not a prerequisite for entrance into medical school, but neither is undergraduate anatomy or physiology. The assumption is that students will learn what they need to know to be physicians when they are in medical school. But I argue that entering the stressful atmosphere of medical education would be easier if students had a basic understanding of challenging topics like embryology. This course focuses on development from an organ-based and not molecular viewpoint. One reason is because I am not a geneticist nor a molecular biologist, but a classically trained anatomist. The other is that there was simply not enough time in the semester to teach and learn both organ systems-based embryology and developmental biology.

Anecdotally through conversations at anatomy education conferences, the incidence of any undergraduate institution having a human organ systems-based embryology course to offer its undergraduate students is minor. An organ systems-based embryology course focused on the gross anatomical structures is not the same as a developmental biology course that teaches about the molecular basis of development. Many institutions offer developmental biology courses; very few offer courses that explain the development of the human organism primarily from the gross anatomy perspective. Also, most medical school embryology coursework focuses more on the development of organs and organ systems, rather than in the molecular underpinnings of the embryology itself. The signaling pathways and molecules typically are covered in other courses in medical school, such as biochemistry. One caveat to this course being approved at Indiana University was that it would not overlap too much with existing courses from other departments. As the Biology Department already had a developmental biology course (that focuses primarily on the molecular underpinnings of embryology), this meant that MSCI M300 needed to have a different, although compatible, course focus. Therefore, the course I developed would therefore be a fairly unique case, one that could be a testament to the potential benefits to be gleaned from offering premedical students the chance to become acquainted with embryology content earlier and take some of the stresses off the basic science curriculum years.

**MSCI M300 Course Expectations**

Prior to teaching the course, I thought premedical undergraduate students should learn an overview of the embryonic and fetal development of every major body system as well as the circulation between the mother and the embryo or fetus. I was unsure if that quantity of content was a practical expectation, but thought that the caliber of student expected to enroll in the course could handle this workload. When teaching embryology to undergraduate students versus medical students, table 4.1 below illustrates the differences that I thought would be encountered. The maturity of the prospective students, predicted to be lower than that of the typical medical student, was also a consideration when designing MSCI M300. I avoided placing content into the explicit curriculum that contained potentially contentious political or social nuances outside of the scope of learning embryological content, but included the medical facts about topics such as abortion or fetal screening so that students could enter conversations outside of the course with peer-reviewed and scientifically accurate knowledge.

Table 4.1: Predictions of student population differences when learning embryology

| **Undergraduate students want to…** | **Medical students want to…** |
|---|---|
| Study every body system | Study only the clinically relevant body systems |
| Learn about the most common congenital anatomic anomalies | Learn about all potential congenital anatomic anomalies |
| Learn interesting facts about development of the human body, but not the fine details of many things | Learn about surgeries and the social or ethical aspects of embryology (e.g., abortion, fetal screening) |

Since I have enrolled and excelled in a graduate/medical level embryology course, I assumed that the teaching of embryology would have to be slightly altered when teaching to undergraduates versus medical students. In addition to the observations in the table above, for medical students the focus is usually on clinical applications such as birth defects, but I did feel that it would be slightly different with the undergraduates. I assumed that students would want to learn the vocabulary and processes, and the clinical aspects would serve to make the course more interesting. The undergraduate students were not necessarily going to be patient-centered, although I assumed the majority of my students would be pre-healthcare, with many nursing and some premedical students because these are the students who typically enroll in courses for the medical sciences minor.

MSCI M300 did count towards the Indiana University medical sciences minor. The basic human anatomy course, Anatomy A215, was a course prerequisite, or students could directly contact me and state their case to be allowed to enroll in the course. Each year I did allow a few students into the course without having taken the A215 prerequisite because they had taken other anatomy coursework at different institutions or even an upper-level anatomy course at their high school. Conversely, the A215 course was not required for premedical students or biology majors, and so this prerequisite unintentionally excluded some individuals who may otherwise have taken the course.

The designation of the previously existing M300 course number was used so that the course could be tested that year – a process that has been used for other trial courses. So the listing of the course in this fashion does not imply that the course will be on the books once I graduate, although it is possible for another graduate student or faculty to offer a human embryology course again. This was my first experience as a course developer and instructor of record. It was also the first time an upper-level, content heavy course was proposed, developed, and implemented by a graduate student in my doctoral program, Anatomy (Education track) at Indiana University.

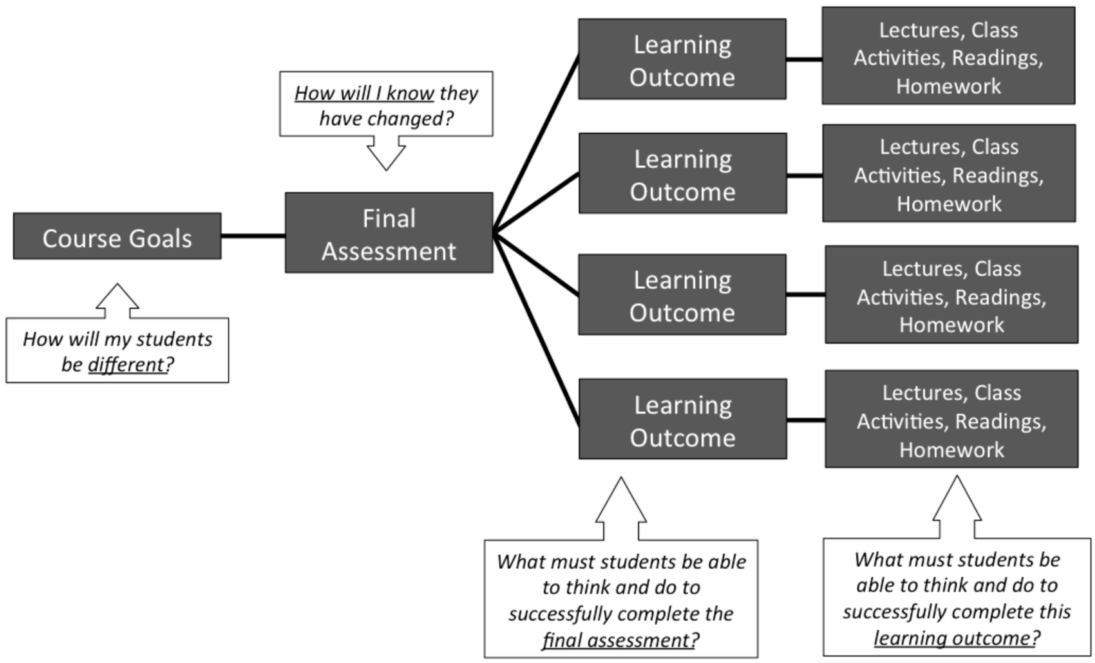
**Development of MSCI M300: Human Embryology**

Once this course was approved by the Indiana University Medical Sciences Undergraduate Education Committee, it was suggested that I apply to take part in the Course Development Institute (CDI) co-facilitated by the Center for Innovative Teaching and Learning (CITL) and Instructional Consulting at the Kelley School of Business. Although I had already enrolled in several graduate level pedagogy courses from which I had learned how to implement effective pedagogical methods and classroom control. This week long, intensive program uses backward course design to develop and revise courses at the institution. I applied and was accepted, and took part in the summer of 2013 to improve my course syllabus and curriculum. The original plan when designing MSCI M300 was to select a textbook, start to formulate PowerPoint lectures, and design engaging in-class activities for the students to assist in understanding difficult embryology concepts. I soon found that the CDI had a very different approach in mind.

**Backward course design.** The CDI has been offered for several years on the Bloomington campus, and is open to instructors of any rank from any discipline or department. The goal of the CDI is to provide a multiday, interactive forum with instructional consultants and colleagues to develop or redesign a course using the specific method of backward course design. Backward course design identifies desired results and determines acceptable evidence, then builds classroom learning experiences and instruction upon that framework. The strategy of backward course design is described by Grant Wiggins and Jay McTighe in *Understanding By Design* (2005). It is a framework used for designing parts of a curriculum that intend to lead students to a deep understanding of the content. Backward course design focuses on the goals of the course rather than specific lesson plans, and requires the instructor to keep a continual self-awareness about both the content of the course and the methods used. In backward course design, the course developer structures student learning based upon assessments that are intentionally designed to provide evidence that students have achieved course goals.

There are four steps shown in figure 4.1:  to identify desired results, determine acceptable evidence, write specific learning outcomes, and lastly to plan learning experiences (Wiggins & McTighe, 2005; Fink, 2003).

Figure 4.1. Four steps of backward course design




(Indiana University Center for Innovative Teaching and Learning, 2015; Wiggins & McTighe, 2005)

During the CDI, my assumptions of what it meant to design a course were challenged and restructured into a more realistic and authentic learning experience for students. The following sections detail the development of M300 using backward course design.

***Step 1:  Identify desired results.*** The first step in backward course design is to identify and clearly articulate the desired results of the course, in the form of course goals (Wiggins & McTighe, 2005). The instructor begins by asking themselves:  What do I want my students to be able to think and do by the end of this course? How do I want my students to be different by the end of the course? These course goals should be measurable and meaningful in the context of the field of study. I used principles from Bloom's taxonomy to structure and scaffold my course goals. For my human embryology course, I decided that by the end of the course, students will be able to:

1. Recognize and define the embryology vocabulary necessary to communicate effectively in this field
2. Explain the three-dimensional development of the embryo/fetus, and the relationships of structures to one another throughout development
3. Interpret and find patterns in the simultaneous, codependent nature of human development
4. Analyze the origins and effects of incorrect development to adult anatomy
5. Monitor and explain their study approaches, attitudes, and beliefs regarding embryology

The course goals are from the most recent iteration of the course, from fall of 2015. However, the goals from fall of 2013 and fall of 2014 were identical to those seen here.

***Step 2: Determine acceptable evidence.*** The second step is to determine acceptable evidence that students have achieved the course goals, often in the form of a final assessment or assignment (Wiggins & McTighe, 2005). For curricula that focus predominantly on content knowledge this can be a challenging step. In the medical and biological sciences, it often helps to look at students' career goals. For example, a physician's primary objective is to diagnose and care for patients. These individuals need to understand the content of the course and also be able to communicate this information effectively and compassionately to patients. A final assignment that includes both of these essential aspects of patient care is one option for instructors.

The vast majority of M300 students intended to enter the healthcare professions. The thinking valued in M300 was a firm grasp of embryological concepts and human birth defects. Therefore, the final assignment was to complete a research project on a human birth defect of their choice. Students were to write the text as if they were a healthcare professional delivering a diagnosis to the expectant parent(s) of the affected individual. Formats in the first year varied between clinical notes, conversation transcripts, informational brochures, governmental information packets, and letters to the hypothetical families. In the second and third years of the course, I required these to be written in the dialogue format. This made the exercise more authentic and brought up more conversations about the blended dichotomy of scientific clarity and clinical compassion. Also included in the assignment was the drawing of at least two original images related to the embryological basis of the human birth defect. See Appendix G: MSCI M300 Research Project Materials for the assignment information sheet and simple rubric for this project.

***Steps 3 and 4: Write learning outcomes and plan learning experiences.*** The final step in backward course design is to plan learning experiences (lectures, activities, homework) based upon the above framework (Wiggins & McTighe, 2005). Instructors should identify what students will need to be able to think and do in order to successfully complete the final assignment. Course content is not chosen by only tradition or convention, but because it has a meaningful role in the achievement of course goals. It was asserted that the goal of the course is to somehow change students' minds and the content is merely the vehicle for doing that.

The nature of human embryology requires organization of both chronological and spatial factors. To accomplish the course goals in an effective and efficient manner as well as cover the appropriate content, in the three years there were either 3 (2013, 2014) or 4 (2015) exams and either 10 (2013, 2014) or daily (2015) quizzes throughout the semester in addition to the final assignment. Learning experiences in M300 included: lectures, team-based and problem-based learning exercises, viewing adult cadaveric donor anatomy, scholarly journal article analyses, and many active learning exercises performed both individually and as a class.

### MSCI M300 Instructor Goals

My overall personal and implicit curriculum goals for MSCI M300 were:

- To provide a solid foundation in embryology to those advancing to professional and terminal degrees. The course student demographics reflected the expected student population, and a possible longitudinal study of past M300 students will further analyze the utility of embryology in their careers after the course was complete.
- To demonstrate relevance of embryology to students' future careers, as relevance often leads to retention. The aforementioned longitudinal study would also assess the presence or absence of embryology (and to what degree) in students' current educational or career states.
- To develop communication skills and empathy in a hypothetical clinical setting. The birth defect research project was a direct link to this goal, to bring in higher order thinking regarding the course content, their topic of interest, and clinical empathy and discussion with patients. It was an authentic exercise, and one that resonated strongly with several students who confided that they chose their topics because a close family member or friend had the birth defect they studied.

**Clinical aspects of M300.** It is difficult for students to understand the etiology of a congenital anatomic anomaly unless they already know the normal and healthy embryological processes associated with the tissues or organs. MSCI M300 met for 50 minutes three times per week for the entire semester. For the organ systems covered in the course I provided lectures and conducted in-class (often hands-on) activities on the normal embryology. Then one entire class period was devoted to "what can go wrong," the clinical correlations of that system. These class periods, of which there were approximately eight, were structured as small group exercises, in which I presented a short case, student conferred with their peers in small groups, and then I chose students randomly out of the groups to explain the etiology, signs and symptoms, or predict the prognosis of the case. This was the students' chance to act like a healthcare professional and make diagnoses and predictions in a low stakes environment while testing their knowledge of normal embryological development.

**My curricular studies knowledge informed MSCI M300 course development.** In the context of curricular studies, I kept the three facets of the explicit, implicit, and null curricula in mind while developing and revising this course for the past three years. I made it very clear to students what my expectations were in the explicit curriculum via detailed assignment sheets, rubrics, and the syllabus. I told students that in MSCI M300 more time is devoted to the organ systems that are seen more commonly with pathologies in the clinic.

The implicit curriculum was present in the course when discussing congenital anatomic anomalies and social issues such as abortion and fetal screening. I prided myself on the fact that my students told me after the course was over that they had no idea what my personal opinions on those types of issues were because the topics were discussed in a nonbiased, nonjudgmental, and scientific way. This environment of scientific understanding mixed with the knowledge of social issues assures the students that the MSCI M300 classroom is a place where they can come to find out the facts behind topics that, outside of the classroom, often involve much emotion or even politicization.

**MSCI M300 content has undergone constant revision.** The question of what and how much content to include in the course was a constant consideration. I wanted the students to be able to describe why adult morphology appears the way that it does, and to explain what can happen if a process goes incorrectly. The first two years I included almost every organ system and spent as much time as I needed to finish the explanations. In 2015, I focused more on what I had heard from medical school faculty, and only maintained the organ systems and tissues that are more commonly seen with human birth defects in the clinic. This meant that cardiovascular, digestive, and urogenital systems saw more coverage time than any other system or body region. See Appendix F: MSCI M300 Syllabus to see the 2015 syllabus for this course.

I collected survey data extremely similar to that found in this dissertation research from each year that I taught MSCI M300. From the 21, 17, and 13 students (in 2013, 2014, and 2015, respectively) I collected data regarding:

- Demographics
- Why they enrolled in MSCI M300
- Career aspirations
- Experience with and perceptions of embryology, as seen in the dissertation student surveys

**Lessons Learned and Future Directions**

The experience of designing and independently teaching my own upper-level course as a graduate student was invaluable for my academic and professional development. But education is a dynamic field, and with progression of scientific research into embryology and developmental biology there always comes new content to learn. The following two sections provide reflections on teaching another embryology course and how teaching MSCI M300 influenced my dissertation research and vice versa.

**Teaching another embryology course.** After graduation and conferment of my doctoral degree, I may teach at an institution that does not have an undergraduate population. The basic principles of teaching an embryology course that I have learned through the last three years will not change much if I am teaching a new population of graduate students. If given the freedom to do so, I will continue to structure the clinical correlations after the normal embryological development content is done, and will include the memory matrices and other useful in-class activities to learn difficult embryological concepts. I will search further for more online embryology animations, and if I procured the financial and departmental support I would consider starting to develop a line of new embryology animations that are computer generated, convey three-dimensionality, and enable the viewer to move through time in an interactive format.

**How teaching MSCI M300 informed my dissertation research and vice versa.** I was beginning my dissertation literature review at the same time as I was first designing this course. It is difficult to separate the two experiences, as they are both firmly entrenched in the curriculum and pedagogical aspects of embryology in higher education. In the dissertation research, I functioned as a survey and interview conductor making observations and analyzing the current perceptions of embryology in the field; in MSCI M300, I was an instructor making activities and finding resources for students to learn the embryology material. Many aspects of teaching embryology that I learned from the faculty surveys and interviews I utilized while teaching MSCI M300. I also read the medical student surveys and continued to slightly revised aspects of M300 based upon the student perspectives. As I near the conclusion of teaching MSCI M300 at Indiana University and this dissertation research, I find that untangling the two experiences is not only basically impossible but also inadvisable. For the lessons I have learned and the knowledge and skills I have gained benefitted both research and teaching aspects of my graduate student experience.

# CHAPTER 5: EMBRYOLOGY FACULTY SURVEY AND INTERVIEW FINDINGS AND ANALYSES

When close examination of a multi-faceted aspect of medical education is the target of a research project, there is no substitute for going straight to those experiencing the situation being studied, here the status of embryology in medical education. Since there is little information regarding how and why the hours and resources devoted to embryology is decreasing in the U.S. and Canada, discussion was initiated with the stakeholders that are most directly immersed in, involved with, and affected by these issues. This was done in the hope that these individuals were more directly immersed in the field and may be able to illuminate factors that have previously gone undiscovered. These stakeholders are the faculty currently teaching embryology content and the first-year medical students enrolled in learning experiences involving anatomy, whether that is an entire course or, more commonly, a course or unit of study which includes embryology content (Drake et al., 2014).

This chapter focuses on the faculty findings and analyses, while the following chapter will expand upon these findings and analyses with that found in the student sample. Chapter 6 will include comparisons between the faculty and student results, forming a solid foundation to forming theories regarding embryology in medical education and a phenomenology, or the essence of what it means to teach embryology in modern medical education. Both chapters will address the latter two research questions, seen below, while this chapter regarding the faculty data will also address the first research question.

The following chapter concludes by synthesizing the results from both faculty and first-year medical student samples and provides a transition into the research conclusions and recommendations in the final chapter. The specific research questions are:

1. What is the current status (e.g., placement, course hours, faculty cohort, content, materials, pedagogy) of embryology in medical education curricula as reported by faculty?
2. What experiences and perceptions do faculty and first year medical students have in regards to the teaching and learning of embryology in medical education, including most interesting and most confusing aspects of teaching or learning embryology?
3. What suggestions do faculty and first-year medical students have for the improvement of teaching and learning embryology in medical education?

For the faculty sample, the first question was answered to the best of the faculty participants' knowledge. Syllabi were requested, but the syllabi varied so drastically in both format and amount of information provided within them that it was deemed to be too difficult to draw conclusions based on these variable documents. Since medical education administrators were not included in this sample, there will be aspects of the curriculum decision making process that are not answered in this research. Instead, this first research question will reveal what faculty who teach or have taught embryology observe to be the main factors influencing embryology education at their institutions. The second and third questions address the bulk of the faculty surveys and were also examined in the faculty interviews. These questions seek to find patterns and themes within the diverse sample of medical school faculty and their institutions who participated.

In this chapter, the findings from the faculty survey and faculty interviews will be presented, starting with faculty and institutional demographics, then the quantitative and qualitative data from the surveys. Then the phenomenology of teaching embryology in modern medical education will be illustrated. Embedded within these sections, the theoretical framework of the explicit, implicit, and null curricula will be used to complete the analysis and interpretation of the results.

Recall from chapter 3 that survey results included descriptive data of the participants themselves and of their institutional curricula. Quantitative data was collected regarding the faculty's level of confidence when teaching embryology, opinions about educational resources, and Likert scale items regarding the utility of embryology in medical education and the medical profession. Qualitative data was collected regarding word associations with embryology, what faculty find most interesting and most confusing about the subject of embryology, and their suggestions for the improvement of teaching and learning of embryology within the medical curriculum. The descriptive and quantitative data were managed with IBM Statistical Package for the Social Sciences (SPSS) Statistics Version 23 (IBM Corp., 2013); qualitative data were managed with QSR International's NVivo 10 qualitative data analysis software (QSR International Pty. Ltd., 2014).

A grounded theory approach was used for the qualitative aspects of the survey to form theories about the teaching of embryology, while the faculty interviews were analyzed using a phenomenological approach. The intention for the phenomenological approach of the research was to form an essence, or a narrative explanation for the lived experience of teaching embryology in modern medical education (Starks & Trinidad, 2007; O'Leary, 2005). This methodology was informed by the conduction of the pilot studies at two different institutions with three different student cohorts (see chapter 3 for more details). The generation of the student surveys and focus group data collection served to illustrate areas where faculty could provide more informative data regarding embryology in medical education.

### Descriptions of the Faculty Survey Participants and Their Institutions

In the following sections, demographic data about the faculty survey participants will be described both about the participants and their institutions.

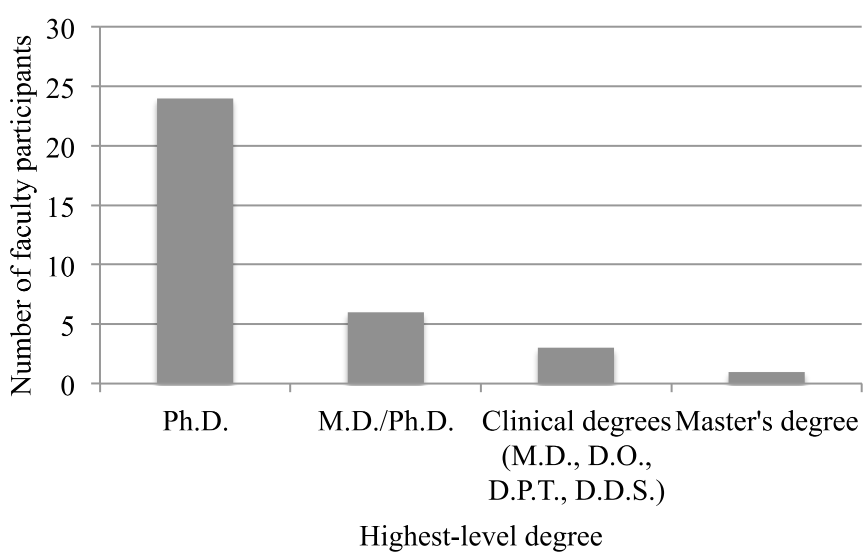
**Descriptions of the faculty survey participants**. Thirty-four (34) faculty members from across the United States participated in the online, open access survey "Faculty and instructors' attitudes and beliefs regarding human embryology in the curriculum" (See Appendix A: Faculty Survey) through SurveyMonkey between October 2014 and October 2015. The survey did not require participants to answer every question in order to progress through the survey, and therefore not all questions received 34 answers total. Nineteen (19) faculty were male and 15 were female for a nearly even distribution of 56% males and 44% females.

Of the 34 faculty respondents, 27 (77.14%) currently teach embryology either as a course or as part of another course; 5 (14.28%) have taught but do not currently teach embryology; and 2 (5.71%) have never taught embryology but have taught anatomy. Those who never taught embryology likely were forwarded the research call for participants by others in their department, had an interest in the topic, and wanted to make their opinions known despite not having classroom experience of teaching embryology. This leaves 94% of the sample as faculty members with direct knowledge of the climate and struggles in regards to the research questions asked about embryology.

For the majority of participants, a doctor of philosophy (Ph.D.) degree was their highest-level of education achieved (68.57%), followed by a combined M.D./Ph.D.

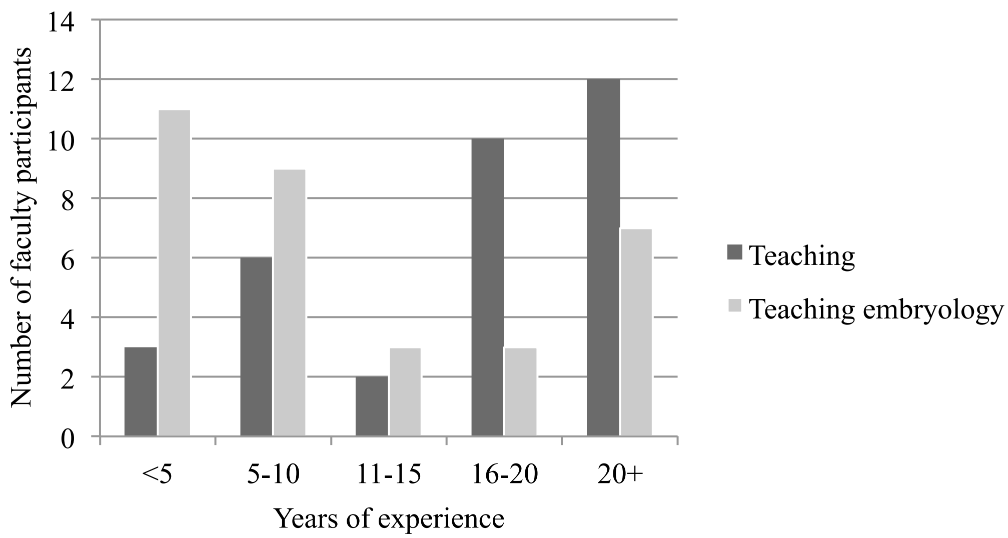
(17.14%), several clinical degrees (M.D., D.O., D.P.T., D.D.S.) (8.57%), and 1 (2.86%) faculty member with the highest level of education as a master's degree (see Figure 5.1). The field in which the highest-level degree was granted was mostly in the life sciences (24; 70.58%), with 5 each (14.29% each) coming from clinical degree programs or science education. When asked to briefly describe their educational background, 20 participants in the life sciences or science education responded. Nine (9) achieved their highest level degree in a program within the anatomical sciences (e.g., clinical anatomy, anatomy education, neuroscience or neurobiology, cell biology), seven in either biological or physical anthropology, and one each in genetics, biomedical research and neuroendocrinology, biology, and pathology. Thus, many individuals who teach embryology did not earn their highest degrees in embryology or even in anatomy.

Figure 5.1: Highest-level degree of faculty participants




Individuals classified as middle career accounted for most (52.94%) of the sample, with 10 (29.41%) with 16-20 years, 2 (5.88%) with 11-15 year, and 6 (17.65%) with 5-10 years of experience teaching students (see Figure 5.2). Some of the participants were later in their academic careers, with 12 (35.29%) having 20 or more years of experience teaching students. Three (3; 9.09%) faculty participants were early career, with less than 5 years of experience teaching students.

Figure 5.2: Years of experience teaching versus years of experience teaching embryology




While most faculty had extensive teaching experience in general, these same individuals had relatively less experience in specifically teaching embryology content or courses (see Figure 5.2). Eleven (11) participants (32.35%) reported they had less than 5 years of experience teaching embryology, 9 (26.47%) reported 5-10 years, there were 3 each (8.82% each) in the 11-15 and 16-20 years categories, and only 7 (20.59%) had been teaching embryology content or courses for 20 or more years. The data collected did not ask if the individual was in a non-tenure or tenure track position, nor did it differentiate between academic rank (i.e., assistant, associate, or full professor). It was deemed more important to collect information about the time of their teaching experience instead of the type of position the person occupied. The pattern in Figure 5.2 shows an almost inverse relationship between these two experience levels of faculty. Faculty in the late-middle to later career stages have, in general, less years of experience teaching embryology, while those in the early to early-middle career stages have more years of experience teaching embryology content or courses. The reasons for this are unclear, although it may have to do with the assignment of duties within medical education departments or with the increasing content of embryology referred to in chapter two as the “molecular metamorphosis” (Tavares, 2004). Faculty in the earlier career stages may have finished their education with more current knowledge about the emerging research in the molecular aspects of embryology, and therefore were asked to teach these courses at their institutions.

When asked about their previous experiences with embryology, there was a wide range of responses in the faculty sample. Most (29; 85.29%) participants had taken some sort of graduate or medical level embryology course, and 17 (50%) claimed to have undergone a self-study about embryology for personal interest. Data was not collected to inform what the participants considered to be a self-study, although it stands to reason that for some individuals this could mean merely reading a book on the subject. Self-study was closely followed by 11 (32.35%) citing an undergraduate level course that included embryology content, 9 citing professional research (6.47%), and 3 citing a professional development course (8.82%) such as an intensive online review of cardiovascular development and congenital anomalies.

Participants were asked why they are teaching or had taught embryology, with the choices of:  volunteered, randomly assigned, they were told they had to, or everyone has to in my department. Out of the 32 participants who had taught embryology before, 22

(66.66%) reported that they had volunteered, 9 (27.27%) said they were told they had to, 4 (12.12%) said that everyone in their department teaches embryological content, and 2 (5.88%) were randomly assigned to the task. Some reported multiple reasons, for example one individual stated that since all individuals in their department teach embryology content they were told that they had to as well, so they selected dual answers for the question. The faculty reports of how they same to be teaching embryology are dependent upon the faculty interpretations and individual experiences.

In order to obtain a conceptual grasp on the teaching responsibilities of these individuals, faculty were asked to report on all anatomy courses (including embryology) that they commonly teach in the academic year. The course options given in the survey were: gross anatomy, cell and tissue biology or histology, neuroanatomy, embryology, various anatomy topics within an integrated curriculum, undergraduate stand-alone anatomy, undergraduate stand-alone physiology, undergraduate combined anatomy and physiology, or other courses. This research did not ask about faculty research or service obligations and activities to their institutions, nor were they asked specifically about the other teaching responsibilities outside of the traditional four anatomical subdisciplines. The most frequently checked courses were gross anatomy, embryology, and various anatomy topics within an integrated curriculum. The courses described in the other category by faculty participants included courses such as medical resident embryology reviews, anatomy for nursing programs and neuroanatomy for physical and occupational therapy programs, ear-nose-throat (ENT) postgraduate and continuing medical education (CME) courses, and an upper level undergraduate medical imaging course.

It is unclear if there is a pattern to whom teaches embryology, though it stands to reason that gross anatomists are obliged to merely because it is placed into their area of expertise most commonly. This data confirms that the sample of faculty that responded to this survey are the group that this research is targeting, individuals with experience teaching embryology with a diverse educational background and a willingness to discuss their perceptions of the field within medical education.

**Descriptions of the institutions.** Within the 34 faculty respondents, there were 23 different institutions of higher education. Although the survey was distributed throughout the United States and Canada, there were no Canadian participants within the one year time frame of data collection. The United States may be divided regionally according to the U.S. Census map with the number of faculty participants and the number of schools at which these faculty are employed: the northeast region yielded 4 participants from 4 schools; the midwest region included 17 participants from 8 schools; the south region included 10 participants from 8 schools; and from the west region there were 3 participants from 3 schools. In the midwest region, 2 institutions are overrepresented with 10 out of the 17 total faculty from the midwest region. However, one of these institutions is a medical school system divided into 8 centers throughout the state, each center with its own faculty cohort, student population, and methods of teaching. So these centers should be thought of as different units, which would alter the numbers above to reflect 10 different locations with 10 out of the 17 total faculty from the midwest region.

The types of institutions that responded were predominantly allopathic and osteopathic medical schools (see table 5.1). Of participants that selected only one type of institution from the choices on the survey, there were 23 allopathic medical schools, 3 osteopathic medical schools, and 1 dental school. Seven (7) participants reported multiple types of schooling at their institutions. Three (3) reported being both an allopathic and four year institution, 2 reported allopathic and dentistry and other clinical and four year types of education, 1 was a combined allopathic and dental and other clinical school, and 1 was a combined osteopathic and dental institution.

Table 5.1: Type of institution for embryology faculty survey participants

| Type of institution | Frequency n = 34 | |
|---|---|---|
| Allopathic | 23 | 67.65% |
| Osteopathic | 3 | 8.82% |
| Dental | 1 | 2.94% |
| Combined allopathic and four year college or university | 3 | 8.82% |
| Combined osteopathic and dental | 1 | 2.94% |
| Combined allopathic, dental, and other clinical | 1 | 2.94% |
| Combined allopathic, dental, other clinical, and four year college or university | 2 | 5.88% |

Following the patterns seen via the type of institution, the primary learners that these faculty participants teach are 77.14% allopathic medical students, 8.82% osteopathic medical students, 5.71% dental students, and 5.71% other graduate level students (see table 5.2). When asked if there were any secondary student populations present at their institutions, 25 out of 34 schools reported there were and 7 of these reported multiple secondary student populations. The most popular choice was other graduate-level students (61.76%), undergraduate students (14.29%), dental students (11.43%), medical residents (5.88%), and allopathic or osteopathic medical students (2.94% each).

Table 5.2: Types of learners at the institutions

| Type of learners | Primary learners | Secondary learners |
|---|---|---|
| Allopathic medical students | 77.14% | 2.94% |
| Osteopathic medical students | 8.82% | 2.94% |
| Dental students | 5.71% | 11.43% |
| Other graduate level students | 5.71% | 61.76% |
| Undergraduate students | 0% | 14.29% |
| Medical residents | 0% | 5.88% |

The majority of faculty participants reported that their schools have an integrated curriculum (23; 65.71%) and the rest have separate courses (11; 31.43%). Faculty were asked to briefly describe the format of the anatomy curriculum, particularly in relation to embryology, and several faculty did describe their curricula, being sure to focusing as instructed by the survey information, on how embryology fits into the overall medical curriculum. Below are selected descriptive responses from the survey, representative of the total number of responses.

> "Embryology content has been reduced with reduction in time for gross anatomy classes. We cover big picture embryology-heart, GIT, urinary and reproductive systems, mostly as a way to help understand adult anatomy."

> "Embryology is only mentioned in passing."

> "Histology, Gross Anatomy, and Neuroanatomy are separate courses in a discipline-based curriculum. Embryology is incorporated into the Gross Anatomy course, but they are not integrated; rather, there are separate lectures and discussion question sessions for both subjects."

> "We don't cover embryology as comprehensively as we probably should. For now, we emphasize the principal elements of the embryological processes and events in our gross anatomy lectures that produce the adult configuration of the anatomic structure or system being covered."

> "In the medical school, all anatomical content is integrated in an organ system-based curriculum. We do not have stand-alone courses for any discipline."

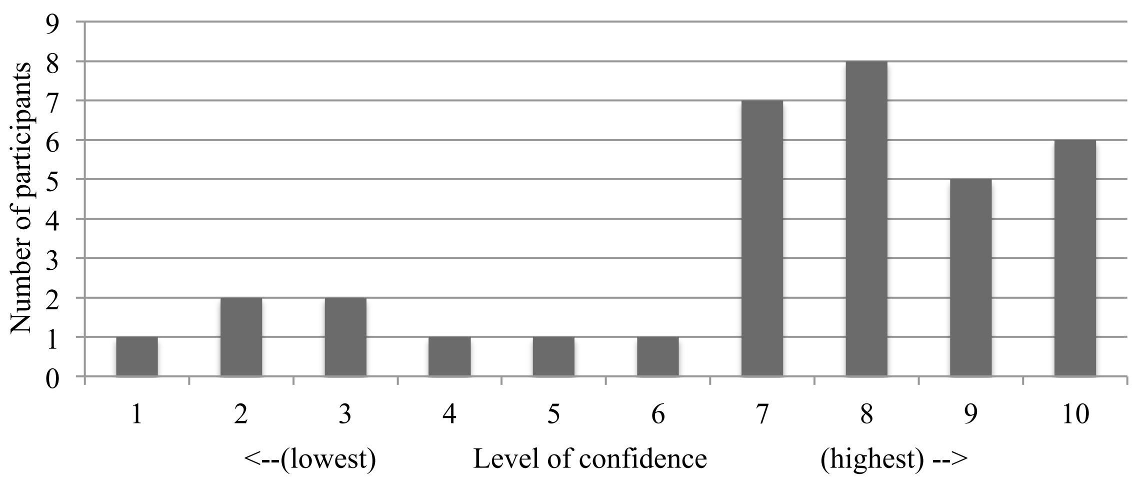
The descriptive data above illustrates there is great variation in the time, placement, and content of embryology in the curriculum. There was no way to quantify the descriptions received other than an affirmation of whether the school has an integrated curriculum because the text that the faculty submitted were of such varied foci and scope. This provides evidence that studying the placement of embryology within medical education is problematic because, as was discussed in chapter 2 regarding definitions of the word “curriculum,” the faculty all perceived the question differently and answered according to their individual interpretations. Next, the quantitative data and analyses from the faculty surveys are explained.

**Quantitative Data and Analyses of the Faculty Survey**

The survey asked faculty to rate their personal level of confidence from 1, the lowest level, to 10, the highest level, when teaching embryology content. The survey also listed educational resources and asked faculty to report whether they require, recommend, or discourage use of the particular categories of educational resources. The last quantitative data gathered in the survey was 12 Likert items regarding the utility of embryology in medical education and the medical profession overall.

**Level of confidence when teaching embryology.** When asked to rate their level of confidence when teaching embryology from a scale of 1 to 10, with 1 being least confident and 10 being most confident, faculty participants displayed a wide spectrum of levels of confidence (see figure 5.3). Along the lower end of the scale (1-6), there were either 1 or 2 individuals at each point. At the moderately high confidence level of 7, the number of participants rose greatly to 7, then to 8 participants for level 8, 5 for level 9, and 6 participants ranked their level of confidence as the highest it could be on this scale at level 10. The mode was 8, the mean was 7.18, and the median was 8. Therefore, it is evident that most of these individuals have a moderately high level of confidence when teaching embryology content. This question was further examined with the subsample of faculty interviewed, as this question was intended as a starting point to follow up with interviews to provide a qualitative reasoning for why faculty reported their levels of confidence at the values that they did.

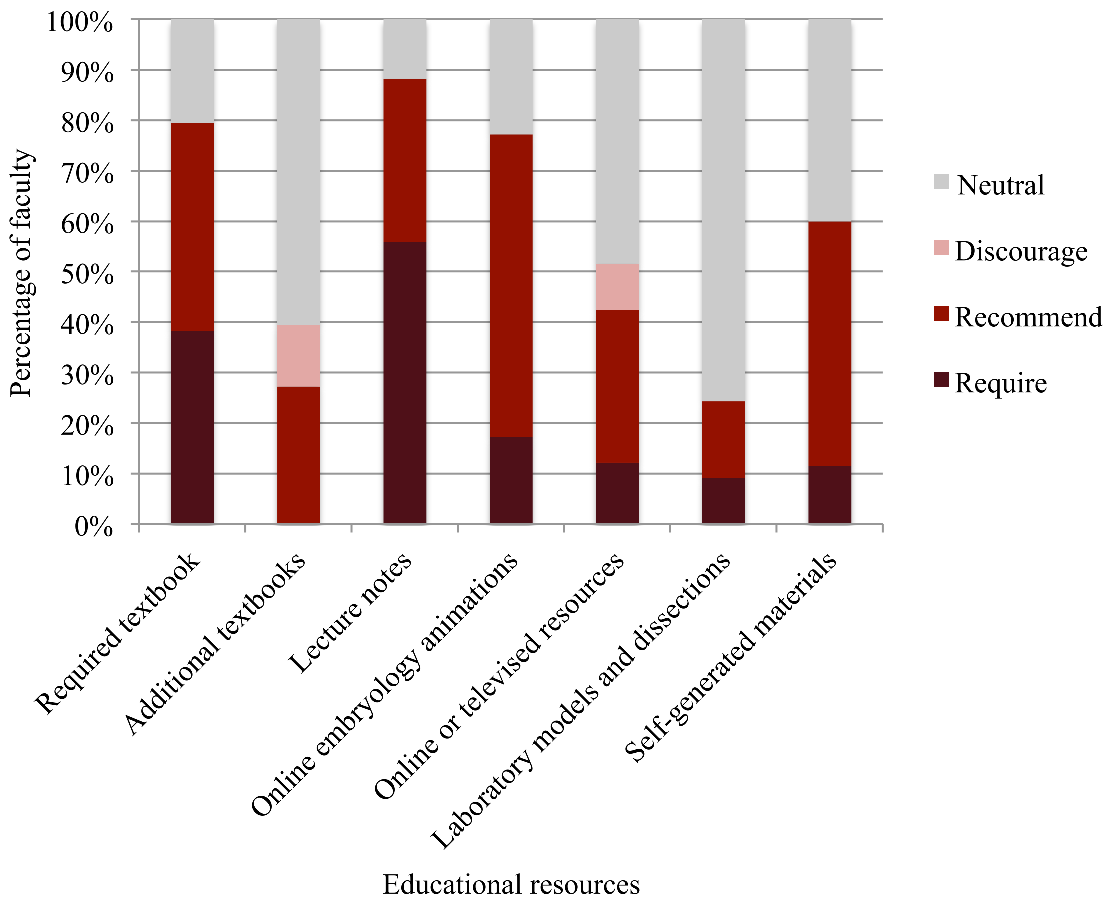
Figure 5.3: Faculty level of confidence when teaching embryology




**Educational resources that faculty require, recommend, or discourage for their students.** When given a list of educational resources, faculty were asked to tell whether they require, recommend, or discourage the use of certain resources by students studying embryology (see figure 5.4). The most commonly required resource was the course lecture notes, followed by the required textbook. Faculty often recommended the use of online embryology animations and self (student)-generated materials (e.g., diagrams, flowcharts, mnemonic devices). The only two types of educational resources that were discouraged by some faculty were additional textbooks and online or televised resources. Speculation is that additional textbooks outside of the scope of the required textbooks may exceed the amount of material that the typical student can handle. Additionally, the online or televised resources may discouraged for first time learners of the materials because some resources may not be peer reviewed, accurate, updated, or at the appropriate level for medical students. Wikipedia, an online encyclopedia platform open for any layperson to access and edit, is often lamented by faculty at medical schools whose students regard or even cite Wikipedia as a reliable source for information (Giles, 2005; Haigh, 2011; Rajagopalan et al., 2011). There may even be concerns, when speaking specifically about embryology, that certain online resources may be biased and hold political agendas relating to miscarriage and abortion embedded within the embryology content.

This question posed to embryology faculty exposes a part of the explicit curriculum, and to a small extent the implicit curriculum. If educators require students to use a certain resource, they are expressing confidence in that information and giving students an idea of the depth and breadth of knowledge that will be needed for success in the course. The generally neutral feelings towards the use of laboratory dissections and models may be seen as a component to the implicit curriculum. For example, if an instructor lectures on embryological content but it is never addressed or mentioned in the gross anatomy laboratory – or if when a student asks they are told not to worry about it because it will not be on the gross anatomy laboratory exam – then this may be seen to send a message that embryology is not extremely involved in the adult anatomical structures. However, the presence of embryological remnants is high when one understands embryological principles. The implicit messages sent to students even about something as simple as what types of resources to use for studying embryology may have more of an impact on the students than we realize.

Figure 5.4: Educational resources that faculty requite, recommend, or discourage for their students




**Likert items regarding faculty opinions on the utility of embryology in medical education and medical practice.** The following three graphics (figures 5.5, 5.6 and 5.7) illustrate the twelve Likert items, divided into three themes, that faculty participants answered on a six-point scale (including not applicable option). The three themes are: embryology in medical practice, personal opinions regarding embryology, and embryology in medical education.

Figure 5.5 shows five Likert items that ask faculty about embryology in medical practice. Most participants strongly agree or agree that understanding embryology is essential to understanding both gross anatomy and certain clinical ailments. This same pattern holds true in saying that the study of embryology is an important and necessary part of medical training and is applicable to modern medicine. Despite these encouraging remarks, just over half of the participants agreed that students will use embryology in actual medical practice. This disconnect between faculty stating that embryology has applicability to modern medicine, yet that students will not use embryology practically (i.e., application) in medical practice is puzzling and the interviews with faculty illuminated some aspects of this paradox. In the interviews, some faculty members clarified that in the students not using embryology in medical practice would be in certain specialties that do not often deal with congenital anomalies, such as radiology or dermatology.

Figure 5.5: Likert items for faculty regarding embryology in medical practice

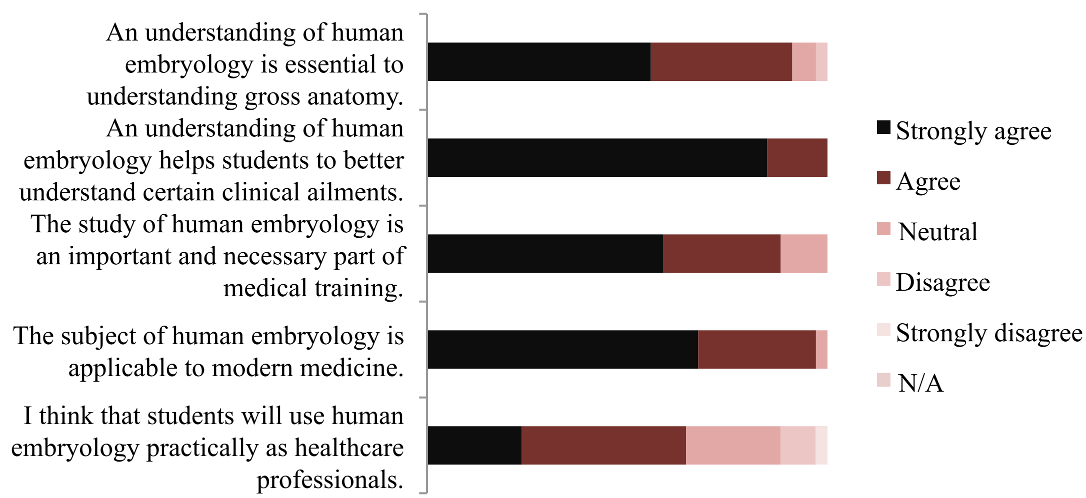



Figure 5.6 shows three Likert items that ask faculty about their personal opinions regarding embryology. Most found the subject of embryology interesting, and just over

half found it difficult to understand. In the qualitative data from the faculty surveys, participants wrote open-ended answers to further explain these factors. As we saw in the previous pages of this chapter when filling out their level of confidence on the ten point scale, most faculty feel quite confident in teaching the subject to others.

Figure 5.6: Likert items for faculty regarding personal opinions about embryology

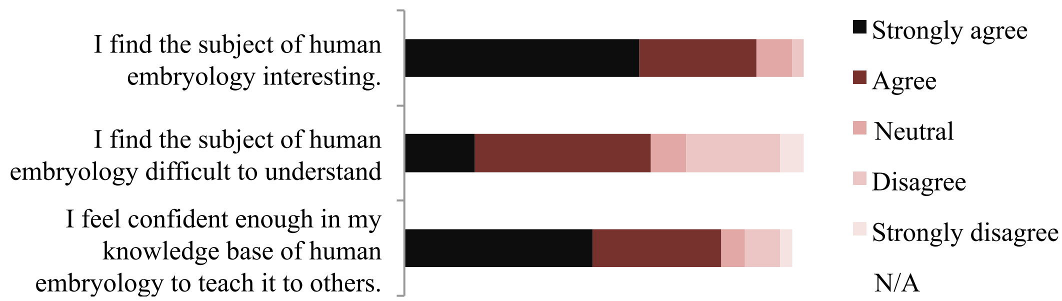
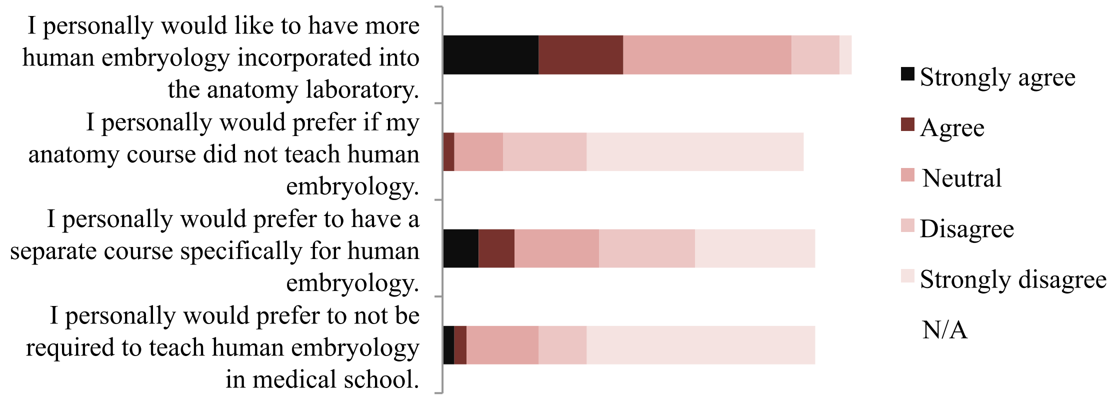



Figure 5.8 summarizes faculty perceptions about embryology in medical education. Most faculty were neutral when asked if they would prefer more embryology to be in the curriculum, but disagreed or strongly disagreed when asked if they would eliminate the subject from their anatomy course or medical schools. Opinions on having a separate course for embryology were varied, but most participants did not want to have a separate course. These responses are encouraging because we see the trend of curricular integration continuing with no sign of slowing or regressing back into separate courses. The support of the faculty in any form of integration is valuable as the onus of confident implementation of curricular reform and integration often rests on the shoulders of those with direct contact with both the medical education administration and the medical students.

Figure 5.7: Likert items for faculty regarding embryology in medical education




**Syllabi and course materials.** Within the faculty surveys, the researcher asked participants to provide their embryology syllabi (or syllabi that pertain to the units covering embryology content) so they could be analyzed for aspects of the explicit curriculum (e.g., textbook, learning objectives, course content). The researcher received 17 affirmations, but the materials sent varied from full syllabi to a course schedule, to a list of embryology objectives to a link to the entire online curriculum structure document for the institution's basic science curriculum. The artifacts received were so varied it was impossible to compare them. Therefore, the intended analysis of syllabi is no longer a goal due to these concerns, but it is a direction to keep in mind for the future. However, the lack of a definitive syllabus for each institution and the variability of the course materials highlights an important point. These materials are clearly adequate for the institution and departments within the function. But the researcher's inability to directly compare one school's curriculum to another's does say something about the massive job of accrediting bodies and administrative individuals. Deciphering these documents can sometimes be just as difficult as writing, designing, and implementing them. There are many diverse ways in which faculty have to display curricular and course information.

The comparisons between these different ways may impact the impression of the time and resources devoted to subjects such as embryology.

Syllabi and other course materials must be written in a way that other faculty, student, administration, and accrediting bodies are able to clearly understand the aspects of the explicit curriculum that he institutions is providing to its students. Ideally, these clarified documents would also demonstrate aspects of the implicit curriculum such as a statement in the course goals that pertains to professional compassion and empathy in the classroom when discussing human birth defects. If the syllabi and course materials are not understandable to individuals outside of the department or institution, then external reviewers (such as this researcher) may fail to identify certain messages trying to be conveyed about the teaching and learning environment. On a broader scale, failure to make the embryology curriculum clear may lead the institution and accrediting bodies to erroneously interpret the subject as not important, leading to even fewer course hours and allocated resources.

**Qualitative Data and Analyses of the Faculty Survey**

The qualitative portion of the faculty surveys included four separate questions. The first was a word association list, in which faculty were asked to write ten words that they associated with embryology. Next, they answered three open-ended questions regarding what they found most interesting about embryology, most confusing about embryology, and finally if they had any suggestions for the improvement of the teaching and/or learning of embryology in the medical curriculum. These four questions were also asked in the student surveys. Student survey responses and their associated descriptive and quantitative data findings and analyses are in the next chapter, with the addition of a comparison between the faculty and the student qualitative question codes and themes.

**Word association list.** The survey question read, “List 10 words that you associate with human embryology. They may be vocabulary, anatomic terms/processes, affective/emotional terms, etc.” The goal of this question was to see the immediate thoughts and reactions of faculty when they are asked to list words that they associate with embryology. The additional cue of saying that these words may be vocabulary, anatomic terms or processes, or affective or emotional terms were so that participants knew they were free to answer with any type of thinking that they desired. Between the 34 faculty participants, not all completed this question of ten words in its entirely and therefore 309 words total were reported.

Initially, the plan was to code the list of terms generated by faculty for positive, negative, or neutral connotations, as was done in the pilot study (see chapter 3). However, upon further thought and after reading the list of 309 terms that the faculty submitted for this survey, there were certain words whose meaning could be interpreted in extremely different ways depending on the bias of the person doing the coding. For example, the word “complicated” when read in no certain context could be either a positive or a negative word, and without the ability to ask participants to expand on or qualify their answers then the decision of how to code could be biased through the researcher. So instead of coding terms as positive, negative or neutral, a different coding scheme was developed.

After data collection, the researcher read through the entire list of words several times in random order, trying to find other themes and patterns in the words chosen. The two major categories that first identified were *Vocabulary* (i.e., terms that could be found in an embryology text glossary) and *Descriptive* (i.e., terms that were adjectives describing embryology itself). However, thinking about the faculty who wrote these words and their goals as educators of future physicians, it was decided to distinguish the practice of medicine-focused vocabulary terms from the general types of vocabulary terms, and so a third major code was created and called *Clinical*. Next, the researcher went through the list of terms and assigned one of the three codes to each word. These codes were mutually exclusive, and each word or short phrase received only one code: *Clinical, Descriptive*, or *Vocabulary*. Examples of each code may be found in the table 5.3. The researcher continued with the grounded theory approach and performed a constant comparative analysis, which entailed continuous consultation of the categories being developed, to separate these three codes from which I could identify a theory about faculty word associations with embryology (Glaser & Strauss, 1967).

Words in the *Descriptive* code were sometimes problematic. There were differences and some nuances as to whether the adjectives were speaking about embryology in a positive manner, in a negative manner, or in a way that could be interpreted differently depending on the individual or was typically a neutral connotation. So the decision was made to form three subcodes within the *Descriptive* code: *negative, ambiguous*, and *positive*. The *negative* and *positive* words were fairly simple to subcode, but the *ambiguous* category required more attention to detail. In the ambiguous subcode, words were placed that were either descriptive with no connotations either positive or negative (e.g., "complex") or those that could be either positive or negative but there was no way of knowing or guessing how the participant meant it ("challenging"). These subcodes were again mutually exclusive, and each term in the *Descriptive* code was also placed within one of the three connotation subcodes.

The researcher considered performing a similar subcoding procedure within the *Clinical* code, with the thought that words such as “pregnancy” would be ambiguous while words like “deformity” would be negative. However, this brought up another potential bias of the researcher in that some words (e.g., “spina bifida”) are academically or conceptually interesting and therefore positive or ambiguous, while in the actual clinical setting they would have a negative connotation. So the decision was made to not subcode the Clinical terms because this could introduce greater bias than the effort would be worth in terms of data analysis.

There were 309 words total from the faculty survey word association list. Again, not all the faculty survey participants listed ten words total; several faculty only listed a few words and did not complete the entire question for unknown reasons. Perhaps they could not think of more words, or did not read the question instructions, or did not want to spend time on a relatively free-form, qualitative question. A full list of these terms and their associated codes can be found in Appendix H:  Faculty Word Association Data. Faculty participants recorded 176 *Vocabulary* words, 68 *Descriptive* words, and 65 *Clinical* words. Within the *Descriptive* words, there were 16 negative, 12 ambiguous and 40 positive terms (See Figures 5.8 amd 5.9).

Table 5.3:  Faculty embryology word association code and subcode frequencies and text examples

| Codes | Subcodes | Frequency of total | | Select examples |
|---|---|---|---|---|
| *Clinical* | | 65 | 21.04% | Congenital, Omphalocele, Ultrasound |
| *Descriptive* | | 68 | 22.01% | (see below) |

| | | | | |
|---|---|---|---|---|
| | *negative* | 16 | 5.18% | Boring, Confusing, Side-lined |
| | *ambiguous* | 12 | 3.88% | Challenging, Complex, Integrative |
| | *positive* | 40 | 12.94% | Amazing, Essential, Interesting |
| *Vocabulary* | | 176 | 56.96% | Blastocyst, Folding, Neurulation |

Figure 5.8: Faculty embryology word association code frequency

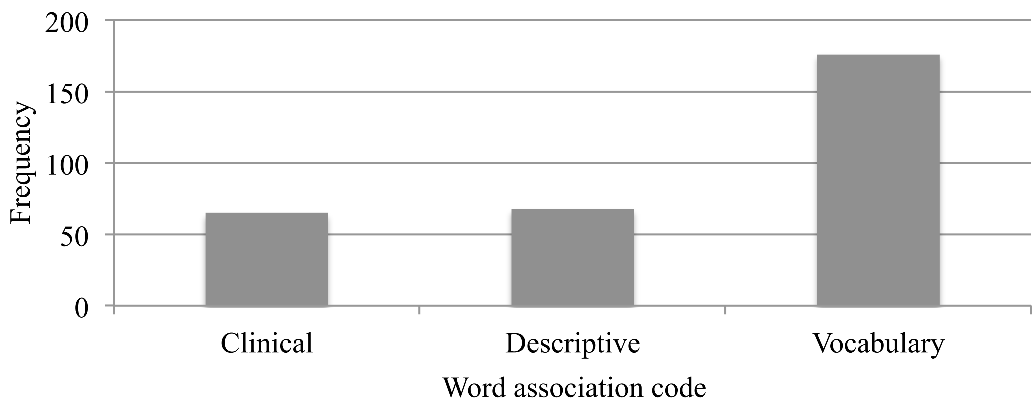
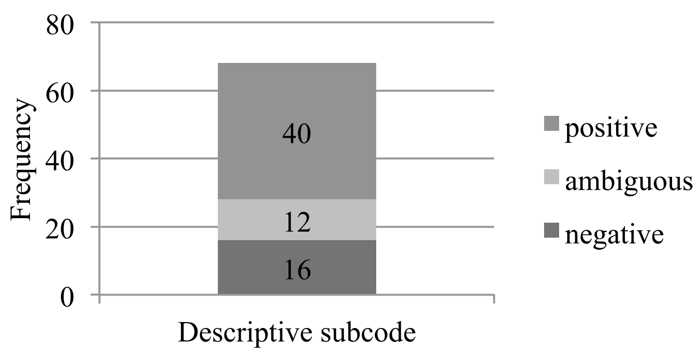



Figure 5.9: Faculty embryology word association *Description* subcode frequency




The most common word, which was often found near the beginning of the 10 word sequence for the individuals who wrote it, was "development" at a frequency of 14, for 4.53% of the total. Next, was gastrulation with a frequency of 10 (3.24%) and neurulation with frequency of 8 (2.59%). These top three results are all in the *Vocabulary* code. The most common *Clinical* term was "teratogen" with a frequency of 6 (1.94%), and the most common *Descriptive* word was “difficult” with 6 (1.94%), which is in the negative subcode of the *Descriptive* code.

Over half of the words cited by faculty were *Vocabulary* terms, and the remainder was an almost even split between *Descriptive* and *Clinical* words. In the *Descriptive* code, over half of the adjectives had positive connotations, and then several negative terms, followed closely by several ambiguous terms. These word choices suggest that when faculty think of embryology, they first think of the vocabulary that they teach to their students, the foundational terms relating to the field of study. These word choices also illustrate the power of the explicit curriculum in embryology education. They then start to think about the experience of being in the classroom and list adjectives that have mostly positive connotations. These word choices represent the general viewpoint of the faculty, and can be expressed as part of the classroom environment via the implicit curriculum. This is different from the student mindset, as will be discussed in the next chapter. As far as the null curriculum and its prevalence in the word association component of this research, one faculty participant wrote “de-emphasized” and another responded, “side-lined.” Although these words only account for 2 out of 309 words, or 0.65% of the responses, both these words demonstrate the idea that embryology is not given much attention in UME curricula thus alluding to the null curriculum of what schools do not teach.

**What faculty find most interesting about teaching embryology.** The open-ended question on the survey said, “What do you find most interesting about teaching human embryology?” The goal of this was to gather a wide variety of textual data in order to see what faculty believe the most intriguing parts of education in this field of study are. Analyzing and publicizing the answers to this query may lead to more authentic embryology teaching approaches because what faculty find to be interesting as academics and clinician-academics, medical students may also find interesting. This type of inquiry could lead to improvements in keeping medical students' attention in the classroom or laboratory while learning the content.

Each response was fairly succinct and only one to two sentences or phrases long. After data collection, the researcher read through the 1 to 2 sentence responses several times in random order, trying to find themes and patterns, until the overarching ideas that faculty participants submitted were revealed. These responses were different from the word association lists, in that the answers were not single words or simple phrases, but rather multiple sentences with the ability to include more than one major theme in one person's answer (Glaser & Strauss, 1967). In other words, these points of data collection regarding what faculty find most interesting about teaching embryology were not mutually exclusive.

After reading through the textual data multiple times, the researcher assigned four main codes: *Anatomy, Clinical, Education*, and *Personal*. The *Anatomy* code was for answers that spoke about concepts such as the relevance of embryology to adult anatomy, giving context to structures found in gross anatomy lab, or when participants cited specific structures or processes such as heart development. The *Clinical* code was for topics like congenital defects, explaining defects, and medical ailments and medical care. The *Education* code was for integration of many topics including embryology for example, how it often gives students the "aha moment". The *Personal code* was more ambiguous, and this was used when participants mentioned divinity or miracles. There were no subcodes for the data analysis of this question because there were not as many nuances found within this category.

There were 31 responses total to this open-ended question. A full list of these answers and their associated codes can be found in Appendix I: Faculty Most Interesting Data. The frequencies for each code were 21 in *Anatomy*, 16 in *Clinical*, 7 in *Education*, and 2 in *Personal* (see table 5.4). In contrast to the word association list, this time the researcher did assign multiple codes for the same answer if it included content from more than one of the four codes. Thirteen (13) of the responses were coded for multiple codes, most often a combination of *Anatomy/Clinical* (7), *Anatomy/Education* (2), *Anatomy/Personal* (2), *Education/Personal* (1), or *Anatomy/Clinical/Education* (1).

Table 5.4: Faculty "most interesting" code and subcode frequencies and text examples

| Codes | Frequency | Select text examples |
|---|---|---|
| *Anatomy* | 21 | Embryology helps us understand the adult anatomy - almost every question a student has about the adult anatomy can be answered with understanding the development; "if it doesn't make sense, we blame embryology"<br><br>I like relating it to Gross Anatomy, to facilitate student understanding of why things are where they are and why they look that way. It provides a bit of context for the anatomy that they see in lab.<br><br>That all terms change names every time that one thing gets to change its name. It is also very helpful in understanding how structures end up in their adult positions. |
| *Clinical* | 16 | Explaining how anomalies are not uncommon and that they often of little clinical significance even though they can seem rather drastic<br><br>The realization that deviation from the event studied leads to congenital anomalies.<br><br>Relating the comparative and historical basis for the medical care we deliver. |
| *Education* | 7 | I like the fact that it is a challenging subject to learn, so, as a teacher, I find that I'm actually able to get points across that |

| | | |
|---|---|---|
| | | students fail to get from textbooks.<br><br>The challenge of learning and understanding the material well enough myself so I can highlight and emphasize the most important and key information to the students in a way they can comprehend and use the material. |
| *Personal* | 2 | It is such a complex process with so many different things occurring at the same time it is a miracle anybody comes out "normal". I also find it very interesting how embryology can account for the organization and appearance of bodily structures. |

The most frequently mentioned aspect of what faculty find most interesting about embryology was its relevance to adult gross anatomy, and the fact that it can explain many things about the morphology of the adult. Responses also focused a great deal on the clinical aspects of embryology, speaking about the prevalence and processes that lead to congenital anatomic anomalies.

After coding for the four codes in this question, the researcher reread the answers while thinking about the explicit, implicit, and null curricula. Aspects of the explicit curriculum were often found in the *Anatomy*, *Clinical*, or *Education* codes. In their answers faculty talked about the development of the adult from the embryo and fetus, or even specific processes such as heart development. These are facts and aspects of embryology that could be found in course materials such as a textbook. The implicit curriculum was found in the idea that human development is a miracle and that it is amazing that anything can go correctly with how complex embryological processes are. Implicit ideas were often placed into the *Education* code, referring to the effort made by faculty to monitor and address student learning within their classrooms. This was not an intentional choice on the part of the researcher, but a pattern that was noticed after coding was performed. As faculty members educating future physicians, 11 responses cited some form of “explaining the why or the story” of embryology. This is one method to structure dissemination of the embryological content. Telling the “story” of embryology rather than a dry list of facts and movements is a great pedagogical tool to use for this subject matter. However, sometimes embryology is not portrayed this way to students and they pick up on that fact as the embryology course progresses. Some instructors make this very clear, but it is more common for a student to find this way to scaffold the material on their own. So in some ways, telling the story of embryology could be either in the implicit or in the null curricula, depending on the faculty member and their approach.

**What faculty find most confusing about teaching embryology.** The question in the survey said, “What do you find most confusing about teaching human embryology?” The goal of this question was to find out what faculty participants struggle with, in the hopes that once this is identified then better pedagogical tools and methods can be found and developed to account for the difficult portions of the embryological subject matter. The aspects of embryology that faculty find confusing can often trickle down to their students and perpetuate confusion or the learning of incorrect information. Each response was fairly succinct and only one to two sentences or phrases long. After data collection, the researcher read through the entire list of textual responses several times in random order, trying to find themes and patterns, until the researcher had a grasp of the overarching ideas that faculty participants submitted. These were similar to the last question regarding what faculty find most interesting about embryology, only for the fact that the codes were not mutually exclusive. More than one major theme could be found and coded in one person’s answer.

At first, the researcher tried to code this with the same codes as the most interesting question discussed in the previous section, in order to have a simple comparison between the two survey questions. But this process was not encompassing the themes and patterns found in the textual data, and even obscured some aspects that were important to discuss. After reading through the answers multiple times, the researcher assigned four main codes: *Content, Education, Research*, and *Visualization*. The researcher formed made a new code called *Visualization* because it was such a prevalent topic in the answers. The researcher formed subcodes into both *Content* and *Education*, as these further groupings seemed necessary to understanding the data and avoid obscuring some common themes within these two codes. The *Content* subcodes were *molecular*, *processes*, *time*, and *vocabulary*. *Education* had two subcodes, *classroom* and *resources*.

In 31 textual answers, there were 42 different codes which means there were again some overlaps. A full list of these answers and their associated codes can be found in Appendix J: Faculty Most Confusing Data. The frequency of each can be found in the table below, and were: 25 for *Content*, 7 for *Visualization*, 6 for *Education*, and 4 for *Research*. The numbers within the subcodes also are found in table 5.5 below. There was a great deal of overlap in this set of textual data, and every one of the nine instances of overlap involved the *Content* code. There were 4 answers that included *Content/Visualization*, 3 for *Content/Research*, and 1 each for *Content/Education* and *Content/Education/Visualization*.

Table 5.5: Faculty "most confusing" code and subcode frequencies and text examples

| **Codes** | **Subcodes** | **Frequency** | **Select text examples** |
|---|---|---|---|
| *Content* | | 25 | (see below) |

| | | | |
|---|---|---|---|
| | *molecular* | 7 | To what extent do students need signaling pathways?<br><br>…Plus any molecular biology and genetics. That's way beyond my expertise. |
| | *processes* | 8 | elucidating complex three dimensional processes such as gut formation and rotation, and cardiac development |
| | *time* | 9 | Conveying the idea that many things are occurring concurrently…<br><br>The temporal aspect. There is so much happening at the same time. |
| | *vocabulary* | 6 | … In addition, unlike Gross Anatomy, many of the terms used do not have an intuitive origin, and so seem like nonsense words which are harder to remember (on the other hand, many Gross Anatomy terms describe structure or function, for example "erector spinae").<br><br>… and that terminology is constantly changing |
| *Education* | | 6 | (see below) |
| | *classroom* | 2 | Generating interests among the students<br><br>How best to incorporate and how much detail to go into in integrating embryology… |
| | *resources* | 4 | … There are not enough good animations to depict to students what is actually happening, and they are left to imagine, which can be confusing |
| *Research* | | 4 | Keeping up with the newest trends and information in cellular and molecular aspects of development.<br><br>… it's difficult to keep up with all the current research. embryology is a field that is constantly changing, in terms of what we know about it. |
| *Visualization* | | 7 | The developmental processes happen early on and on a minuscule scale, so they are difficult to visualize. There are not enough good animations to depict to students what is actually happening, and they are left to imagine, which can be confusing… |

This question's codes were more varied than the previous question's regarding the most interesting facets of embryology. *Content* was included with a very high prevalence, in 80.60% of the answers. This data is a very clear indicator that even the faculty who teach embryology can find the content that they are teaching confusing. This is concerning since faculty teaching courses are seen as content experts, but not surprising given that most embryology educators are not classically trained embryologists. Adding to this is the overall nature of the subject embryology, one that is often described as an anatomical science that attempts to describe a structure undergoing both molecular and gross development, with many transient structures, constantly moving, and all through months of time in the scale of human development. Unfortunately, many of the embryology teaching resources do not illustrate all of the facets of the complex embryological processes. They are often classically trained anatomists or clinicians, as seen in this faculty sample where 30 participants were either Ph.D.s or M.D./Ph.D.s. These individuals are responsible for teaching medical students this foundational knowledge with often little guidance and, as the faculty have stated, limited resources.

So one of the most difficult parts of embryology is the content itself, which is the explicit curriculum. But when placed into the category of being a challenging thing even for instructors, this difficulty can bleed into the implicit and null curricula very easily. For example, if a faculty member is struggling and voices this struggle to the students in a negative way, this sometimes public struggle will influence the way that student think about embryology and may lead to neglect or a long-term issue with the subject. The faculty may also choose to cut some lectures or content based on the level of difficulty, sometimes rightly so for the medical student level of knowledge needed. Medical students are being prepared to be clinicians, not embryology researchers. But when content is eliminated, embryology content is placed into the null curriculum and students no longer learn the information. At that time, they may not even be aware that it exists.

**Suggestions for the improvement of teaching and/or learning embryology in medical education.** The final question in the survey said, "Do you have any suggestions or ideas for how to improve the teaching and/or learning of human embryology within the curriculum?" The goal of this question was to gather as wide of a net of ideas and suggestions as possible, and there is no better individual to ask for improvements than the faculty who are dealing with the daily and long-term struggles of teaching and learning embryology in medical education. The researcher read through the 29 one to two sentence responses several times, until the major groupings and ideas became clear. This set of textual data was quite simple to distribute into two main codes with four and five subcodes each.

The two main codes were *Curriculum* and *Resources*. Curriculum was further divided into four subcodes*: administration, clinical, instructor*, and *placement*. *Resources* was further subdivided into five subcodes: *animations*, *high tech*, *interactive*, *low tech*, or *textbook*. Similar to the most interesting and most confusing queries, multiple codes and subcodes could be assigned to the same answer if it included content from more than one (see table 5.6). There were only four instances of overlap between *Curriculum* and *Resources.* A full list of these suggestions and their associated codes can be found in Appendix K: Faculty Suggestions for Improvement. There were 18 answers assigned to the *Curriculum* code and 17 to the *Resources* code. Within the *Curriculum* code, the subcode *placement* had the highest frequency at 8, while in the *Resources* code, the subcode *animations* had the highest frequency at 10. The remainder of the subcodes for each all had between 1 and 4 responses.

Table 5.6: Faculty "suggestions for improvement" code and subcode frequencies and text

| Codes | Subcodes | Frequency | Select text examples |
|---|---|---|---|
| *Curriculum* | | 14 | (see below) |
| | *administration* | 2 | How can we convince administration to allot more time with students for embryo? |
| | *clinical* | 4 | All material should be vetted by clinicians--we should not cover material that does not inform regular clinical practice--there just is not the time... |
| | *instructor* | 4 | Faculty need to do a better job of emphasizing the clinical relevance of embryology and appreciating its significance. I have seen some instructors who were overwhelmed with the subject either dismiss embryology or transfer their negative feelings to their students. Embryology is challenging to understand, but when you start to get the basic concepts, it is fascinating! rah rah, embryology! |
| | *placement* | 8 | The hardest thing to do with embryology is to figure out which course does early embryology/early embryonic period fit. It seems to be a struggle for students when it is introduced in an anatomy course. |
| *Resources* | | 13 | (see below) |
| | *animations* | 10 | High quality animations seemed a required component to learning embryology. |
| | *high tech* | 2 | Create innovative ways that utilize today's technology to grab our students' interests. |
| | *interactive* | 2 | A colleague and I are creating an interactive timeline so that students can tract the continuity of development through multiple system-base units |
| | *low tech* | 1 | … I use simple modeling with tubes and paper for some explanations. |
| | *textbook* | 2 | I wish there was more embryology in my course textbook. I refer to supplements they may not have purchased. |

The fact that there were only two major codes, *Curriculum* and *Resources*, is important to note. It reflects the same pattern that was found in the question about what faculty find most confusing about embryology. This pattern makes it clear that faculty believe that the curriculum needs improvement, particularly in the areas of the placement of embryology, and that there needs to be better resources available, ones that are technologically and pedagogically advanced enough to appeal to both teachers and learners of this embryological content. Animations were mentioned in approximately one third of all the responses, which accounted for most of the coding to the *Resources* code.

The idea of the development of animations being particularly valuable, or even necessary, for the teaching and learning of embryology has been repeated in the literature for many years (Habbal & Harris, 1995; Moraes & Violin, 2010; Travis, 2014; Rao, 2012; Cork & Gasser, 2012; Fredieu, Watson, Hughart, Almon, & Nikiforova, 2010; Kakusho et al., 2002). Animations are a resource for teaching and learning topics like embryology that enable efficient explanations of a changing organism through time. The temporal aspect of learning embryology is unique amongst most of the anatomical sciences, and often contributes to the perceived difficulty of learning embryological content. In typical embryology textbooks, students view a series of static images, labels, and captions and have to make the mental leaps between non-moving images in order to fill in the gaps left behind. Some textbooks include online materials such as animations, which display these images in a series (often with the addition of labels, captions, or audio explanations) of images moving through time. Embryology animations can serve to illustrate the intricate and simultaneous nature of anatomical development from the stage of a single cell, the zygote, through the full-term fetus. Animations can decrease the mental workload and leaps that students have to make when they're presented with traditional images that may skip over complex movements, shifting of tissues, and changes in organ structure, shape, and size.

The demand for improved resources and animations for embryology may seem to be a clear explicit curriculum issue, as these are considered course materials. But when there is a lack of motivation and development of these materials – even when they are in such high demand – this morphs into an implicit marginalization of the matter and places the improvement of the teaching and learning of embryology to the side and almost into the null curriculum. One can purchase a plethora of new gross anatomy textbooks, atlases, models, and other reference materials but it is rare to find a new embryology resource, or one that is revised and updated as often as the gross anatomy resources are updated. The curriculum placement struggle in UME is mostly an implicit issue because subtle and often subconscious message are sent to stakeholders when content is distributed seemingly piecemeal into the existing curriculum or when that content is the only topic that is placed into a purely online format without adequate justification.

The following section of this chapter describes the findings and analyses of the interviews performed with faculty as the final phase of this research. The interviews focused on the experiences the faculty interviewees have had while teaching embryology in U.S. medical schools and their perceptions of the importance of embryology in medical education and practice.

**Qualitative Data and Analyses of the Faculty Interviews**

Thirteen (13) faculty interview participants consented to this component of the research by checking one box with the survey saying that they were willing to undergo a follow-up interview with the researcher. Detailed demographic data of these 13 participants is found later in this section. The interviews with faculty were originally intended as a chance for the expansion of answers to the questions addressed within the survey itself. While formatting the interview and designing the questions and general flow of the predicted conversations, the interview script began to transform into something different. The questions written for the final interview script were not extensions of the survey questions; rather, they were on a related but alternate level that necessitated a restructuring of the researcher's understanding of the goal of the interviews. This different level was a more affective component to the faculty's experiences while teaching and perceptions of embryology in medical education, which would illuminate factors of the actual first person experience of teaching embryology: how an individual approaches a classroom on the day they teach embryological content, their mindset while discussing social and ethical issues (if these topics are addressed), and their impressions of the importance that their department and the medical profession as a whole places on embryology. After realizing this shift in focus and before conducting the follow-up interviews with faculty volunteers, this approach was identified as a phenomenological analysis of teaching embryology.

The detailed theoretical background and steps to performing a blended grounded theory and phenomenological analysis are described in chapter 3 of this research project (see table 3.2 for comparisons between grounded theory and phenomenology). As a reminder before reading the findings and analyses presented here, coding for this component of the research began using a grounded theory approach, and then added the phenomenological approach to combine the strengths of the two research approaches.

The goal of a phenomenology is to produce a narrative that is the essence of the lived experience of the phenomenon being studied (van Manen, 1990). Here, that phenomenon is teaching embryology in modern medical education. A phenomenological analysis produces the short narrative, then explains each facet of the narrative while producing examples from interviews with the participants in the form of lengthy quotations. The ideal sample size for a phenomenological analysis varies according to which researchers are asked, but varies from under 10 individuals to at least six participants to between 5-25 participants (van Manen, 1990; More, 1994; Creswell, 1998). This deviates from the more familiar and typical research mindset of larger the sample sizes being better for the study, because the analysis of phenomenological research requires such extreme immersion in the data that large samples can become unwieldy (van Manen, 1990).

Faculty interview participants were recruited within the faculty survey with the final question that stated, “If you are willing to participate in a follow-up interview regarding these topics, please check the box below and enter your email address. The interview will take no more than 30 minutes and will be via telephone or Skype, depending on your personal preferences and logistics. The interview will take place at a day and time convenient for you.” The survey participants that responded and provided their email addresses were contacted in the late spring of 2015 and interviews were conducted during the summer of 2015. The researcher conducted each of these one-on-one interviews either in person or over the telephone and recorded them using smartphone audiorecording capabilities. The length of the interview ranged from 20-56 minutes, and averaged approximately 33 minutes including introductions, an explanation of the research to the interviewees, and concluding remarks. Table 5.7 (also found in

Appendix D: Faculty Interview Questions) below provides the questions asked during each interview. During interviews, the researcher used a document that listed the planned questions to be sure that all facets of the interview plan were covered. All of the inquiries were addressed during each interview, whether explicitly asked or participants covered the material while answering a different question. The order of the interview questions started typically with the first question regarding course hours, then subsequent questions followed the natural flow of conversation. In the question that asked about the curriculum format, the researcher consulted interview participants' survey answers in order to correctly report the description back to the interviewees.

Table 5.7: Faculty interview questions

| |
|---|
| <u>Faculty/Instructor Interview Script</u><br><br>The following are general questions that may be addressed during the interviews. The order and specifics will be based on the conversational flow and upon individuals' survey responses that could use a detailed explanation or that have already been addressed.<br><br>Approximately how many course hours are devoted to embryology/embryological topics in your course (program/department)?<br>    Do you think that is too many, too few, or just right?<br>    Do you know what factors go into deciding that number, and who makes that decision?<br>I see from the survey that your department has a ________ curriculum (briefly describe).<br>    What does the placement of embryology look like within that framework?<br>    Do you think this does or does not work well?<br>Describe to me what a typical day looks like in the classroom when you are teaching embryology content.<br>        Do you ever have a lab component to embryology? (or anything else?)<br>        Tell me about your mindset when you are teaching embryology.<br>            What influences your level of confidence when teaching embryological content?<br>        What is your rationale for deciding whether or not a certain topic should be included, and the time spent on it?<br>            Are any subjects avoided (purposefully or not)?<br>            What types of human birth defects do you teach?<br>            What social and ethical issues associated with embryology do you teach?<br>                (If they can't think of any examples: screening fetuses, abortion, in-utero surgery)<br>What importance do you think your department places on the teaching and learning of embryology as related to medical education? |

| |
|---|
| What importance do you think the medical profession places on embryology?<br>Do you see it as being a foundational anatomical subject or as more specific to certain specialties (e.g., ObGyn, Peds, Neo)?<br>Is there anything else you would like to say about the teaching and/or learning of embryology within your experiences in (medical) education? |

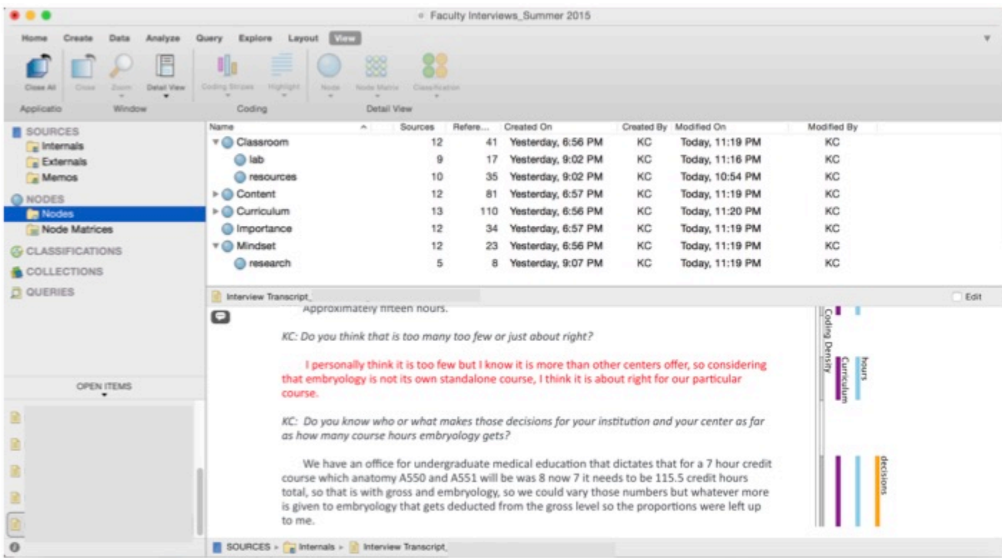
After conducting the interviews, they were transcribed in total from their audio recordings and formatted into a word document by a research assistant, which were then imported into the NVivo qualitative data analysis software. Rather than coding words and phrases, the researcher coded paragraphs within the interviews so as to not lose the context of the quotations being coded. An example of the NVivo data analysis for one of the interviews is shown in figure 5.10. As can be seen in that figure, there were five codes determined by the researcher's questions asked during the interview. The codes and subcodes are at the top of the screen, while the text being analyzed is highlighted below. These questions focused on: the format of the participant's embryology curriculum (*Curriculum*), which could if necessary be subcoded into decisions, hours, and placement; the topics covered and choices made in embryology course content (*Content*), with the subcodes clinical, priority, and social; the format of the actual embryology learning space (*Classroom*), with the subcodes lab and resources; the feelings that faculty enter the embryology course with (*Mindset*), and the subcode research; and their impressions of the level of importance placed on embryology by their department and by the medical profession (*Importance*). Although some of these codes within the interview text data use the same labels as the codes found in the qualitative data from the faculty surveys, this illustrates congruencies in the themes and patterns found within the data and should not be mistaken for merging the data in any way other than to form the final conclusions and recommendations overall.

First, after reading the documents multiple times and then performing the coding of the 13 interview transcripts using NVivo to organize the researcher's chosen codes, the researcher reread and adjusted any coding discrepancies. This adjustment took the form of adding codes and subcodes to the transcripts, rather than eliminating any codes. Simultaneously, the researcher highlighted sections of eloquent or interesting text with the expectation of using these excerpts to illustrate a point during the phenomenological analysis.

Second, the transcripts were separated by code. For example, a query was produced within NVivo that isolated all coded text that was coded for *Content* and subcoded for *social*. This enabled the researcher to see which participants spoke about the social aspects of their embryology content, how often, and what they said in one screen. Third, these documents were exported for each code and subcode, then read through the textual data multiple times. For each paragraph of text, the researcher wrote notes summarizing the overarching ideas and highlighted more pertinent quotations. The fourth step in analysis was to write a summary for each code and subcode with the general experience and messages from each faculty participant that addressed the question included. For each code and subcode, every participant was represented at least once in the textual data. Finally, the researcher took each code and subcode summary and generated the essence of the phenomenon of teaching embryology in medical education in the form of a multifaceted phrase. The codes are the themes that formed this essence, and were then each explained and exemplified by lengthy quotations from faculty interview participants.

The phenomenology was not analyzed for the explicit, implicit, and null curricula because a phenomenology is the lived experience and therefore does not have to be made to fit into the trappings of curricular analysis. Investigation of how the phenomenology of teaching embryology in medical education can influence or is influenced by the curriculum is a possibility for future directions of this research.

Figure 5.10: Screen capture of interview transcription data using NVivo




**Descriptions of the faculty interview participants.** The thirteen faculty participants consisted of 9 males (69.23%) and 4 females (30.77%), all currently teaching embryology at a medical or dental school. This is reflective of the sample for the faculty surveys, as described earlier in this chapter, and these participants completed the survey as well. Eleven (11) faculty participants had a Ph.D. degree (84.625%) and 2 had a M.D./Ph.D. dual degree (15.38%). Twelve (12) of the Ph.D. designations were in the life sciences, and 1 is in science education (Genetics). Within the life science degrees, 4were unspecified, 3 in Anthropology, 3 in Anatomy, and others included Biomedical Research and Neuroendocrinology, and Biology. These individuals will henceforth be referred to using the alphanumeric identification codes found in the figure below, F01 through F13. Refer to that table for the institutional description from which the quotations are coming, within the explanation of the phenomenology.

**Descriptions of the represented institutions.** The 13 participants hail from 12 different schools across the United States (See Tables 5.8 ad 5.9). Ten (10) are allopathic medical schools, 2 are osteopathic medical schools, and 1 is a dental school. Two (2) of these institutions are located in the northeast, 8 in the midwest, and 3 in the south. Eight (8) of the 12 schools (69.23%) utilize an integrated curriculum, while 4 (30.77%) have separate courses in their curriculum. All faculty participants teach either medical or dental students as their primary learners.

Table 5.8: Distribution of institutions' size and public or private status

| ***Characteristics*** | **Public** | | **Private** | |
|---|---|---|---|---|
| | *Number of schools* | *Percentage of sample* | *Number of schools* | *Percentage of sample* |
| **Large** | 4 | 30.77% | 2 | 15.38% |
| **Small** | 1 | 7.69% | 6 | 46.15% |

Table 5.9: Faculty interview participant identifiers and institutional descriptions

| **Participant identifier** | **Select institutional description** | | |
|---|---|---|---|
| | *Size* | *Public or Private* | *Type of medical school (Allopathic or Osteopathic)* |
| **F01** | Small | Private | Allopathic |
| **F02** | Small | Private | Allopathic |
| **F03** | Small | Private | Osteopathic |
| **F04** | Large | Private | Allopathic |
| **F05** | Large | Public | Allopathic |
| **F06** | Small | Private | Allopathic |
| **F07** | Large | Public | Allopathic |
| **F08** | Large | Public | Allopathic |
| **F09** | Small | Private | Allopathic |
| **F10** | Small | Private | Osteopathic |
| **F11** | Large | Public | Allopathic |
| **F12** | Large | Private | Allopathic |
| **F13** | Small | Public | Dental |

The remainder of this section of chapter 5 will detail the phenomenology of teaching embryology in modern UME, based upon the 13 interviews conducted with the faculty volunteers. First, the narrative phenomenology will be presented. Next, its themes will be underlined and described, then demonstrative descriptions from the faculty interviews provided.

**The phenomenology of the medical embryology educator.** The phenomenological analysis of the transcripts from the interviews with the faculty participants generated the essence of the individuals who teach embryology in modern medical education, shown in Table 5.10.

Table 5.10: Phenomenology of teaching embryology in modern UME

| |
|---|
| **To teach embryology as a foundation of human gross anatomy, aiming content toward the development of future clinicians responsible for forming their own approaches to the social aspects of medicine, while striving to maintain departmental and professional impressions of embryology's importance to the application of modern medicine.** |

The themes forming this essence are described below and exemplified by quotations from participants (credited via the alphanumeric identifiers in brackets at the end of a quote). These phenomenological themes are all connected and may be explained as the pieces that structure the lived experience of teaching embryology as summarized above (van Manen, 1990). Recall from the description of this research methodology in chapter 3 that grounded theory was used to first begin the coding process, then phenomenological analysis of the themes used to generate the narrative essence of the phenomenon, teaching embryology in modern medical education. The below three sections will provide the thematic focus by highlighting a portion of the phenomenology, briefly explain the major idea, conclude each section with exemplar quotations from faculty interviewees demonstrating the themes and corresponding explanations why these quotations were chosen to demonstrate the phenomenology themes.

Table 5.11: Phenomenological theme *Curriculum*

| |
|---|
| **To teach embryology as a foundation of human gross anatomy, aiming content toward the development of future clinicians responsible for forming their own approaches to the social aspects of medicine, while striving to maintain departmental and professional impressions of embryology's importance to the application of modern medicine.** |

Embryology is more often than not a small component of the modern UME curriculum, but it is a foundational anatomical science. Understanding the embryological processes for the various tissues, organs, and organ systems will lead to a more comprehensive understanding of the adult gross anatomy. The following interview responses nicely encapsulate the faculty responses leading to the phenomenological theme of curriculum:

> "I feel I need to give the students the basics of embryology so they understand the human body plan. Within each module of the course, each kind of regional module, they need to know the embryological development of the organ systems so they can explain developmental disorders and disease persistence." [F04]
>
> "If we went through a specific anomaly, I would make it clear to them that what the anomaly caused or the impact on the daily living for this individual or survival of this individual, rather cognitive dysfunction or not, we went through the aspects of this person's life and what they are facing." [F09]
>
> "I think it certainly in terms in the depth of detail, how many small structures, how many small details do we need to layout to get a critical message across? We don't want the students to get hung up on minute things that are not essential to understanding a larger picture of what is going on, certainly not at this point in their education. There will be

plenty of time later if and when they go into other subject specialties that will have a need for the added levels of information." [F01]

"We do no induction factors, no molecular anything, we don't do any congenital malformations, unless it really helps us describe the development of the definitive structure." [F11]

The majority of the faculty interviewees agreed that the presence of embryology in UME is to prepare and assist students in understanding the adult morphology, or the mature anatomy of the human. Since medical students will eventually be taking care of patients in the clinical setting, their embryology education must be geared towards how patients will present and the prevalence of developmental disorders and diseases pertinent to the adult morphology. Overall, faculty agreed that the extreme details of embryology and the molecular aspects of human development should be included not in the foundational anatomical sciences curriculum but instead, respectively, in certain specialties (e.g., pediatrics, obstetrics and gynecology, cardiology) and other coursework (e.g., biochemistry, genetics).

Table 5.12: Phenomenological theme *Classroom, content, and mindset*

| |
|---|
| **To teach embryology as a foundation of human gross anatomy, <u>aiming content toward the development of future clinicians responsible for forming their own approaches to the social aspects of medicine</u>, while striving to maintain departmental and professional impressions of embryology's importance to the application of modern medicine.** |

Medical students should be taught embryology keeping in mind what they will see as clinicians. This approach includes the rationale for what organs and organ systems to concentrate on, what clinical correlations are taught, and any social issues that arise with the study of embryology (e.g., abortion, fetal screening). The following are representative quotations providing evidence of this phenomenological theme:

> “I have only one or two slides on methods of birth control and the distinction between contraception and abortion. And the point I make to the students, the reason they should be familiar with this material, is so they can give educated opinions to their patients about these issues and also the general public. I think physicians have a role in society to be informed and educate the public about what abortion and contraception really are, they have a role to play in that.  I have a little say on that.” [F04]

> “How do you present this information to a patient and what, if any, kind of advice or counseling are you going to extend to the patient? In our anatomy sequence we are not typically going to pursue those issues very far, but the students will pick up those issues in things such as learning communities that we have in our system or other courses.” [F01]

> “When I started with medical school, they really pushed on this, it needs to be as clinically relevant as possible. And so when you are talking about this, you need to show the students why this is important. So when I am talking about gastrulation, I will talk about the primitive pit and the primitive streak, and when babies are born they can have these remnants that are clearly obvious.” [F10]

As introduced in the previous theme, medical students should learn embryology within the scope of caring for patients in the clinical setting. Future physicians need to know the healthy and atypical modes of embryological development in order to be able to correctly diagnose, treat, and explain aspects of future patients’ developmental disorders and diseases. Additionally, there are social aspects of medicine that may have ethical, moral, or political connotations. The faculty interviewees agreed that they wanted to provide medical students with the information and tools to be able to communicate with patients and form their own educated opinions and plans regarding how they would approach social issues relating to embryology (e.g., abortion, fetal screening, in-utero surgery) in medical practice.

Table 5.13: Phenomenological theme *Importance*

| |
|---|
| **To teach embryology as a foundation of human gross anatomy, aiming content toward the development of future clinicians responsible for forming their own approaches to the social aspects of medicine, <u>while striving to maintain departmental and professional impressions of embryology's importance to the application of modern medicine</u>.** |

The faculty who teach embryology continue to emphasize the importance of the subject matter through the messages they send in the classroom. Portraying embryology as being important to the department, school, and the medical profession as a whole relies on the clinician perspective and their willingness to also be proponents for the study of embryology in medical education. The quotations below illustrate the importance that faculty interviewees perceive to be placed on embryology in UME:

> "Based on the feedback I have had, just talking to people who are in clinical practice and so forth, the longer people are in practice, the more and more they appreciate understanding embryology. It is just so foundational in so many areas. You have to understand some essential things about developmental processes. Certainly, people in pediatrics, very much so, obstetrics, gynecology, general surgery, I have talked to surgeons on our faculty, the longer they are in the field the more they find themselves going back and reviewing principles of embryology because they are going to encounter things that are not text book normal and often times, probably more than not, you are going to encounter those situations when you are least expecting it. I think it is one of those subjects that get short changed early in medical education, I think largely because of time allowances and restraints, but I think it is a subject that consistently and constantly grows in importance as people go through their education and their career." [F01]

> "I think as far as the anatomists are concerned, I think they are on the same page, they think embryology is important…I think in the other courses it is the molecular aspect that is considered more important because that is where people's strength levels are located, once you get to the second year curriculum the pathologist and the instructor of the medicine course I think have an explicit recognition and appreciation for that and I think they feel the students should have a basic understanding

of the principles, not to detailed but at least the basic understanding." [F08]

All of the faculty that volunteered to be interviewed agreed that embryology is important in medical education, but reported that their feelings did not necessarily reflect the climate in their departments, institutions, or the medical education field as a whole. They often spoke about being the main proponents of embryology education at their schools. This was not surprising because these individuals are a very select group of experts on embryology and other anatomical or medical sciences. Their agreement to partake in the interview phase of this research demonstrates the investment they have in embryology in UME. It also shows their role in continuing to assure that embryology is taught in medical school as a foundation to the adult morphology, to facilitate the explanation of clinical conditions with embryological origins, in order to assist students in developing personal stances on social issues, and increasing the awareness of embryology as an essential and foundational science for medical education and practice.

**Final Thoughts Regarding Faculty Data Findings and Analysis**

Medical education leaders and researchers must listen to faculty, particularly those that are supplying the information, to better embryology education. These faculty are the individuals in the trenches working with the teaching materials and the medical student populations, and they are the people that can see most clearly where there is need for adjustment and change. The faculty interviews addressed several aspects of the research questions (below) for this study, and used the information given to generate both grounded theory themes and a phenomenology of teaching embryology in medical education.

1. What is the current status (e.g., placement, course hours, faculty cohort, content, materials, pedagogy) of embryology in medical education curricula as reported by faculty?
2. What experiences and perceptions do faculty and first-year medical students have in regards to the teaching and learning of embryology in medical education, including word associations, most interesting, and most confusing aspects of teaching or learning embryology?
3. What suggestions do faculty and first-year medical students have for the improvement of teaching and learning embryology in medical education?

The data collected and analyzed via the faculty surveys and interviews provided valuable perspectives, and with the blended approach of grounded theory and phenomenology the researcher was able to find commonalities that served to strengthen the validity of this research. Faculty in both surveys and interviews expressed views that embryology is not a major focus in most medical education environments, but that it is important and should be included (sometimes to a greater extent than it currently is) in the UME curriculum. While actual embryology course or content hours varied greatly, most faculty interviewed believed their allotted time to be too little. The explicit curriculum was illustrated in ways such as the time and resources allocated, to embryology and a general call for better embryology teaching and learning resources as well as increased faculty expert input during curricular planning. The implicit curriculum arose frequently in the faculty surveys and interviews. Some important aspects of the implicit curriculum found included the goal of teaching students how to think as clinicians about developmental defects and the perceived difficulty of embryological content to both faculty and first-year medical students.

The themes and patterns found in the faculty surveys and interviews described in this chapter form the background for the classroom experience of the medical student. The generation of a phenomenology regarding the teaching of embryology in modern medical education makes clear the fact that embryology may be the only anatomical subdiscipline that must constantly defend and advocate for its inclusion in the UME curriculum. In the next chapter, chapter six, the first-year medical student perspective is examined and compared to the relevant faculty findings and analyses to form a more complete tableau of the current perceptions about and attitudes toward embryology in medical education, that may in totality prove useful to future attempts at curricular reform and revival.

# CHAPTER 6: FIRST-YEAR MEDICAL STUDENT SURVEY FINDINGS AND ANALYSIS

The examination of the subject of embryology in UME is complex and requires the additional viewpoint of the first-year medical students learning embryology. When analyzed in conjunction with the faculty experiences and perceptions detailed in the previous chapter five and by comparing and contrasting these two simultaneously occurring, parallel points of view will lead to expansion of what is already known about embryology in UME, and provide valuable and fresh perspectives. As the previous chapters have stated, there is little information regarding the status of embryology in UME in the U.S. and Canada. The data collected from the stakeholders who are directly involved in and affected by the issues surrounding embryology in UME will serve to uncover aspects of the curriculum that previously went unnoticed or unstudied. Recall that the research questions of this study are:

1. What is the current status (e.g. placement, course hours, faculty cohort, content, materials, pedagogy) of embryology in medical education curricula as reported by faculty?
2. What experiences and perceptions do faculty and first year medical students have in regards to the teaching and learning of embryology in medical education, including most interesting and most confusing aspects of teaching or learning embryology?
3. What suggestions do faculty and first-year medical students have for the improvement of teaching and learning embryology in medical education?

All three of these questions were addressed in the previous chapter by the faculty participants, but the first-year medical students involved in this research have more limited knowledge of the decision making aspects of the UME curriculum. Therefore, this chapter focuses on the research questions by asking first-year medical students about their learning experiences and perceptions of embryology and assessing the differences between the beginning of course student (BCS) survey and the end of course student (ECS) survey. In the remainder of this chapter, the findings from the BCS survey will be presented, compared to the ECS survey, and finally these students' perspectives will be compared in their entirety to the faculty findings from the previous chapter. The research data analyses will be performed using a grounded theory approach, and the findings then placed within the theoretical framework of the explicit, implicit, and null curricula of UME. Both sets of BCS and ECS survey results included:

- descriptive data of the participants and identification of the type of institution they attend
- quantitative data regarding plans for study groups and use of educational resources, and Likert scale items regarding the utility of embryology in medical education and the medical profession
- qualitative data that explains word associations with embryology, what students find most interesting and most confusing about the subject of embryology, and their suggestions for the improvement of teaching and learning of embryology within the medical curriculum.

The descriptive and quantitative data were managed with IBM Statistical Package for the Social Sciences (SPSS) Statistics Version 23 (IBM Corp., 2013); qualitative data were managed with QSR International's NVivo 10 qualitative data analysis software (QSR International Pty. Ltd., 2014).

A grounded theory approach was used for the qualitative aspects of the survey to form theories about the teaching of embryology. A phenomenological analysis was not performed for the student sample because the researcher did not have the first person, face-to-face interaction with this sample as was done with volunteer interviewees from the faculty sample. Also, the students were assuredly much more diverse in terms of career goals and interpretations of their medical education career than were the faculty participants. The faculty participants were all terminal degree holders teaching embryology content at medical institutions across the U.S. and were able to provide more comprehensive views of the issues at hand regarding embryology in UME.

The original research plan was to link each student participants' beginning of course and end of course surveys, in order to analyze the change over the semester. The courses referred to were any course at medical schools that included embryology content. Since the integration of embryology into other courses, typically gross anatomy, is the norm in the U.S. the majority of the students participants completed the surveys according to the schedule of their gross anatomy course experiences. Unfortunately, due to timing of participant recruitment in the early fall and opinions regarding the timing of the study and student workloads by some faculty members, many students were not forwarded the information to complete the BCS survey by the faculty members who were contacted by the researcher. Out of the 114 students who completed the BCS survey and the 114 students who completed the ECS survey, only 32 students did both. In the future, the researcher plans to extract this subsample of students who completed both surveys and compare their data to see if their perceptions of embryology change significantly throughout the time they're enrolled in the course containing embryology content. But for the aforementioned reasons in this research project, the BCS and ECS surveys will be treated as separate entities and, while being compared to one another in totality and also to any related faculty survey data, will not be directly linked and compared for each student participant.

This chapter is presented in a similar order to the previous faculty chapter. In the following sections the presentation of the findings, analyses, and comparisons will generally follow this pattern:  introduction to the question, BCS survey findings and analyses, ECS survey findings and analyses, and comparison between the two student surveys and the faculty responses (when present).

**Descriptions of the Student Survey Participants and Their Institutions**

This section describes the demographic data collected primarily in the BCS survey. First-year medical students from across the United States participated in the online, open access surveys before the course (See Appendix B) and after the course (See Appendix C) through SurveyMonkey. Students were instructed to complete the first survey at or near the beginning of the course in which they learned the embryology content (typically around October 2014 or January 2015), and the second survey after the component of the course including embryology content was complete (typically around December 2014 or June 2015). The surveys did not require participants to answer every question in order to progress through the surveys, and therefore not all questions received 114 answers total.

As part of the BCS survey, students were asked to provide a seven-digit identifier that would be used to link their BCS and ECS surveys during data analysis. This design meant that the ECS survey did not collect information regarding the institution, type of institution, and previous experiences of students with embryology since it was already collected in the BCS survey. Unfortunately, out of 114 respondents for the BCS survey and 114 respondents for the ECS survey only 32 first-year medical students completed both surveys. Therefore, for the ECS survey participants who did not complete the BCS, the aforementioned categories of demographic data do not exist.

**BCS survey: Student demographics, experiences, and institutions.** Students took the BOC student survey in the fall 2014 at the start of their medical school coursework. The number of students that completed the BOC student survey was 114. Out of these, 47 (41.23%) were male, 66 (57.89%) were female, and 1 (0.88%) preferred to not answer the question of gender (see table 6.1). Students answered a question about the college or university at which they were currently enrolled. Eighteen (18) medical schools were represented in the BCS survey. When divided regionally in the United States, out of these 18 schools there were 3 in the northeast region with 17 (15%) students, 13 in the midwest region with 77 (68.75%) students, 2 in the south region with 18 (16.5%) students, and zero schools or students from the west region. The midwest region is overrepresented in that there were two institutions with very high responses – 31 and 40 students. In the midwest region, 2 institutions are overrepresented with 71 out of the 77 total students from the midwest region. However, one of these institutions is a medical school system divided into 9 centers throughout the state, each center with its own faculty cohort, student population, and methods of teaching. So these centers should be thought of as different units, which would alter the numbers above to reflect 11 different locations with 71 out of the 77 total students from the midwest region.

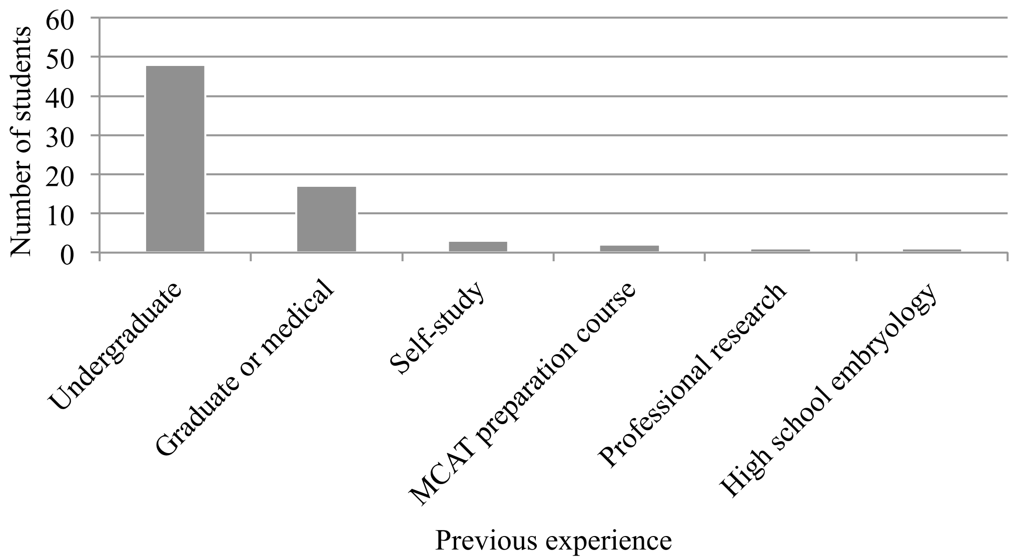
Students were asked if they were currently an allopathic or osteopathic medical student, what clinical specialty they were particularly interested in pursuing at the time they took the survey. One hundred and three of the students were attending allopathic medical schools and 11 were attending osteopathic medical schools. Students could choose up to three specialties in the survey and the most commonly cited specialties were internal medicine, emergency medicine, and family medicine.

Students also answered a question regarding their previous experiences with embryology, and a summary of the responses may be found in table 6.1. Students reported either one type of previous experience (64.28%) or no previous experiences with embryology (35.71%). Forty-eight (42.85%) students had taken an undergraduate course with a human embryology component, 17 (15.18%) took a graduate or medical course with a human embryology component, 3 (2.68%) reported to have self-studied the topic, two (1.79%) said they did Medical College Admissions Test (MCAT) preparations that involved embryology, one (0.89%) did professional research, and one (0.89%) said they studied embryology in high school. These self-reported facts on students' prior experiences with embryology are very open to interpretation. A component of human embryology may be interpreted by some to mean even a single lecture in a course, and so the continuum of experience is much wider than may appear to be indicated upon first glance at this data.

Table 6.1: Comparison between BCS and ECS surveys: Demographics

| Demographics | BCS survey | | ECS survey |
|---|---|---|---|
| Sample size (n) | 114 | | 114 |
| Gender | | | |
| Male | 47 | | 50 |
| Female | 66 | | 64 |
| Prefer not to answer | 1 | | 0 |
| Region of medical schools | | Number of students from each region | |
| Northeast | 3 | 17 | not collected |
| Midwest | 13 | 77 | |
| South | 2 | 18 | |
| West | 0 | 0 | |
| Type of medical schools | | | |
| Allopathic (M.D.) | 103 | | not collected |
| Osteopathic (D.O.) | 11 | | |
| Specialties | Internal medicine<br>Emergency medicine<br>Family medicine | | Surgery<br>Internal medicine<br>Obstetrics and gynecology |

Figure 6.1:  Student previous experiences with embryology




**ECS survey:  Student demographics.** For the ECS survey, 114 students completed the survey. Out of these, 50 (43.86%) were male and 64 (56.14%) were female. Unfortunately, due to the original intention to link the BOC and EOC student surveys, some data was not being gathered for the EOC student survey to eliminate needless repetition in the surveys. Therefore, as said before the data regarding the institution, type of institution, and previous experiences of students with embryology does not exist for the EOC. Students were asked what clinical specialty they were particularly interested in pursuing at the time they took the survey. They could choose up to three. The most commonly cited specialties were surgery, internal medicine, and obstetrics and gynecology.

**Comparison of student demographics, experiences, and institutions between BCS and ECS surveys, and related data from faculty surveys.** The student sample size is exactly the same between the BOC and EOC, which simplifies certain calculations despite not being all the same participants. Likewise, the gender proportions are very similar with just over half of the student participants reported as female. In the faculty survey, just over half of the participants reported as male. However, this is more or less reflective of the national proportions of the sexes in medical student populations and medical faculty.

In comparing the regional distribution of participants in both BOC student and faculty surveys, the western region is underrepresented and the midwest, northeast, and south regions are dominant. Both student and faculty samples included numerous participants from two schools in the Midwest. For the BOC student survey, these two school accounted for 71 out of the total 114 students. The prevalence of mostly allopathic medical school participants, followed by osteopathic medical school participants held true for both BOC and faculty surveys.

**Quantitative Data and Analyses of the Student Surveys**

The following sections provide the findings and analyses for the quantitative component of the student surveys by describing the BCS, then the ECS, and finally comparing the BCS, ECS, and data from the faculty surveys.

**Student plans for studying and use of educational resources.** In the BOC, students were given a time percentage scale broken into 20% increments and asked to estimate how often they would study alone, with a partner, or with a group. For the BOC (see figure 6.2), most students predicted they would study by themselves for the most part, then for a short amount of time with a partner, and very seldom with a group. In the EOC (see figure 6.3), students reported their actual (not predicted) times studying medical course with an embryology component. The predicted (BOC) and actual (EOC) breakdowns for self versus group studying held constant. Most students studied by themselves and seldom worked in partners or in a group.

Figure 6.2: BCS survey: Student group format predictions for studying

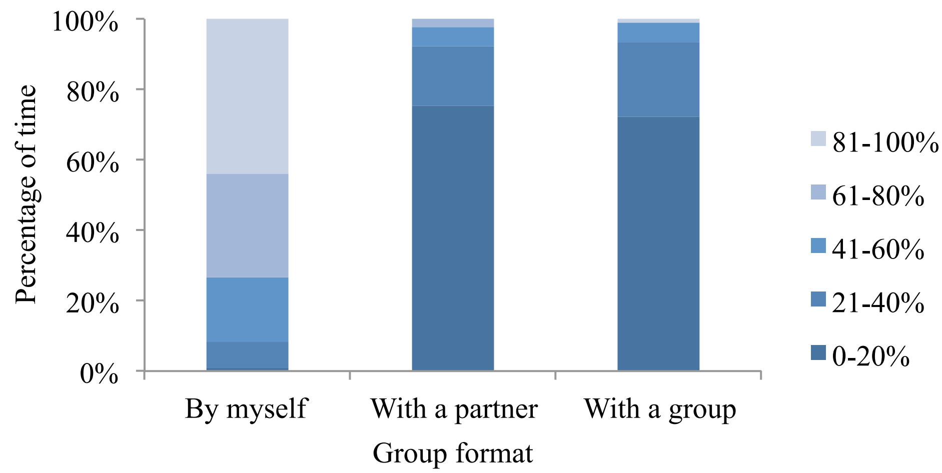
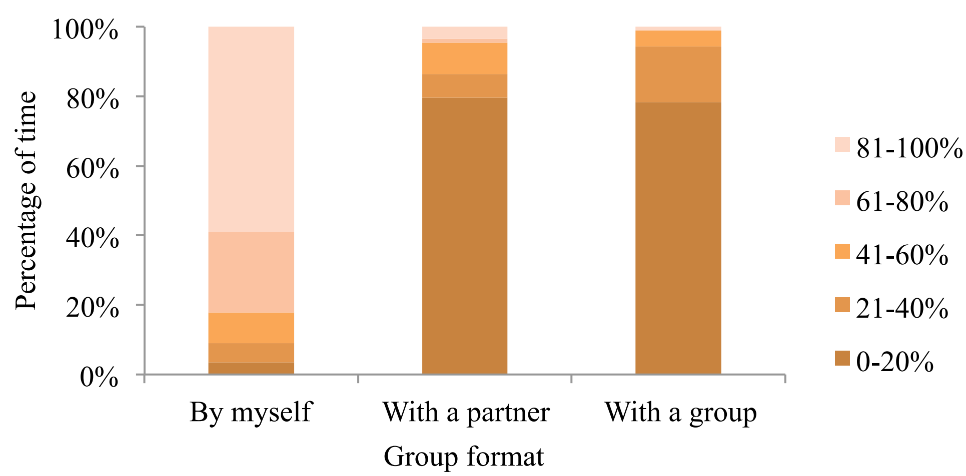



Figure 6.3: ECS survey: Student actual group format for studying




Students were then asked to predict what types of educational resources they would use to study for the human embryology component of the course in the BOC. Most students predicted that they would use their lecture notes, then online embryology animations, then self-generated materials such as drawings, flowcharts, and mnemonic devices, and the required textbook. There was less interest in using educational resources such as online or televised resources, additional textbooks, laboratory models and dissections, or resources that students volunteered in the ‘other’ category, such as class discussion, images from online searches, and recorded class lectures. After the embryology course or content was complete, students took the ECS survey and their predictions about the educational resources they would use from the BCS survey were confirmed in what educational resources they actually did use as reported in the ECS survey (see figures 6.4 and 6.5).

Figure 6.4: BCS survey: Student educational resource use predictions for studying embryology

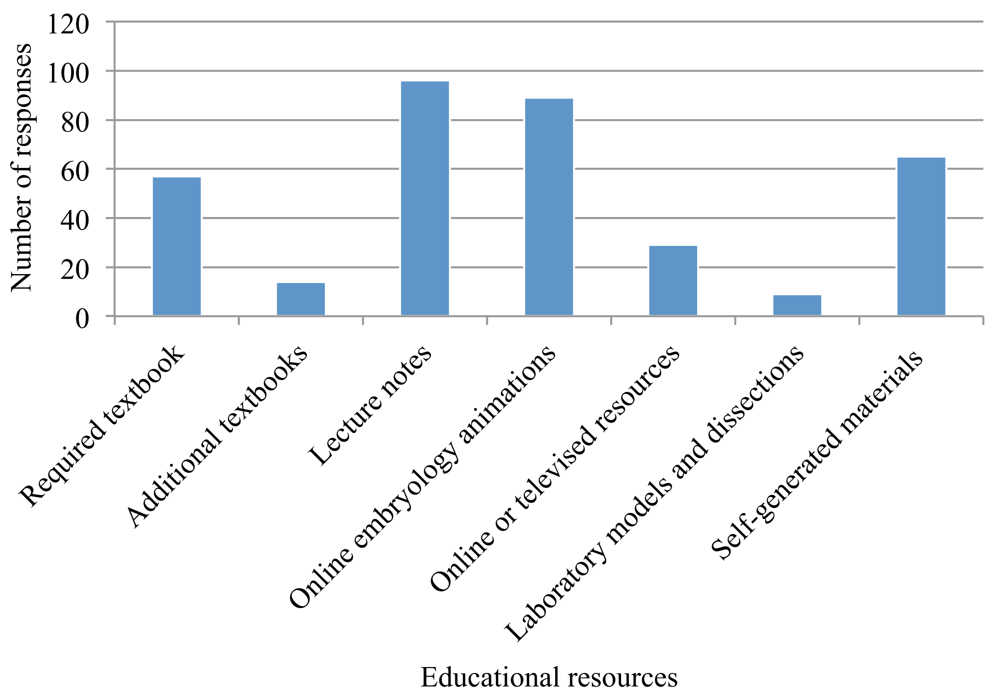
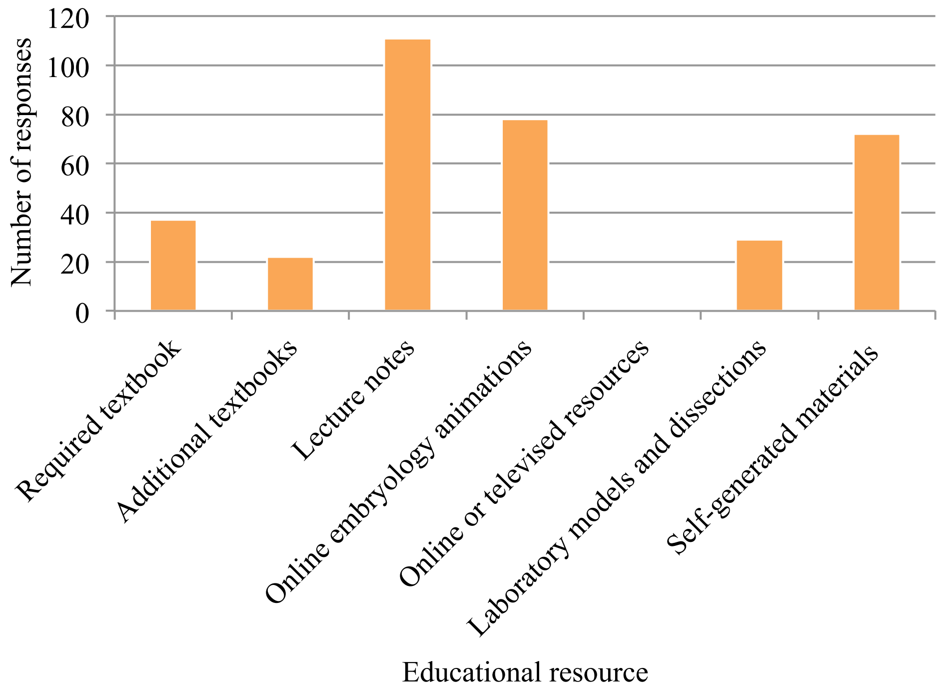


Figure 6.5: ECS survey: Student actual educational resource use for studying embryology




**Likert items regarding student opinions on the utility of embryology in medical education and medical practice.** The following six figures (6.6 through 6.11), illustrate the thirteen Likert items, divided into three themes, that BCS student participants answered on a six-point scale (including not applicable option). The three themes were: embryology in medical practice, personal opinions regarding embryology, and embryology in medical education.

Figure 6.6: BCS survey: Likert items for students regarding embryology in medical practice

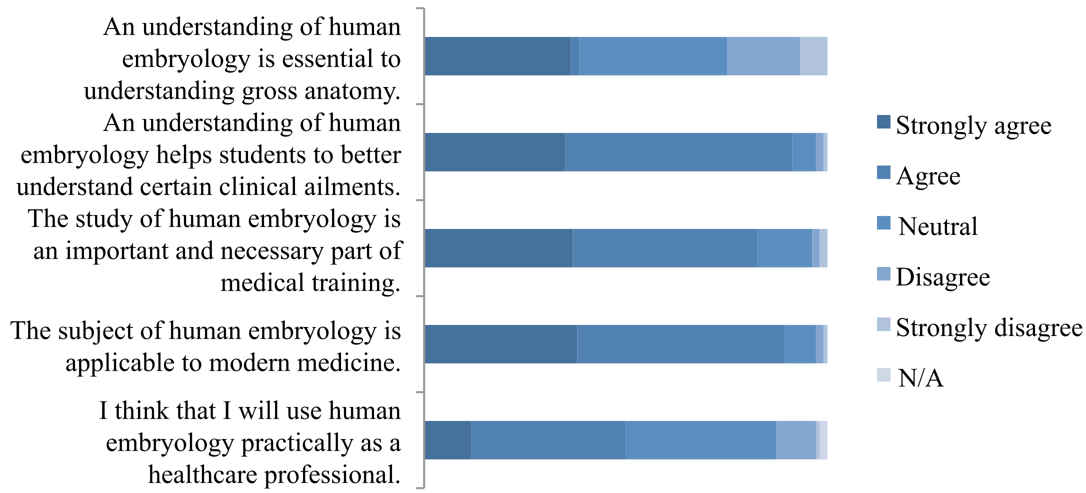
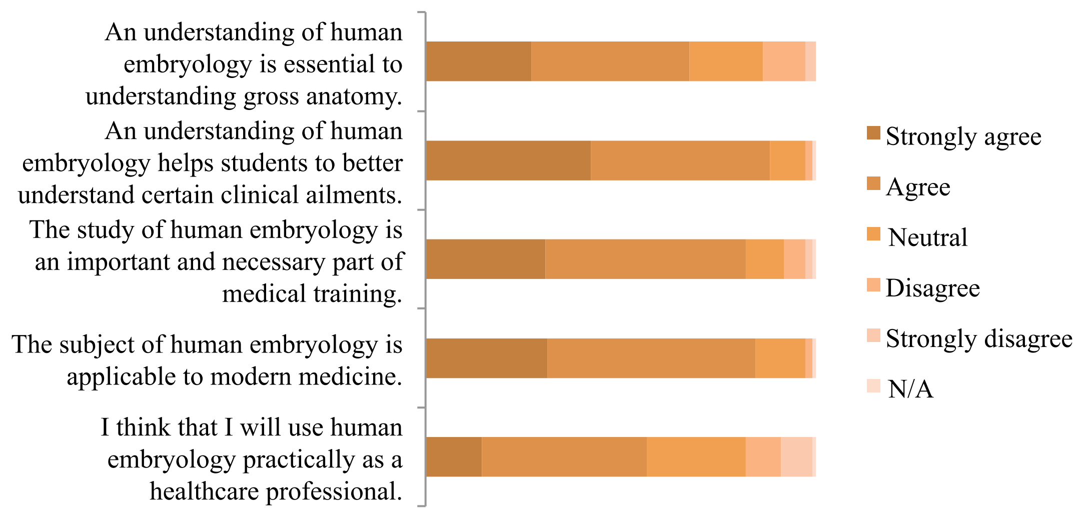



Figure 6.7: ECS survey: Likert items for students regarding embryology in medical practice




Figures 6.6 and 6.7 show five Likert items that ask students about embryology in medical practice. In the BCS survey (figure 6.6), most participants agreed that understanding embryology is essential to understanding both gross anatomy and, even more so, certain clinical ailments. In the ECS survey (figure 6.7), students felt even more strongly about this in the affirmative. This same pattern holds true in saying that the study of embryology is an important and necessary part of medical training and is applicable to

modern medicine. Despite these encouraging remarks, students were either neutral or agreed that they would use embryology practically as healthcare professionals, although in the ECS survey this did sway closer to the affirmative.

Perhaps, prior to learning embryology, medical students are skeptical of the topic's importance to their daily medical interactions with patients. After they have gone through the coursework and learned more about embryology, some students may begin to recognize the significance of this topic in medicine. As for the students who remained neutral for these Likert items, it is possible that at their schools embryology was not represented as an anatomical science that was important for their future medical practice. This may be indicative of traditions or opinions on the part of the faculty members involved in conveying the embryology content to students.

Figures 6.8 and 6.9 show four Likert items that ask students about their personal opinions regarding embryology. In the BCS survey (figure 6.8), most agreed that the subject of embryology is both interesting and difficult to understand. This did not change in the ECS survey (figure 6.9). In the BCS survey, the group was evenly split on finding embryology exam questions more stressful than gross anatomy exam questions, and in the ECS survey there were fewer in agreement or strong agreement. Most students were neutral or did not feel confident enough in their embryology knowledge to explain it to others in the BCS survey, but in the ECS survey more students agreed and less disagreed with this statement of confidence. One can conclude from this set of Likert items that in this sample of first-year medical students, the participants feel that they have learned enough to be competent in answering questions about embryology but not confident enough to claim complete proficiency in the subject matter.

Figure 6.8: BCS survey: Likert items for students regarding personal opinions about embryology

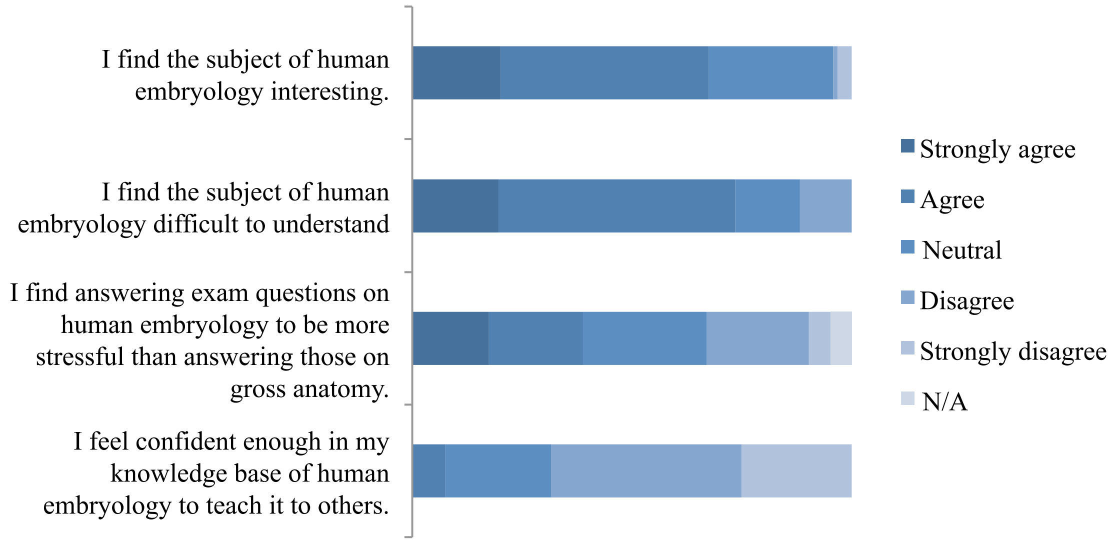
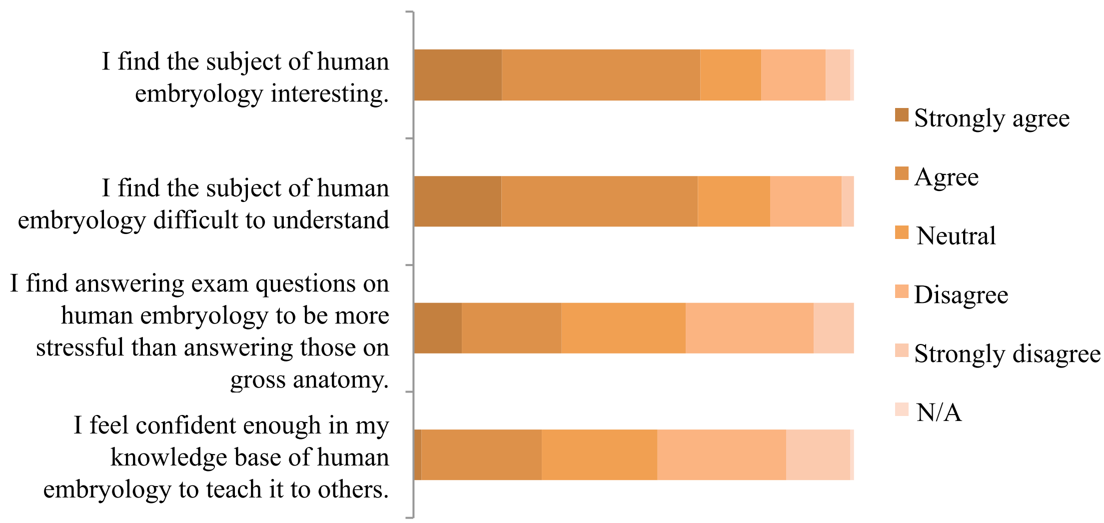



Figure 6.9: ECS survey: Likert items for students regarding personal opinions about embryology




Figures 6.10 and 6.11 show four Likert items that ask medical students about embryology in medical education. In the BCS survey (figure 6.10), most students were neutral or disagreed when asked if they would prefer more embryology to be in the anatomy lab, and were fairly neutral and evenly split when asked if they would eliminate

the subject from their anatomy course or medical schools. In the ECS survey (figure 6.11), there was a slight increase in the affirmative for increasing embryology in the anatomy lab, and a decrease in the affirmative of preferring the anatomy course to not teach embryology or to not have the course in medical school. Opinions on having a separate course for embryology were evenly split amongst the scale for both iterations of the survey. The desire for more embryology in the gross anatomy laboratory is encouraging as this could signify an acceptance of and desire for a more integrated curriculum, at least within the anatomical sciences.

Figure 6.10: BCS survey: Likert items for students regarding embryology in medical education

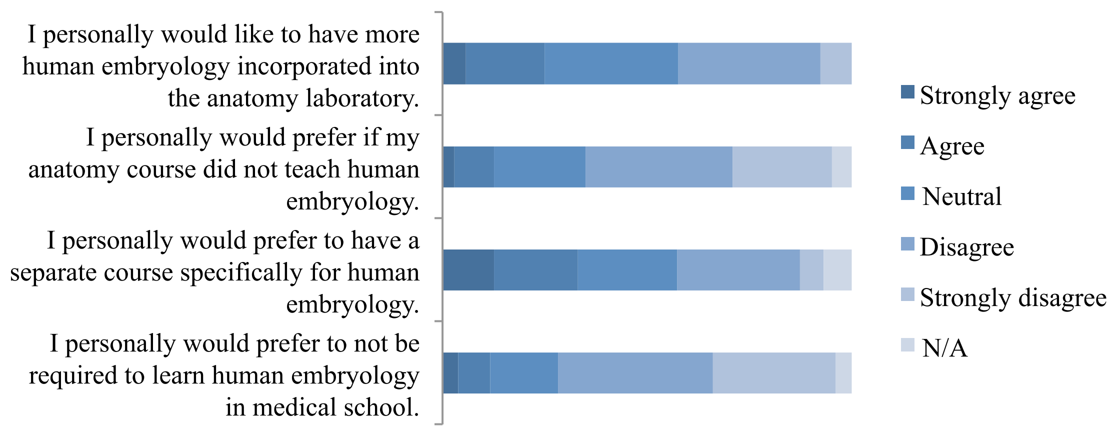
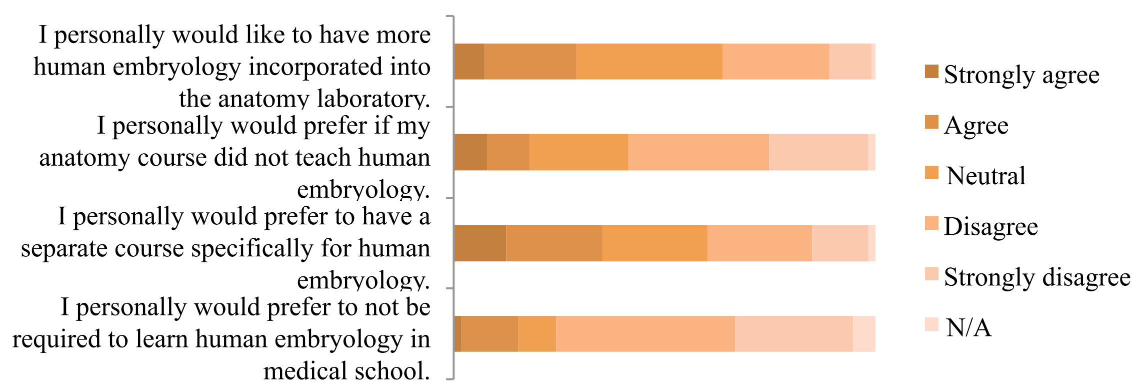



Figure 6.11: ECS survey: Likert items for students regarding embryology in medical education



**Comparison of plans for studying, use of educational resources, and Likert items between beginning and end of embryology instruction, and related data from faculty surveys.** The student and faculty ideas about what learning resources to use when studying embryology were comparable. Faculty wanted students to focus their efforts on using lecture notes, online animations, and the required textbook. Students complied but they also heavily utilized self-generated materials. Perhaps this is not surprising, as this is probably the first time that most students are encountering much of the embryology content delivered in medical school. Faculty are no longer novice embryology learners, and so they may have forgotten what the knowledge requires a new learner to do to organize the information in an efficient and effective manner (Qiao et al., 2014; Husmann, Barger, & Schutte, 2016).

As for the Likert item responses about the utility of embryology in medicine and medical education, it appears that for most instances the faculty and the students were on the same general track but the students did not feel as strongly about many of the items. Faculty cannot expect these novice learners to understand the nuances of embryology and its relevance to human structure unless students are invested in the course and trust that they are being taught content that will be used in their futures. In medical education some courses are able to take this for granted. For example, it is rare for a medical student to ask why they must learn gross anatomy. It is more common to hear these inquiries directed towards subjects such as geriatrics or embryology, sciences that are just as essential for the formation of a well-rounded future physician.

## Qualitative Data and Analyses of the Student Surveys

The qualitative portion of both the BCS and ECS student surveys included three and four separate questions, respectively. The first question on both the BCS and ECS surveys was a word association list, in which the medical students were asked to write ten words that they associate with embryology. Next in the BCS survey, the medical students answered two open-ended questions regarding what they found most interesting and most confusing about embryology. In the ECS survey, the medical students completed the above three questions and also a final question for any suggestions for the improvement of the teaching and/or learning of embryology in the medical curriculum. These four questions were also asked in the faculty surveys, as seen in the previous chapter. Throughout this section of this chapter, there will be comparisons made between the faculty and the student qualitative question codes and themes using a grounded theory approach.

**Word association list.** The survey question read, "List 10 words that you associate with human embryology. They may be vocabulary, anatomic terms/processes, affective/emotional terms, etc." The goal of this question was to see the immediate thoughts of students when they are asked to list words that they associate with embryology. The additional cue of saying that the words may be vocabulary, anatomic terms or processes, or affective or emotional terms were to give the participants the freedom to answer in any type of thinking that they desired.

The codes and subcodes for this question (developed using a grounded theory approach) were the same ones designated for the faculty word association list for three reasons (See Table 6.2). First, when reading through the BCS and ECS student survey word association lists, I did not see any large deviations from the types of terms in the faculty responses for this question. Second, if the codes and subcodes were already appropriate it seemed prudent to keep them identical and to not introduce complications where none existed previously. Third, using the same codes and subcodes for both the faculty and both student surveys will enable a comparison between the data and frequencies of the codes and subcodes that would be impossible if the codes and subcodes were different.

The BCS student survey produced 1,001 terms while the ECS student survey produced 1,010 terms. A full list of these terms and their associated codes and subcodes can be found in Appendix L: Student Word Association Data.

Table 6.2: Comparison of student embryology word association code and subcode frequencies and text examples

| Codes | Subcodes | **BCS frequency** | | **ECS frequency** | | Select examples |
|---|---|---|---|---|---|---|
| *Clinical* | | 102 | 10.2% | 70 | 6.9% | Birth defect, Pregnancy, Teratogens |
| *Descriptive* | | 247 | 24.7% | 242 | 24% | (see below) |
| | *negative* | 93 | 9.1% | 100 | 10% | Difficult, Frustrating, Nonsense |
| | *ambiguous* | 115 | 11.5% | 78 | 7.7% | Abstract, Intricate, Complicated |
| | *positive* | 49 | 4.9% | 64 | 6.3% | Foundational, Miracle, Relevant |
| *Vocabulary* | | 641 | 64% | 698 | 69.1% | Amnion, Development, Gastrulation |

***BCS survey word association list.*** The 99 BCS student respondents (not all students completed the question) had 1,001 terms. There were 641 *Vocabulary* terms, 247 *Descriptive* words, and 102 *Clinical* terms. Within the 247 *Descriptive* terms, 115 (11.5%) had *ambiguous* connotations, 93 (9.1%) *negative*, and 49 (4.9%) *positive*. These word associations were expected in the BCS surveys because the students are unfamiliar with embryology. They are just starting medical school and may be confused by embryology and other medical school subjects or they may have spoken with past students who disliked embryology, or heard anecdotally that embryology is a low yield topic on the national exams. The most common words in the BCS survey were “development” (40; 4%), “fetus/fetal” (33; 3.3%), and “notochord” (28; 2.8%). These are all classified as *Vocabulary* terms. “Notochord” may have been popular because it is a fairly early embryological structure to develop and students would know this word early in the course. There were many other words in *Vocabulary* that had numerous responses, but the next highest word in a different category was the word “difficult” which was in the *Descriptive negative* subcode, with 19 (1.9%) of the total words. The most common *Clinical* term was “baby/babies” with 17 (1.7%).

***ECS survey word association list.*** The 101 ECS student participants (not all students completed the question) provided 1,010 words. There were 698 *Vocabulary* terms, 242 *Descriptive* terms, and 70 *Clinical* words. Within the 242 *Descriptive* terms, 100 (10%) had *negative* connotations, 78 (7.7%) *ambiguous*, and 64 (6.3%) *positive*. The most common words in the ECS survey were “development” (41; 4.06%), “mesoderm” (24; 2.38%), and “ectoderm” (23; 2.28%). Other than the massive amount of *Vocabulary* terms, the next highest word was “interesting” (16; 1.58%) which was from the *Descriptive positive* subcode. The most common *Clinical* term only had 10 responses and was “congenital”. The words “mesoderm” and “ectoderm” are two of the three germ layers (the third, “endoderm”, had a frequency of 22), which do not show up until week three of development. So it is possible that students had not even known these words when they took the BCS student survey, but after week three of development these terms will constantly show up in the organogenetic period as extremely important derivative layers.

***Comparison between BCS and ECS survey word association lists, and faculty survey.*** All three groups' (faculty, BCS, ECS) highest frequency was in the *Vocabulary* code. At the beginning of the course, students are in the mode of learning vocabulary terms since embryology is like a foreign language and requires a great deal of learning unfamiliar words. Students are not quite sure how to describe embryology, and they simply have not had the content in medical school yet. When they did describe embryology, their choices were either ambiguous or negative. At the end of the course, when compared to the beginning, students were able to list more vocabulary terms. Although they listed slightly less *Descriptive* words, they decreased the frequency of *ambiguous* terms and increased the frequency of terms with *positive* connotations.

Students who responded to the ECS survey were getting closer to the faculty mindset regarding embryology, compared to the students from the BCS survey. Students in the ECS were similar to faculty because they produced more vocabulary terms and more positive descriptors of embryology and less ambiguous descriptors. Faculty still had almost three times more clinical terms than either of the student surveys, but this may be a way of thinking that is more educator oriented. Faculty want students to know the normal embryologic processes and be able to figure out clinical correlations, but students do not have the clinical words solidified yet. These patterns indicate that students are taking on massive amounts of content from the explicit curriculum, but in relation to the implicit curriculum perhaps the faculty mindset is rubbing off and increasing students' positive associations with the subject matter. It should be noted that for many of the students that participated in this research, their faculty members forwarded them the recruiting materials, so the faculty is probably already interested and invested in embryology within medical education.

**What students find most interesting about embryology.** The open-ended question on the survey said, “What do you find most interesting about human embryology?” The goal of this question was to gather a wide variety of textual data in order to see what students believe the most intriguing parts of this field of study are, both at the beginning and at the end of their first time learning embryology content in medical school. Some first-year medical students will not have had any preconceived notions or experiences with embryology, some students in the BCS survey may be predicting to the best of their knowledge for this question and the following question. After reading through the student responses multiple times, four main codes were assigned: *Anatomy*, *Clinical*, *Education*, and *Personal*. These are the same codes as those developed for the faculty responses, because the same themes and patterns were present, albeit in different frequencies. Again, in contrast to the word association list, this time multiple codes were assigned to the same answer if it included content from different ones. A full list of these terms and their associated codes for both the BCS and the ECS can be found in Appendix M: Student Most Interesting Data.

***BCS survey most interesting***. When coding the students’ answers out of the 112 codes, there were 74 (66%) in *Anatomy*, 25 (22.3%) in *Clinical*, 1 (0.9%) in *Education*, and 12 (17%) in *Personal* (See Table 6.3). It was rare for any student response to this question to have multiple codes, but 8 out of the 19 answers that did warrant assignment of more than one code were a combination of the Anatomy and Clinical codes. This can be explained by remembering that while taking this survey medical students were in the midst of studying and learning embryology (since the BCS survey was administered at the beginning of the course, possibly even during the first few weeks of the semester). The things that the medical students found interesting may not have had to do with how they are learning the content or what it means to them personally, but rather the discrete facts and processes in which they are immersed at the time.

During the first round of coding, the researcher only found one clear instance of a *Personal* code. However, when undergoing the next few rounds of coding, the researcher noticed more students citing how “amazing” embryology is or calling it a “miracle.” So the vision of the *Personal* code broadened, resulting in the addition of 11 more words to the *Personal* code. Recall that in grounded theory data analysis, the researcher must immerse himself or herself into the data in order to be able to accurately assess the themes and patterns in the data. Rereading the word that were eventually coded into *Personal* was not a stretch of the coding process, but rather an intentional choice on the part of the researcher to spend time considering all the possible meanings of the words that were finally assigned to the *Personal* code. This process resulted in seven more *Anatomy/Personal* answers and four more *Clinical/Personal* responses, bringing the total number of overlapping codes in this question to 19. This, too, can be explained by thinking of the students’ perspective at this time in their educational careers. These students would be learning a great deal of facts about embryology and simultaneously realizing that it is a very complex and intricate process.

Table 6.3: BCS survey "most interesting about embryology" code frequencies and text examples

| Codes | BCS frequency | Select text examples |
|---|---|---|
| *Anatomy* | 74 | …discovering how some adult anatomical structures unexpectedly arise from embryology (why diaphragm is innervated by C3,4,5 but is located much more inferiorly)<br><br>How one fertilized cell can turn into an entire human being through many many processes all happening at the same time. And that it happens inside a woman's body! |
| *Clinical* | 25 | Hard to pick a certain aspect. Pregnancy and fetal development is fascinating as a whole. When the professor points out clinically relevant points in development it really grabs my attention.<br><br>I have enjoyed learning about the developmental process in relation to the different birth defects or abnormalities that can arise at different points of the developmental process. It helps put the different processes in to context. |
| *Education* | 1 | How we learned all of it |
| *Personal* | 19 | It is very elegant, and kind of divine. |

Medical students revealed through this question that they are being influenced in major ways by the explicit curriculum (found mostly within the *Anatomy* and *Clinical* codes) and the implicit curriculum (found in the *Personal* code) at the beginning of their embryology studies. The implicit curriculum was found when students mentioned phrases that revealed an admiration or wonder for the subject matter (e.g., "it gives me a new appreciation for the human body," "amazing to see how human life develops," "like a miracle"). This is not something that is taught in the classroom, but rather an underlying current that influences how students think about the material. As these individuals become future physicians, this is a very encouraging mindset to see developing at the start of their medical educations.

***ECS survey most interesting.*** Student answered this question with a total of 104 codes, the frequencies which included 68 (65.4%) in *Anatomy*, 29 (27.9%) in *Clinical*, 2 (2%) in *Education*, and 5 (4.8%) in *Personal* (See Table 6.4). It was again rare for any student response to this question to have multiple codes, but eight out of the 11 answers that did warrant assignment of more than one code were a combination of the *Anatomy* and *Clinical* codes, which was similar to the BCS student surveys. When proceeding through multiple readings of the material, as in the BCS analysis, the researcher found more examples of *Personal* code responses which accounted for 3 of the 11 answers with multiple codes, each from the *Anatomy/Personal* code combination.

There was a difference between the BCS and ECS question of what students find most interesting about embryology that is both intriguing and perhaps concerning. From the BCS to the ECS, students found more things interesting in the *Clinical* code and much less in the *Personal* code. Remember that the differences between BCS and ECS surveys may be to an extent attributable to the fact that the two student samples do not consist of the exact same individuals. The *Clinical* increase may be explained by the fact that they learned more over the course and, as future physicians, rightly found this type of content to be compelling. However, this came at the expense of the sense of excitement and wonder illuminated through the *Personal* code. It is possible that as students progressed through the course, they found scientific answers to the processes they previously described as “astonishing” and “pretty incredible.” It is also a potential explanation that we are seeing an illustration of an early stage of the all too common transition from eager first year medical student to jaded advanced medical student (Jennings, 2009).

Table 6.4: ECS survey "most interesting about embryology" code frequencies and text examples

| Codes | ECS frequency | Select text examples |
|---|---|---|
| *Anatomy* | 68 | Building on an understanding of gross anatomy, it can strengthen an understanding for locations and relationships in gross anatomy.<br><br>I liked how embryology answered many of the 'why' questions I developed throughout anatomy. For example, embryology answered 'why' there were so many confusing structures in the heart and 'how' the heart came to look the way it did. |
| *Clinical* | 29 | Even though I think the abnormalities in anatomy are the most challenging part to comprehend, they really do help explain a lot of clinical phenomena. (like the testes referring pain to the T10 dermatome, because that is where they developed, etc.) I also really enjoyed learning about the congenital defects.<br><br>It explains why certain anatomical things ended up the way they did, or why certain diseases/malformations occur. |
| *Education* | 2 | When portions of anatomy integrated with other classes, it really helped me learn and remember things for those courses. |
| *Personal* | 5 | It is a miraculous feat and beyond imagination how it could happen. |

***Comparison between BCS and ECS survey most interesting, and faculty survey.*** When directly compared, the BCS and ECS student survey responses for what students find most interesting about embryology reflect a gradual increase in clinical curiosity or knowledge and a decrease in personal wonder. This suggests that in comparison to the faculty responses to this question, students later in their studies had more in common with the faculty than they had at the beginning of their studies. The exception to this was that faculty did not report a decrease in the personal wonderment of embryology. In both the ECS student survey and faculty survey, the frequency of codes was high in Anatomy, moderate in Clinical, and low in Education and Personal. Faculty had a higher frequency of codes related to educational issues, which is to be expected since that is the focus of their careers and the focus of the survey they were taking. This pattern – medical students moving closer to the faculty perspectives as they progress through their educations – may hold true for other questions in this research project. If it does, this pattern is a clear view of the implicit curriculum in which a combination of the experiences medical students go through and their interactions with faculty, clinicians, and patients form the attitudes and beliefs they hold as future physicians (Eisner, 1985; Hafferty & Castellani, 2009).

**What students find most confusing about embryology.** Another open-ended question on the survey asked, "What do you find most confusing about human embryology?" The goal of this question was to gather a wide variety of textual data to see what parts of this field of study are most difficult for students, both at the beginning and at the end of their first year of medical school. After reading through the student responses multiple times, the researcher assigned four main codes: *Content*, *Education*, *Research*, and *Visualization*. There were 4 subcodes within *Content* (*molecular, processes, time, vocabulary*) and 2 within *Education* (*classroom, resources*). These codes are the same as the faculty codes because the same themes and patterns were present, albeit in different frequencies. As seen in the previous question, multiple codes were given to the same answer if it included content from different codes. A full list of these terms and their associated codes for both the BCS and the ECS can be found in Appendix N: Student Most Confusing Data.

Table 6.5: BCS survey "most confusing about embryology" code frequencies and text examples

| Codes | Subcodes | BCS frequency | Select text examples |
|---|---|---|---|
| *Content* | | 71 | (see below) |
| | *molecular* | 6 | All of the very many morphogens and keeping them straight |
| | *processes* | 42 | The sheer amount of changes that the embryo undergoes in such small time frame. Also, tracing the derivatives of each germ layer, etc. |
| | *time* | 13 | It is really difficult to visualize what is happening, and many processes are all happening at the same time, so it is challenging to wrap your head around what is happening when and where and what that would look like. |
| | *vocabulary* | 14 | There are a lot of terms that are solely used in embryology, it is like learning yet another language |
| *Education* | | 11 | (see below) |
| | *classroom* | 3 | It's not the topics so much that are confusing, it is the pace at which we are expected to learn everything. It would be more beneficial, I believe, to either introduce it before beginning gross anatomy or require reading for it before the overload of classes begin. Maybe even a summer online class. |
| | *resources* | 10 | The dynamic nature of the topic can be hard to follow, especially when figures in text books aren't clear about what plane you're looking in. Well made animated videos would be very useful, but most of them online are not quite up to the textbook standards |
| *Research* | | 1 | How did we learn all of these minute details about how we developed? |
| *Visualization* | | 31 | Being able to visualize these processes in three dimensions. It would be exceedingly helpful to have a realistic 3D model of these events, rather than simple cartoons.<br><br>I really could not understand the formation of the primitive streak; I wasn't able to visualize the changes occurring during gastrulation. When the epiblast cells proliferate, I can't visualize the formation of the streak, notochord, or the lateral folding that occurs later. It's very difficult to conceptualize and visualize these changes in 3D when we only see them in two dimensions--on paper or a computer screen. |

***BCS survey most confusing.*** In the 93 student responses, there were 114 different elements to be coded which means there were several answers with overlaps between codes. The frequency of each code was: 71 (62.3%) for *Content*, 31 (27.2%) for *Visualization*, 11 (9.7%) for *Education*, and 1 (0.9%) for *Research*. Within the *Content* code's subcodes, there were 13 related to *time*, 42 for *processes*, 6 for *molecular*, and 14 for *vocabulary*. For the *Education* subcodes, there were 10 for *resources* and 3 for *classroom*. Within the 19 responses with multiple codes, all except 4 contained *Content* and all except 3 contained *Visualization*. The answers that overlapped had the following patterns: 10 *Content/Visualization*, 4 *Visualization/Education*, 3 *Content/Education*, and 2 *Content/Visualization/Education* (See Table 6.5).

Since the aspect of embryology that students found most confusing was the actual content they are learning and the lack of ability or assistance in visualizing these structures and processes, these findings represent a failing of the explicit curriculum. Perhaps when students participated in the BCS survey, they were into the course far enough to be able to answer this question thoughtfully, or maybe they heard from past students that these aspects of embryology are a struggle for the field. The high frequency of confusion via a dearth of visualization resources is very important to note, because it demonstrates a real need within the medical embryology education system (Foo et al., 2013; Qiao et al., 2014).

Table 6.6: ECS survey "most confusing about embryology" code frequencies and text examples

| Codes | Subcodes | ECS frequency | Select text examples |
|---|---|---|---|
| *Content* | | 83 | (see below) |
| | *molecular* | 5 | I am confused about how some of the signaling works |
| | *processes* | 44 | All of the different processes happening at the same time. It is very difficult to envision where the different processes are happening and what that would look like.<br><br>I would say the shifting of structures from their original locations was difficult to grasp. |
| | *time* | 25 | It is difficult to understand the topic quickly because many things are happening at once, and the language that is used is new to me. |
| | *vocabulary* | 9 | The number of new words that were often very similar to each other often confused me, I needed a very deep understanding of the meaning of each word in order to keep the terms straight. |
| *Education* | | 15 | (see below) |
| | *classroom* | 7 | The beginning portion seems random and arbitrary. By organogenesis, things start to meld a little better and you have more "oh that makes sense because of X and X," where in the beginning you just think, "okay you said that so I'll just memorize it and believe you." |
| | *resources* | 8 | Timelines--understanding how different aspects of development are progressing at simultaneously. Also hard to imagine development in 3D since texts mostly use simplistic pictures. |
| *Research* | | 1 | Many of the things are just so conceptual that it's frustrating to understand it all! |
| *Visualization* | | 25 | It was hard for me to picture the 3D development of structures some times. The videos that we were provided were very helpful to picture how things develop in space.<br><br>Three dimensional thinking and comprehending everything that happens simultaneously when you are learning about it in isolation from each other |

***ECS survey most confusing.*** In the 94 student responses, there were 124 different codes which means there were several answers with overlaps between codes. The frequency of each code was: 83 (67%) for *Content*, 25 (20.2%) for *Visualization*, 15 (12.1%) for *Education*, and 1 (0.8%) for *Research*. Within the *Content* code's subcodes, there were 25 related to *time*, 44 for *processes*, 5 for *molecular*, and 9 for *vocabulary*. For the *Education* code's subcodes, there were 8 for *resources* and 7 for *classroom*. Within the 13 responses with multiple codes, all except 3 contained *Content* and all except 4 contained *Visualization*. The answers that overlapped had the following patterns: 4 *Content/Visualization*, 3 *Visualization/Education*, 3 *Content/Education*, 2 *Content/Visualization/Education*, and 1 *Content/Research* (See Table 6.6).

These patterns are almost identical to the BCS student survey responses. This indicates that despite learning the embryology content and assumingly passing the courses, students find the same aspects of embryology challenging. The difficulty of the content cannot be changed except perhaps the level of detail that faculty require students to know at their institution. But the visualization struggles that students face can and should be addressed by individuals with the embryological content knowledge and technological skill to formulate improved educational resources (Foo et al., 2013; Quiao et al., 2014).

***Comparison between BCS and ECS survey most confusing, and faculty survey.*** There were no major differences between the BCS and ECS student answers regarding what they find most confusing about embryology. Both surveys saw the majority of respondent' focus on content and visualization and the struggles that students identify for themselves in relation to learning embryology did not change much throughout their first year of medical school. The faculty responses to this question did differ in that they found the content to be the most confusing, and the distant second most confusing aspect was visualization followed closely by education. Students did not mention education very often in their answers, but they are not employed as teachers and would not be expected to focus on that element of embryology.

**Suggestions for the improvement of teaching and/or learning of embryology.** The ECS survey asked one additional open-ended question: "Do you have any suggestions or ideas for how to improve the teaching and/or learning of human embryology within the curriculum?" The goal of this question was to gather as wide of a net of ideas and suggestions as possible. This question was only asked in the ECS survey and it was assumed that at the beginning of the course students would not have known enough about embryology in medical education to give constructive ideas for its improvement. I read through the 89 one to two sentence responses in the ECS survey several times, until I had a feel for the major groupings and ideas, and these were essentially the same as the faculty responses. The two main codes were *Curriculum* and *Resources*. *Curriculum* was further divided into four subcodes: *administration*, *clinical*, *instructor*, and *placement*. *Resources* was further subdivided into five subcodes: *animations*, *high tech*, *interactive*, *low tech*, or *textbook*. Similar to the most interesting and confusing questions, this time the researcher did assign multiple codes to the same answer if it included content from multiple codes. A full list of these terms and their associated codes and subcodes can be found in Appendix O: Student Suggestions for Improvement.

In 89 responses, there were 106 different codes. There were 55 in *Curriculum* and 51 in *Resources*, for 51.89% and 48.11% respectively (See Table 6.7). The *Curriculum* subcodes with the highest frequencies were placement and instructor. Students at the end of their first semester or first year of medical school struggle with where embryology content should be placed within the broader context of the other coursework and responsibilities they have. They also suggested having faculty with more embryology teaching experience or more skill in disseminating information be the individuals instructing embryology. Within *Resources*, the highest frequency by far was in animations. Related to the visualization theme found in the previous question about what student find most confusing about embryology, students would like better animations with which to envision the complicated embryological structures and processes taking shape through time.

Table 6.7: Student "suggestions for improvement" code and subcode frequencies and text examples

| Codes | Subcodes | ECS frequency | Select text examples |
|---|---|---|---|
| *Curriculum* | | 55 | (see below) |
| | *administration* | 0 | N/A |
| | *clinical* | 6 | Keeping the material related to clinical medicine only |
| | *instructor* | 22 | Just have the best embryo teachers (not physicians) to teach us. They are much better at building a firm foundation of embryology for the students. We had several guest embryo lecturers who are great physicians/surgeons but they are not necessarily good at teaching. |
| | *placement* | 27 | Don't treat it as a course that is just thrown on top of anatomy.<br><br>I have taken developmental biology before, and in my opinion foundational orientation was not emphasized enough in this class. It was often difficult to decipher where in space lecture material was derived from, and without this concept firm, it made learning the material difficult. |
| *Resources* | | 51 | (see below) |

| | | | |
|---|---|---|---|
| | *animations* | 23 | Showing more supplementary videos of what is going on would also help in visualizing everything.<br><br>The more animations, the better. This really helps me visualize the structural changes that are happening during development. |
| | *high tech* | 3 | The more advanced 3D models and videos that can be shown would aid in the process of understanding. |
| | *interactive* | 3 | Some study groups or small group discussions of the material might have helped in synthesizing the information as well. |
| | *low tech* | 5 | The diagrams were generally very difficult to follow. I'm not sure if that's just the nature of the material, but clearer (perhaps more simple) imagery could be very helpful. |
| | *textbook* | 17 | I would recommend that the book be more integrated with the lectures, so that a student is getting two presentations of the same resource, which would make studying easier. |

***Comparison between ECS survey suggestions, and faculty survey.*** The ECS student survey frequency distribution between each code and subcode is similar to that of the faculty. Students and faculty both struggle with where embryology should be placed within the curriculum. However, they are on opposing sides of the curricular integration and reform debate. Faculty feel that integrating embryology with the rest of the basic science coursework is advisable, ideal, and makes intuitive sense for how one can best make meaning of the content. Students are not in favor of integrating embryology, and in the ECS survey answers often mentioned their preference of having separate courses instead of the growing prevalence of the integrated curriculum. However, it seems curricular integration is likely to remain a reality for the foreseeable future. The first years of a major reform effort are admittedly often fraught with resistance from many groups involved in the process. Instead of arguing against integration, medicals students would be better served to assist in the formation of the curriculum by providing constructive suggestions for the optimal placement of embryology within the integrated curricular framework (Mennin & Krackov, 1998). Students had a disproportional frequency in the subcode for *instructor*, stating specific opinions on the effectiveness or lack of effectiveness of certain embryology instructors. Based on the use of faculty's proper names in many of the responses, this was mostly from one of the overrepresented school student populations in the sample. Further analysis demonstrates that this is not indicative of a theme across the United States but rather at one of the schools in this study. It is possible that, because embryology is so difficult, the effectiveness of an instructor can truly make or break a student's perception and understanding of embryology.

Both students and faculty desire better teaching and learning resources; in particular, animations and other advanced technological ways to teach and learn embryology. Students also suggested that embryology textbooks should publish new editions more often and include additional electronic supplements. But perhaps because faculty don't often look for more resources, and they are comfortable teaching with the ones with which they are familiar. Medical students have the tendency to over source, or attempt to compile too many references, which can become overwhelming. This is why it is important for experts to produce embryology resources for the elite medical education level that are inclusive of the most contemporary research and clinical aspects of embryology without being overly complex for what will be needed in students' future medical careers. Development of these resources requires a great deal of energy, time, money, and multiple perspectives and stakeholders, which for the anatomical subdiscipline of embryology is sometimes difficult to muster when compared to others such as gross anatomy.

**Final Thoughts and General Comparison Between Faculty and Student Surveys**

Faculty and first-year medical students approach medical education from different paths, but with the same common goal: to produce future physicians. For faculty, this goal entails disseminating massive amounts of information and assisting students in the development of critical thinking skills and the beginnings of clinical thinking skills during their early basic science curriculum. For students, their part in this plan is to learn the basic sciences content and to begin to develop their physician persona. The evidence presented in the preceding two chapters regarding the faculty survey and interview data and the student survey data shows that there are many similarities between these two groups in their mindset regarding embryology. The similarities are especially evident when comparing the ECS student surveys, taken at the end of their embryological studies in the first year of medical school, and the faculty surveys. Throughout the first year it appears that students begin to perceive embryology, and possibly other subjects outside of the scope of this study, more like experienced faculty members than like the novice learners these students were at the beginning of the year.

The struggle that can be found in this similarity between faculty and more advanced first year medical students is that the commonalities are often not apparent when observing UME. There is still a disconnect between the faculty and students regarding what faculty want the students to learn via the explicit curriculum, how faculty want students to think about embryological content via the implicit curriculum, and other aspects related to the explicit, implicit, and null curricula.

The following chapter summarizes the overall findings of this research, focusing on the placement of the findings and analyses from the faculty surveys and interviews and the first-year medical student surveys into the framework of the explicit, implicit, and null curricula in UME. The final chapter of this research concludes with evidence-based recommendations for the treatment of embryology in undergraduate medical education's current and future curricular reforms and future directions for related research.

# CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS REGARDING EMBRYOLOGY IN UNDERGRADUATE MEDICAL EDUCATION

The experiences with and perceptions of faculty teaching embryology and first year medical students enrolled in courses with embryology content are essential to forming a comprehensive view of the treatment of embryology in modern undergraduate medical education. The reduction in overall contact hours and the introduction of other essential coursework and content into the early years of this curriculum necessitates a closer look at subjects like embryology, subjects whose time and resources are declining in the face of these changes. The purpose of this study is to investigate and describe the perceptions and experiences of these individuals in order to describe the current climate and to form evidence-based recommendations for the future of UME.

This chapter provides a summary of the findings and analyses addressing the research questions of this study that investigated the curriculum and classroom views of embryology in UME. These results were analyzed within the theoretical framework of the explicit, implicit, and null curricula in chapter five, for the faculty, and chapter six, for the first-year medical students. The remainder of this final chapter of the research will focus on using the major findings from both grounded theory and phenomenological approaches to form evidence-based recommendations for embryology in UME. The chapter will conclude with future directions for this and related research, and final thoughts about the improvement of the teaching and learning of embryology in medical education.

## Summary of Data Findings and Analyses

The 34 faculty from 23 different institutions and first-year medical students (114 for the beginning of course student (BCS) survey and 114 for the end of course student (ECS) survey) from 18 different institutions who took part in this research assisted the researcher in describing the current status of embryology in UME from the points of view of these two stakeholder populations. The following two sections of this chapter summarize the quantitative and qualitative findings and analyses within the framework of the explicit, implicit, and null curricula in UME. Comparisons and contrasts are made between the faculty and the first-year medical student responses in the remainder of this chapter. Any general trends or patterns are noted, and their connections explained or reasoned through using the historical context of embryology in UME and curricular reform.

## Embryology in the Undergraduate Medical Education Curriculum

Discussions about the design of any given curriculum can be fraught with historical and obscure issues that may not be apparent to those not directly involved with the specific institution. This research asked faculty and students about embryology coursework, but did not delve into the administrative and professional medical organizational aspects of how medical schools decide the placement, time allotment, teaching cohort, materials, and content of embryology courses (or courses/blocks/units that include embryology content). Therefore, the data and evidence given should be treated as a select sample of the available perspectives.

The information about how these decisions are typically made was found in the faculty surveys and interviews, and mainly involved the explicit curriculum with sometimes a peek into the implicit curriculum. The grounded theory approach generated themes around the choices made about embryology, namely that in general, embryology is taught in the U.S. typically within an integrated curriculum. The placement of embryology within the medical curriculum and the individuals teaching embryology were often decided by committees at the institution, although faculty involvement in these decision making bodies varied from the embryology faculty heading the committees to a complete lack of input or a token membership on a committee in which the faculty's opinions were disregarded, as discussed with faculty interview participants. However, faculty were often tasked with the choices regarding the actual content of embryology courses or course content, which was ultimately restricted by boundaries imposed by the overall committees and time constraints within the curriculum. The goal of teaching embryology was not only providing students with a foundation for understanding the adult gross anatomy, but also to provide students with a base of knowledge for the clinical issues that will present to their medical practices when embryological processes go incorrectly. Faculty participants varied on their opinions as to how much molecular content should be taught to medical students, but most agreed that any content within medical education must provide a clinically relevance to future medical practice. The faculty participants reported that they, in general, had more power in the daily classroom activities and content than the decisions made about the embryology component of the UME curriculum. These content decisions are discussed below, within the framework of the three facets of the curriculum described throughout this research.

**Embryology in Undergraduate Medical Education's Explicit, Implicit, and Null Curricula**

This research also addressed the experiences and perceptions that faculty and first year medical students have within the classroom and regarding content decisions in embryology in UME. There were a myriad of themes within each open-ended questions asked in the faculty and student surveys the faculty interviews. When viewed as whole, there was a great deal of data that described the explicit curriculum, much for the implicit curriculum, and little evidence addressing the null curriculum. This was expected, as the very nature of the null curriculum is often amorphous and elusive. Further studies are suggested later in this chapter to elicit more information about the null curriculum surrounding embryology in UME.

**Embryology and the explicit curriculum.** The explicit curriculum in UME consists of the publicly announced program of study and its materials. Faculty and first-year medical students have very different perspectives on the explicit curriculum, because the former uses it as the source for what is being conveyed while the latter is attempting to take it in and form knowledge about embryology for, potentially, the first time. The following paragraphs describe overarching patterns found in the research that illuminate embryology's place in the explicit curriculum of UME as seen by faculty and first-year medical students.

When asked about educational resources for learning embryology, faculty most often required the use of class lecture notes and the required textbook, while discouraging the use of additional textbooks and online or televised resources (e.g., online animations). Students predicted (in the BCS) and reported that they actually used (in the ECS) the resources of class lecture notes, online or televised resources, and self-generated materials the most. As first-time learners, they found comfort in using familiar resources such as the faculty-supplied knowledge in the form of notes taken during class, or the technology-based references their generation is familiar with and proficient in. It is not clear why there is a disconnect between the faculty's predilection to learning with the required textbook and students' eschewing of this resource in favor of others. It is possible that for the current generation of medical students textbooks are seen as too static, and not updated often enough to stay relevant. These students may prefer web-based and dynamic learning tools, rather than reading texts. Whether true or not, there is definitely a perception of a dearth of embryology textbooks and resources when compared with the other anatomical sciences. This will be discussed again later in this chapter in the recommendations for embryology in UME.

Faculty found syllabi and embryology course materials at their own institutions to be adequate and representative. But when the researcher compiled a set of these syllabi and course materials, direct comparisons were impossible due to the extreme variation in the curricula (e.g., traditional, different integration formats) and explanatory presentation of course materials. Students claimed that they planned to and did study mostly by themselves when learning embryology content. Depending on the institution they are attending, they may have study or laboratory groups that they are required to interact with, and working pairs was a distant second choice for most, but this research did not go into that much detail for the individual students.

The faculty word association lists of ten words that they thought of in regards to embryology most often related to content, the very substance of the explicit curriculum.

The word association lists from the students also focused on content. However, it is important to note that between the BCS and ECS, first-year medical students who responded to the ECS survey were moving closer to the faculty mindset regarding embryology, compared to the students from the BCS survey. This was observed in the relative increase in ECS survey responses that focused on vocabulary terms for the word association exercise. More details about this question are in the next section, about embryology and the implicit curriculum.

When asked about the most interesting and the most confusing thing about teaching embryology, for both questions the majority of the faculty participants reported that it related to actual embryological content. Students during both the BCS and ECS surveys agreed, and for the question about confusions, these students also cited difficulties visualizing embryological structures and process accurately. Both groups reported that they found the application of embryological content relating to the adult morphology and to certain clinical conditions the most useful aspects of teaching and learning the subject in medical education. Therefore, the suggestion of focusing the embryology course or course content on these two main tracks is supported by both the faculty and first year medical students.

Faculty suggested many things to improve the teaching and learning of embryology in UME, most notably improved resources (e.g., animations, textbooks) and increased faculty input towards curriculum planning and implementation. Students also struggled with where embryology truly fit in the curriculum. However, as discussed in the previous chapter, these two groups are on opposing sides of the curricular planning debate. Faculty feel that integrating embryology with the rest of the basic science coursework is advisable, ideal, and makes intuitive sense for how one can best make meaning of the content. Students are not in favor of integrating embryology, and in the ECS survey answers often mentioned their preference of having separate courses instead of integrated courses. Another area for improvement in the teaching and learning of embryology that fits in the explicit curriculum was that both faculty and students desire better teaching and learning resources (e.g., new editions of textbooks with electronic supplements, interactive animations).

After synthesizing faculty and student opinions, the ideal embryology curriculum in UME would begin with a clear placement within the overall medical education experience. Whether the embryology content is distributed amongst other courses or within an integrated curriculum, or has a stand-alone embryology course, or is taught solely in an online format, the reasoning behind the placement of this content must be justified to be advantageous to the faculty and students. The learning objectives would focus on teaching embryology in order to accomplish two explicit curriculum goals: to learn the embryology as it pertains most directly to the adult morphology and to learn the clinical correlations that will most often be seen in medical practice. This means that (as several faculty interview respondents reported) there would be a greater focus on body systems such as cardiovascular, urogenital, and digestive because they have a greater prevalence of birth defects. Resources available for teaching and learning embryology in the ideal explicit curriculum would consist of one comprehensive textbook that provides online animation access, clinical correlations throughout the text, and directions for how students can build and make their own low technology learning materials (e.g., clay dough to learn the germ layers, an apron to demonstrate the development of the gastrointestinal system) (Cassidy, 2015).

**Embryology and the implicit curriculum.** Comparison between the faculty and the first-year medical students in relation to the implicit curriculum, the informally learned values and behaviors, raises important points to consider for UME reform. The implicit curriculum can exist between any group of people, locations, or materials for UME. In this research the implicit curriculum was primarily studied as it can be found in faculty-to-faculty, faculty-to-student, and student-to-student interactions. This section summarizes the findings and analyses relating to the implicit curriculum in this research.

When asked about educational resources, faculty placed most of their trust in the required textbook and lecture notes, while students preferred the lecture notes and online or televised resources (e.g., animations, videos). This implies that for both groups, the specific course or unit's lecture notes were the most trusted source of information. Students' relative non-use of the textbooks is concerning, since faculty value this resource higher than students do. Faculty participants' preference was not for the online or televised resources that students used to study, showing a generally implicit dismissal of these resources that may not be completely peer-reviewed before being placed in the public forum.

The syllabi that faculty provided did not yield much detailed information on the implicit curriculum, although in many UME programs professionalism is becoming more of a focus for the development of future physicians. When asked about their level of confidence when teaching embryology, most faculty were moderately to very confident. The faculty interviews followed up on this question, and many participants said their high level of confidence came from years of experience teaching embryology. As the implicit curriculum includes the informal expectations of the school, the confidence level and years of experience teaching embryology correlation means that medical schools probably expect faculty to improve every year based on experience. However, with the molecular metamorphosis of embryology, large amount of embryology content material available but relative lack of common resources, and other important responsibilities of being a faculty member it is difficult to stay completely up-to-date in embryology content (Tavares, 2004).

The implicit curriculum found in the Likert items asked of both faculty and students (see chapter five for faculty data and chapter six for student data) found that most of the faculty participants strongly agreed or agreed that understanding embryology is essential to understanding both gross anatomy and certain clinical ailments. This same pattern held true in saying that the study of embryology is an important and necessary part of medical training and is applicable to modern medicine. Despite these encouraging remarks, just over half of the faculty participants agreed that students will use embryology in actual medical practice. The Likert items then illuminated a change in the first-year medical student attitudes toward embryology over the course of the time they were learning the content. The BCS student participants showed a respect for the academic difficulty and content of embryology, but did not necessarily see the implementation of the subject in medical practice. The ECS student participants showed the same respect for the subject, but their attitudes toward the usefulness of embryological knowledge in medical practice were more favorable and closely mirrored that of the faculty. This trend of the ECS survey participants' attitudes and perceptions regarding embryology in both medical education and medical practice moved further from the BCS students' and closer to that of the faculty. It is possible that this is due to student experiences and exposure; simply, the more one knows about a subject, the more one is able to see the connections between content and theoretical application and medical practice. This research did not follow individual students journeys, but it stands to reason that there may be an important facet of addressing the shift in student attitudes lying within the way the faculty at their institutions presented the embryology content. If the faculty was more enthusiastic and championed the utility of embryology in medical education and practice, then first-year medical students would be more likely to buy in to the idea as well.

The word association question was rich in data for the implicit curriculum (see chapter five for faculty data and chapter six for student data). Both faculty and students most commonly listed vocabulary terms, as described in the prior section on the explicit curriculum in UME. But in the descriptive words, the two samples diverged when their words were coded for positive, negative, or ambiguous connotations. Faculty listed descriptive words with mostly positive connotations (e.g., amazing, essential), rather than negative (e.g., boring) or ambiguous (e.g., challenging) nuances. Between the BCS and ECS surveys, students' descriptive terms became more positive, less ambiguous, and unchanged in the neutral connotations. The student responses became more similar to the faculty descriptive word responses by the end of the course. This affects the implicit curriculum in much the same way that the Likert items above did, due possibly to student exposure and experiences with the embryology content. In the word association exercise, certain faculty and students cited words such as "miracle" or "wonder," which imply a positive and mysterious meaning. While it is unknown why participants listed these particular words, it insinuates that there are values and perceptions of teaching and learning embryology being formed in UME.

When asked what are the most interesting and confusing things about teaching embryology, faculty focused on the explicit curriculum, described in the previous section. The implicit curriculum was present when some faculty described teaching embryology as "telling a story" with the structure and processes. This approach to instruction was often cited as a very effective method of portraying human development. As mentioned earlier, faculty did find the content to be the most confusing aspect of teaching and learning embryology which is a potential issue. If faculty struggle with the content or predict that their students will find embryology inherently difficult, then their attitudes while teaching may subconsciously bias students against embryology or make the subject too daunting and lead to weaker learning outcomes. When students were asked the same questions, there was a difference between the BCS and ECS survey participants. The ECS survey responses had an increase in the explicit curriculum (e.g., stated that they found the content to be the most interesting but also the most confusing), but a decrease in an attitude housed in the implicit curriculum (e.g., their sense of wonder and awe at human development decreased over the course of learning embryology). It is possible that as students progressed through the course, they found scientific answers to the processes they previously wondered about. In comparison to the faculty responses to these questions, students later in their studies taking the ECS survey had more in common with the faculty than they had at the beginning of their studies taking the BCS survey.

Finally, suggestions for improvement in the teaching and learning of embryology did not fit well into the implicit curriculum of UME. However, the most common suggestions from both faculty and students were for improved and more available resources. While this is an explicit curriculum task, one possible reason for the relative dearth in embryology materials is that there may be a lack of motivation for the development of these materials. The need for new resources but relative lack of formation of these resources illustrates an overlap between the explicit and implicit curricula. The curriculum placement struggle in UME can also be labeled as an implicit issue because subtle and often subconscious message are sent to stakeholders when content is distributed seemingly piecemeal into the existing curriculum or when that content is the only topic that is placed into a purely online format without adequate justification.

The ideal implicit curriculum for teaching and learning embryology in UME, according to faculty and first-year medical students, would include small behind-the-scenes adjustments to the typical functioning of a medical school. In the ideal UME embryology curriculum, faculty would teach inherent compassion and empathy (i.e., professionalism as is being done in many curricula already) when discussing human birth defects and how to talk to patients. Students would implicitly learn all perspectives (physical, mental, social, ethical) for issues like abortion and fetal screening, so that as physicians they will be able to independently form their own thoughts on these multifaceted medical conditions and procedures. Keeping these skills as part of the implicit curriculum, the responsibility placed upon students being able to communicate their thought processes on topics not being overtly taught in the classroom would be an essential part of developing an independent and confident physician.

**Embryology and the null curriculum.** The null curriculum is what schools do not teach, whether this is on purpose or by accident. In this research on teaching and learning embryology in UME, the null curriculum was difficult to identify and analyze. This was not exceedingly surprising, as the null curriculum is often elusive and amorphous, changing according to institutions, regions, faculty and student populations, and – perhaps most importantly – the current climate of UME evaluation and reform. It is much simpler to identify tangible objects and concepts that are present, as seen in the explicit and implicit curricula, than it is to attempt to describe everything that is not present when researching the teaching and learning of a subject in UME. Also, first-year medical students typically have no idea what UME traditionally does and does not include in the educational experience so they would be less likely to know what is not included in their personal contact. Faculty participants are assumed to be more knowledgeable about UME norms, and so the majority of the null curriculum findings come from their data. The following paragraphs summarize the null curriculum findings for this research and conclude with some ideas for the best practices for the null curriculum in UME.

Although both faculty and students claimed there was a need for more and improved embryology resources, the production of these has not been fruitful. Perhaps this is due to publishing companies not being interested, authors being difficult to find, or a myriad of other reasons. But the lack of choice in resources can be argued to place some of embryology in UME into the null curriculum. If new resources are not being developed, then they are not being used to teach. Faculty generally reported that they did not teach about social issues, mostly by choice because they either did not feel it fit within the scope of their embryology content or they believed students would get the information in other courses and learning experiences.

The word association exercise from faculty participants only yielded two words that alluded to the null curriculum: "deemphasized" and "side-lined." These words only accounted for 2 out of the 309 words, about 0.65% of the responses, but they demonstrate the idea that embryology is not given much attention in UME curricula, thus alluding to the null curriculum of what schools do not teach. In the query of what faculty and first-year medical students find most interesting and most confusing about teaching and learning embryology in UME, there were no patterns or themes that pointed to the null curriculum. However, several faculty interviewees expanded upon their thoughts from the survey and mentioned that they would sometimes leave out embryology content that they found to be confusing for students in past courses. While these choices regarding what content is appropriate for medicals students being prepared for medical practice are the job of the individuals designing the curricula and courses, for better or worse the embryology content that is not being taught is, by definition, resigned to the null curriculum.

The best practices for an ideal null curriculum regarding embryology in UME will most likely change more than the explicit or implicit curricula do because the null curriculum is by nature a very dynamic facet of the framework. The null curriculum should not always be considered to be a negative thing, although if something is placed into the null for the wrong reasons then a negative label may be appropriate. If certain content, such as obscure and rarely prevalent birth defects, are not taught in UME coursework but the students are given the knowledge to work out what is causing a birth defect using their knowledge of healthy embryology, then there is no problem with those defects being in the null curriculum. In fact, this situation may lead to students developing research skills and furthering their curiosity of medical knowledge. When thinking about social issues such as abortion, it is a wise approach to keep political and religious discussions outside of the classroom. While first-year medical students should be aware that there are issues surrounding abortion in society, classroom discussion of the political and religious connotations related to abortion may send the class down an unintended pathway. This could even lead to the obstruction of a healthy environment for the teaching and learning of embryology in UME.

**Phenomenology of teaching embryology in modern medical education.** Phenomenology is the study of experiences as they present themselves in individuals' direct awareness, with an emphasis on understanding individuals' subjective perceptions and the effect of those perceptions on behavior. Phenomenology explores the lived experience of participants and attempts to describe this so well that the reader is able to imagine and share in the event (Starks & Trinidad, 2007; O'Leary, 2005). The phenomenology in this research was developed through intensive one-on-one interviews with faculty volunteers who have taught or currently teach embryology in medical schools across the U.S.

The phenomenology generated using faculty interviews was as follows, seen below in Table 7.1. The three aspects of this phenomenological analysis, when combined into the above language, can be read as a mission statement for the individuals responsible for this aspect of medical education. This is the essence of the experience, or phenomenon, of teaching embryology in medical education today. Adopting this phenomenology and using it as a call to action or as an abbreviated guide for how faculty can approach the classroom may make inroads toward the development of explicit guidelines for this anatomical subdiscipline. The following section details evidence-based recommendations and suggestions for the improvement of teaching and learning embryology at the high levels found in medical education.

Table 7.1: Phenomenology of teaching embryology in modern UME

| |
|---|
| **To teach embryology as a foundation of human gross anatomy, aiming content toward the development of future clinicians responsible for forming their own approaches to the social aspects of medicine, while striving to maintain departmental and professional impressions of embryology's importance to the application of modern medicine.** |

**Recommendations for Best Practices in Embryology Education**

Based on the data and evidence produced during surveys and interviews with faculty as well as multiple surveys of first year medical students, this section contains suggestions and ideas for improving how embryology can be approached through the lens of UME curriculum planning and the daily lens of teaching and learning in modern UME. The suggestions begin with a broad view of UME then become more specific and target the explicit, implicit, and null curricula in turn.

1. **Increase transparency and faculty input towards medical curriculum planning.** This first recommendation is a general recommendation for all types of reform, which relates to embryology amongst many topics. Many of the tensions described during the embryology faculty interviews were in relation to a lack of faculty input during the decision-making processes of medical curricular reform. The involvement of faculty throughout all steps of designing a new or revising a former medical curriculum

will ensure that those actually implementing the new standards have bought in to the change and had a chance to express their points of view and opinions. The justification of curricular changes must be transparent and ideally backed by a combination of quantitative and qualitative data in order for long-term success and faculty and student support.

Based on the literature review and this research with faculty and first-year medical students, attempts to standardize aspects of medical education have been met with mixed results (Guze, 1995; Matson et al., 2013; Lempp & Seale, 2004; Whitehead et al., 2013; Woodbury & Gess-Newsome, 2002). The standardization of the teaching and learning of embryology should not be attempted unless all aspects of UME are being examined and assessed for standardization. Evaluation of learning objectives and competencies covered in embryology courses or units that contain embryology content should be continued in order to progress with the best interests of all stakeholders in mind.

The fourth chapter of this research was about the development of a premedical undergraduate embryology course for students prior to UME. If students began medical school with a background and foundation of embryology from their premedical undergraduate coursework, perhaps they would minimize some of the disconnect (mentioned earlier in this chapter and in chapter six) seen between the BCS students and faculty. The basic sciences are all experiencing a decrease in allotted time in UME, and perhaps making embryology a recommended course prior to medical school could alleviate some of the struggles faced in UME trying to fit more content into less time. However, it is impractical to require a human embryology course as a prerequisite to medical school because not very many undergraduate institutions have human embryology-focused courses. Additionally, gross anatomy is seldom a requirement for medical school. As gross anatomy and embryology are often integrated in UME, the argument could be made that due to the amount of content, gross anatomy should be made a prerequisite far before embryology is made a prerequisite to medical school admission. The benefit to this could be a simpler transition into the medical coursework and greater academic successes in the early years of UME.

**2. Focus the explicit curriculum of embryology as it relates to the foundation to adult gross anatomy and relevance of clinical correlations.** Embryology can be a very difficult concept to teach and learn, for many reasons including the simultaneous changes and transient structures observed during human development. Since both faculty and students found the content of embryology to be one of the most challenging aspects of teaching and learning the subject, a clear focus of the explicit curriculum is necessary. When the goal is to form future physicians by providing both a foundation for the adult gross anatomy and a framework around which to scaffold the development of clinical anatomic anomalies, embryology makes more intuitive sense and can more easily find its niche amongst the rest of the basic science coursework. The molecular aspects of signaling and pathways in embryology should only be taught to the extent that they assist in student understanding of clinical presentations. Most faculty in this research agreed that molecular embryology should not be the main focus of the embryology content students learn, but should serve as an additional pool of knowledge where students can turn if they need further explanation or if they progress to specialties that focus on fields such as clinical genetics. Medical education curricula must be deliberate about what content is taught, and be able to justify the inclusions and exclusions in their curriculum.

In addition, the syllabi for embryology courses or courses and units that teach embryology content need to be more consistent and should convey the need and purpose for the course. These course materials should highlight the explicit curriculum and attempt to make clear aspects of the implicit curriculum that will be addressed in the course. When accrediting bodies and institutional committees try to assess and evaluate the need for courses containing various degrees of embryology content, having clear syllabi and course materials will provide clear, tangible evidence that will assist the faculty in making the case for embryology education in UME reform.

**3. Develop improved embryology teaching and learning resources for the explicit curriculum.** Without many quality, contemporary teaching and learning resources that faculty can choose from, particularly animations and interactive formats, teaching embryology (which is an often abstract anatomical subdiscipline) becomes problematic. Students struggled with visualization of embryological structures and processes, and faculty reported that their students have trouble visualizing embryological content and applying it to anatomy and clinical presentations. When students' learning can be supplemented by well-done resources, then that mental leap of visualization can be lessened and students can spend that cognitive and mental workload on other tasks, such as integrating other parts of their basic science curriculum into what they are learning about embryology (Foo et al., 2013; Quiao et al., 2014).

This is not to say that the current resources available are not high quality. There are several textbooks, online animations, tutorials, and other sources of embryology content that greatly assist in teaching and learning embryology. The issue it that there are not enough of these resources, they are not updated often enough to satisfy either the faculty or the students, and the variation in materials is not enough to appeal to different types of learners. Textbook and hard copy resource publishers must listen to the individuals asking for these resources and continue to develop the market availability. The development of online animations and interactive tutorials are especially in demand by students, who desire to see a progression in embryology structures and processes through time. The use of static images and the leaps of imagination used to go between these images reportedly requires too great of a mental workload when students study embryology. The resources being called for do not necessarily have to be cutting edge technology or involve futuristic programming; a simple, hands-on tutorial using common classroom or office materials is helpful as long as it furthers student understanding. Many faculty perform activities like this, but are not aware of what other instructors have done. Educational databases like the Multimedia Educational Resource for Learning and Online Teaching, MERLOT.org, or MedEdPORTAL provide instructors a central location where they can find creative ways of teaching content to their students (MERLOT, 2016; Association of American Medical Colleges, 2016). Posting embryology teaching techniques, tools, activities, and tutorials to websites like this would enable a more efficient way of sharing ways to help the novice student learners move more quickly to being experts in the content area.

For example, an embryology educator could provide the lesson plan used when teaching medical students about the differences between fetal and infant circulation. This would include the learning objectives, access to a high quality, three-dimensional animation that diagrams blood flow through the fetal thorax, and instructions for how to assist students in making a simple schematic of the vessels involved using an adult torso model, pipe cleaners, clay, and paper labels. The animation would include the ability for students to pause and rotate the images, an appropriate color scheme for oxygenation rates, and progression through time. Students would no longer have to rely solely on two-dimensional textbook diagrams and legends to illustrate this information, but can use that resource as a foundation with which to build upon using the interactive animation. After studying the processes, the students would spend the remainder of the class time in groups using their torso model to show the adult circulation and the pipe cleaners, clay, and paper labels to illustrate where fetal circulation differs from that of the adult. This use of multiple resources and modalities gives faculty more creative ways to help students internalize the content being learned. It also assists students in taking the content one step further and thinking about the physiological aspects of the transient organ, the placenta, and the anatomical and embryological roles this organ plays in human development and the birthing process.

**4. Continue to develop aspects of the implicit curriculum for embryology.** UME has made large strides towards the development of medical students behaviors such as professionalism, but more emphasis should be placed on the compassion and empathy aspects of professionalism. In teaching and learning embryology, faculty and students must remember that there are at least two patients involved when thinking about an embryo or fetus: the woman carrying the embryo or fetus, and the individual itself. All students, but especially those considering a specialty in medicine that focuses on these populations, should be reminded that pregnancy is an extremely vulnerable state and their patients will need to have physicians caring for them who are both knowledgeable about the processes occurring to develop a human being and about the social and public health issues surrounding pregnancy in modern society.

Within the explicit curriculum of embryology, courses often discuss critical periods, during which development of certain organ systems are much more vulnerable to teratogens, agents that can disturb healthy development of an embryo or fetus. The teratogens themselves may not be explicitly taught in the UME curriculum, but these are what pregnant patients will want to know about. For example, a woman may want to know how much coffee she can safely drink while pregnant. It is the responsibility of her physician to be able to consider what they know about normal embryological development, integrate that with their knowledge of teratogens, and advise the patient accordingly. Some of this knowledge may come during the clinical experiences of students in the later years of UME, but they should be given a basic foundation of knowledge (e.g., definitions of words like teratogen, knowing where to find more information for their patients) in their UME coursework in embryology.

**5. Be deliberate about and provide justification for the embryology content and related topics relegated to the null curriculum.** As stated previously in this chapter, the null curriculum is not inherently a negative entity. However, it is beneficial to stakeholders and policymakers in UME when the choices made as to what is and is not included in the explicit and implicit curricula are able to be explained and justified. For the teaching and learning of embryology, faculty reported that the social issues (e.g., abortion, fetal screening, in utero surgery) related to this anatomical science are not typically discussed or they are intentionally left out of the classroom. However, this omission may lead to medical students not learning about these important aspects of embryology until much later in their clinical years – if ever. Removing some of these topics from the null curriculum and placing them in the explicit curriculum could enable future physicians to have enough of a knowledge base to be able to communicate with patients about these concepts and provide better overall healthcare. Many nursing educational programs already think about teaching social issues to their students, and although the educational experiences are still not quite ideal the nursing education field is attempting to make the education of its students comprehensive enough to provide adequate care for patients in need of these conversations (Foster, 2016).

The above suggestions for improving embryology in medical education come from themes and patterns found in the faculty and students surveyed and interviewed. There are more important, quality ideas to be found that were not categorized as themes because not as many individuals reported them. But the solicitation of experiences with and perceptions of embryology from those actually in the process of teaching and learning this content is invaluable for the insider perspective it offers.

**A Call for More Qualitative and Mixed Methods Research in Undergraduate Medical Education**

The use of the blended approach of both grounded theory and phenomenology allowed the researcher to collect and analyze larger and more descriptive data than a purely quantitative research study would have (Kennedy & Lingard, 2006; Glaser & Strauss, 1967). The qualitative aspects of this research enabled the researcher to generate concepts and theories about embryology education that would not have been possible without collecting both types of data. Medical education researchers should acknowledge the utility, effectiveness, and relative efficiency of using mixed methods or qualitative data to research problems in UME that require multiple points of view. Research studies that collect large amounts of textual data that contain themes and patterns may necessitate the use of qualitative data analyses such as grounded theory and phenomenology, and the usefulness of these approaches must be accepted and promoted in the medical education research field (Grbich, 2007; Starks & Trinidad, 2007; O'Leary, 2005).

**Limitations**

The methodology of any mixed methods research study must be consistent, systematic, and designed to account for research subjectivities. The researcher must recognize his or her personal bias and worldview, consider how this might affect the research process, and attempt to balance subjectivities to ensure the integrity of the theories and essences being produced (O'Leary, 2005). Within the process of phenomenological and grounded theory data analysis, both the researcher and the participants will construct meaning. It is the responsibility of the researcher to minimize his or her impact on the setting and any possible overinterpretation of the situation in favor of highlighting the views of those researched (Grbich, 2007). Limitations of this study were discussed in detail in chapter 3 and include: the one year limit for data collection reported here; the limitation of the recruitment and sampling of expert faculty members and first-year medical students; and attribution of change between the BCS and ECS surveys.

While consideration of limitations is important, the quality of the study may be evaluated by looking at the inferences made and their transferability, the degree to which these conclusions may be applied to other specific settings, people, time periods, contexts

(Bergman, 2008). In this study, the transferability will likely be low because the goal was to describe the current status and perceptions of embryology within medical education and not to form a theory that is generalizable to many other curricular situations. Instead, this research found themes and patterns to the faculty and first-year medical students experiences with and perceptions of embryology in UME and generated a phenomenology of the phenomenon of teaching embryology in modern UME.

**Future Directions for Related Research**

This research documents how mixed methods research can yield significant results and evidence to start answering questions about medical education. The reliance on pure quantitative data is not ideal when approaching a topic that by its nature necessitates gathering the perceptions and experiences of those involved, such as the treatment of embryology in modern medical education. The dual approach of grounded theory and phenomenology meant that grounded theory was able to identify themes in the data and the product of these themes as well as faculty interviews provided the identification of a phenomenology of teaching embryology. More research along these qualitative and mixed methods lines is recommended for investigating aspects of medical education.

The following is a small sample of future directions of research related to what was described in this and the previous six chapters of this dissertation. Some but not all of these projects will be launched by this researcher, and many will require collaboration with multiple researchers of varied perspectives in order to yield a rigorous study worthy of the medical education field.

- Continue to survey and interview faculty and medical students about embryology in medical education, but also formulate a survey for medical school administrators and governing bodies regarding embryology. Including these alternate perspectives and increasing awareness of the issues facing not only embryology, but UME curricular reform as a whole, may decrease the chances of the most contemporary round of reform resulting in another reform without change.
- Additionally, increase the sample size of this research with the aim of increasing the statistical power of the quantitative data. As discussed in chapter 3, the phenomenological data ideally keeps a lower sample size as long as saturation is reached (Morse, 1994; Creswell, 1998).
- This present research focused on faculty and first-year medical student perceptions of embryology in the medical curriculum. This research did not collect data from later medical students, residents and clinicians about embryology. It is likely that perceptions of embryology will evolve and modify as an individual progresses through medical school and begins practicing medicine. Thus, it is essential for future research to ask residents and clinicians what embryological knowledge is essential for success in daily medical practice. This inquiry should include asking about molecular aspects of embryology, as well as social issues addressed in the clinic.
- Delve deeper into the null curriculum, which despite the best efforts of this research often remained unclear. More data must be collected with different populations, research questions, and methodologies that will target the null

curriculum in order to illuminate this important facet of the UME curriculum. This research provides the start of a potential aim for this type of inquiry, investigation of the presence or absence of political and religious points of view present in medical education's discussions regarding abortion.

- Use faculty and medical student feedback to formulate guidelines for making new embryology teaching and learning resources (e.g., textbooks, interactive forums and animations, accessible models and experts), including positive and negative aspects of current resources as well as what their ideal embryology resource tools like look and provide.
- Examine all aspects of the undergraduate medical education curriculum for their explicit, implicit, and null curricula. Investigation of different areas of the UME curriculum using a specific trifold framework such as this would provide a regimented and organized way of looking at what is known to be taught in the explicit curriculum, what is informally learned as part of the medical school experience in the implicit curriculum, and what is not present in UME via the null curriculum (Eisner, 1985; Flinders et al., 1986).

**Final Thoughts on Embryology and the Explicit, Implicit, and Null Curricula in Undergraduate Medical Education**

This mixed methods research illuminated the underlying issues and experiences that built the perceptions of faculty and first-year medical students toward embryology in UME. Each point of view was valuable in building the themes surrounding the explicit, implicit, and null curricula and generating a phenomenology of teaching this subject. When reflecting upon the experience designing and conducting this research study, it is striking to what extent all three facets of the UME curriculum shapes ones mindset towards embryology. The explicit provided the content knowledge to understand facts and processes, while the implicit and null curricula assisted in developing personal opinions and approaches toward the content and related issues. The understanding that all three curricular facets, the explicit, implicit, and null, work together to shape students in modern undergraduate medical education means that all three must all be recognized, addressed, and continually improved in order for UME to instigate widespread reform with positive and evidence-based change.

Appendix A: Faculty Survey

## Study Information

The purpose of this survey is to investigate faculty and instructors' attitudes and beliefs regarding human embryology in the curriculum. The researchers are specifically looking for responses from individuals who have some form of experience teaching human embryology in the classroom. If your institution does not have a stand-alone human embryology course, please answer the following questions in this survey regarding the course(s) at your institution in which components of human embryology are taught.

This survey is voluntary and will be anonymized after data collection. This survey will take approximately 10-15 minutes to complete.

This research is being conducted by individuals at Indiana University, and is approved as an exempt study #1303010942 through the Indiana University Institutional Review Board. Please contact Keely Cassidy (xxxxxxxx@xxxxxxx.xxx) with any questions or comments.

**1. Please select your gender.**

- Male
- Female
- I prefer not to answer

**2. Please select all that apply.**

- I currently teach human embryology.
- I have taught human embryology.
- I have never taught human embryology.
- Other (please specify)

**3. What is the highest level degree that you have completed?**

- Clinical (M.D., D.O., P.T., D.D.S.)
- M.D./Ph.D.
- Ph.D.
- Master's
- Bachelor's
- Other (please specify)

**4. In what field is your highest-level degree?**

- Life sciences
- Clinical degree programs (M.D., D.O., P.T., D.D.S.)
- Science education

Briefly describe (i.e., Biology with emphasis in Biomaterials).

**5. At what college or university are you currently an instructor?**

**6. What type of institution is this?**

- ☐ Medical school (M.D.)
- ☐ Medical school (D.O.)
- ☐ Dentistry school
- ☐ Other clinical/professional school (e.g., nursing)
- ☐ Four year college or university
- ☐ Two year college or university
- ☐ Other (please specify)

**7. Who are the primary learners that you teach?**

- ○ Medical students (M.D.)
- ○ Medical students (D.O.)
- ○ Physical therapy students
- ○ Dentistry students
- ○ Other graduate-level students
- ○ Undergraduate students
- ○ Other (please specify)

**8. Are there secondary student populations that you also teach? (Check all that apply)**

- ☐ Medical students (M.D.)
- ☐ Medical students (D.O.)
- ☐ Physical therapy students
- ☐ Dentistry students
- ☐ Other graduate-level students
- ☐ Undergraduate students
- ☐ Other (please specify)

**9. Which of the following best describes your institution's format of the anatomy curriculum?**
**(Note: Anatomy is defined as any combination of the following four subjects: gross anatomy, cell and tissue biology or histology, neuroanatomy, and embryology.)**

- ○ Separate courses
- ○ Integrated
- ○ Other (please specify)

**10. Please briefly explain your response to the above question (#9).**

**11. How many years of experience do you have teaching students?**

- Less than 5
- 5-10
- 11-15
- 16-20
- 20 or more
- N/A

**12. How many years of experience do you have teaching human embryology?**

- Less than 5
- 5-10
- 11-15
- 16-20
- 20 or more
- N/A

**13. Check all the anatomy courses that you commonly teach in an academic school year.**

- Gross anatomy
- Cell and tissue biology or Histology
- Neuroanatomy
- Embryology
- Various anatomy topics within an integrated curriculum
- Undergraduate stand-alone anatomy
- Undergraduate stand-alone physiology
- Undergraduate combined anatomy and physiology
- Other (please specify)

**14. If you do teach a human embryology course (or component of a course) and are willing to share your course syllabus with the researchers, please check the box below and enter your email address. You will be contacted via email to collect the document.**

- Yes, you may contact me to obtain a copy of my syllabus.

Email address

**15. Why have you taught or are you teaching human embryology?**

- I volunteered.
- I was randomly assigned.
- I was told that I have to.
- Everyone teaches the subject at my institution.
- Other (please specify)

**16. What previous experiences have you had with human embryology? (Check all that apply)**

- [ ] Took an undergraduate course with a human embryology component
- [ ] Took a graduate or medical course with a human embryology component
- [ ] Took a professional development course with a human embryology component (e.g., CME)
- [ ] Professional research
- [ ] Self-study for personal interest
- [ ] Other (please specify)

**17. On a scale of one to ten (1 being the least confident, 10 being the most confident), how confident do you feel when teaching human embryology?**

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

**18. What resources do you recommend, require, or discourage students to use when studying human embryology?**

| | Require | Recommend | Discourage | Neutral (neither require, recommend, nor discourage) |
|---|---|---|---|---|
| Required textbook | ☐ | ☐ | ☐ | ☐ |
| Additional textbooks | ☐ | ☐ | ☐ | ☐ |
| Lecture notes | ☐ | ☐ | ☐ | ☐ |
| Online embryology animations | ☐ | ☐ | ☐ | ☐ |
| Online or televised resources | ☐ | ☐ | ☐ | ☐ |
| Laboratory models and dissections | ☐ | ☐ | ☐ | ☐ |
| Self-generated materials (drawings, flowcharts, mnemonic devices) | ☐ | ☐ | ☐ | ☐ |

**19. Please read carefully and rate your responses to the following statements by indicating your level of agreement.**

| | Strongly agree | Agree | Neutral | Disagree | Strongly disagree | N/A |
|---|---|---|---|---|---|---|
| An understanding of human embryology is essential to understanding gross anatomy. | ○ | ○ | ○ | ○ | ○ | ○ |
| An understanding of human embryology helps students to better understand certain clinical ailments. | ○ | ○ | ○ | ○ | ○ | ○ |
| The study of human embryology is an important and necessary part of medical training. | ○ | ○ | ○ | ○ | ○ | ○ |
| The subject of human embryology is applicable to modern medicine. | ○ | ○ | ○ | ○ | ○ | ○ |
| I think that students will use human embryology practically as healthcare professionals. | ○ | ○ | ○ | ○ | ○ | ○ |
| I find the subject of human embryology interesting. | ○ | ○ | ○ | ○ | ○ | ○ |
| I find the subject of human embryology difficult to understand. | ○ | ○ | ○ | ○ | ○ | ○ |
| I feel confident enough in my knowledge base of human embryology to teach it to others. | ○ | ○ | ○ | ○ | ○ | ○ |

| | | | | | | |
|---|---|---|---|---|---|---|
| I personally would like to have more human embryology incorporated into the anatomy laboratory. | ○ | ○ | ○ | ○ | ○ | ○ |
| I personally would prefer if my anatomy course did not teach human embryology. | ○ | ○ | ○ | ○ | ○ | ○ |
| I personally would prefer to have a separate course specifically for human embryology. | ○ | ○ | ○ | ○ | ○ | ○ |
| I personally would prefer to not be required to teach human embryology in medical school. | ○ | ○ | ○ | ○ | ○ | ○ |

**20. List 10 words that you associate with human embryology. They may be vocabulary, anatomic terms/processes, affective/emotional terms, etc.**

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

**21. What do you find most interesting about teaching human embryology?**

**22. What do you find most confusing about teaching human embryology?**

**23. Do you have any suggestions or ideas for how to improve the teaching and/or learning of human embryology within the curriculum?**

**24. If you would like to qualify or expand upon any of your answers in this survey, please do so in the comment box below.**

**25. If you are willing to participate in a follow-up interview regarding these topics, please check the box below and enter your email address. The interview will take no more than 30 minutes and will be via telephone or Skype, depending on your personal preferences and logistics. The interview will take place at a day and time convenient for you.**

○ Yes, you may contact me to schedule an interview.

Email address

Appendix B: Student Beginning of Course Student Survey

## Study Information

The purpose of this survey is to investigate students' attitudes and beliefs regarding human embryology in the curriculum. The researchers are specifically looking for individuals' responses who are currently enrolled in a learning experience in human embryology in the classroom. If your institution does not have a stand-alone human embryology course, please answer the following questions in this survey regarding the course(s) at your institution in which components of human embryology are taught.

This survey is voluntary will be anonymized after data collection. This survey will take approximately 10-15 minutes to complete.

This research is being conducted by individuals at Indiana University, and is approved as an exempt study #1303010942 through the Indiana University Institutional Review Board. Please contact Keely Cassidy (xxxxxxxx@xxxxxxx.xxx) with any questions or comments.

**1. I acknowledge that this is the Beginning-of-Course Survey about my study approaches, attitudes, and beliefs regarding human embryology.**

- Yes

**2. Please enter your seven digit phone number (NOT including area code). This information will only be used to link your Beginning-of-Course Survey and End-of-Course Survey**

#
#
#
#
#
#
#

**3. Please select your gender.**

- Male
- Female
- I prefer not to answer

**4. At what college or university are you currently enrolled (include center if applicable)?**

**5. What type of institution is this?**

- Medical school (M.D.)
- Medical school (D.O.)
- Dentistry school
- Other clinical/professional school (e.g., nursing)
- Four year college or university
- Two year college or university
- Other (please specify)

**6. What previous experiences have you had with human embryology? (Check all that apply)**

- [ ] Took an undergraduate course with a human embryology component
- [ ] Took a graduate or medical course with a human embryology component
- [ ] Took a professional development course with a human embryology component (e.g., CME)
- [ ] Professional research
- [ ] Self-study for personal interest
- [ ] Other (please specify)

**7. How do you think you will study for the human embryology component of this course? Estimate the percentage of time that will be spent on each method.**

| | 0-20% | 21-40% | 41-60% | 61-80% | 81-100% |
|---|---|---|---|---|---|
| By myself | ○ | ○ | ○ | ○ | ○ |
| With a partner | ○ | ○ | ○ | ○ | ○ |
| With a group | ○ | ○ | ○ | ○ | ○ |

**8. What resources do you think you will use to study for the human embryology components of this course? (Check all that apply)**

- [ ] Required textbook
- [ ] Additional textbooks
- [ ] Lecture notes
- [ ] Online embryology animations
- [ ] Online or televised resources
- [ ] Laboratory models and dissections
- [ ] Self-generated materials (drawings, flowcharts, mnemonic devices)
- [ ] Other (please specify)

**9. If you are a medical student (M.D. or D.O.), is there a clinical specialty that you are particularly interested in pursuing at this time? (Check up to 3)**

- [ ] Allergy and Immunology
- [ ] Anesthesiology
- [ ] Dermatology
- [ ] Emergency medicine
- [ ] Family medicine
- [ ] Internal medicine
- [ ] Neurology
- [ ] Obstetrics and Gynecology
- [ ] Ophthamology
- [ ] Orthopaedic surgery
- [ ] Otolaryngology
- [ ] Pathology
- [ ] Pediatrics
- [ ] Plastic surgery
- [ ] Radiology
- [ ] Surgery
- [ ] Urology
- [ ] Not sure at this time
- [ ] Other (please specify)

**10. If you are not a medical student (D.O. or M.D.), what field are you pursuing?**

- ☐ Physical therapy
- ☐ Occupational therapy
- ☐ Dentistry
- ☐ Nursing
- ☐ Other (please specify)

**11. Please read carefully and rate your responses to the following statements by indicating your level of agreement.**

| | Strongly agree | Agree | Neutral | Disagree | Strongly disagree | N/A |
|---|---|---|---|---|---|---|
| An understanding of human embryology is essential to understanding gross anatomy. | ○ | ○ | ○ | ○ | ○ | ○ |
| An understanding of human embryology helps me to better understand certain clinical ailments. | ○ | ○ | ○ | ○ | ○ | ○ |
| The study of human embryology is an important and necessary part of medical training. | ○ | ○ | ○ | ○ | ○ | ○ |
| The subject of human embryology is applicable to modern medicine. | ○ | ○ | ○ | ○ | ○ | ○ |
| I think that I will use human embryology practically as a healthcare professional. | ○ | ○ | ○ | ○ | ○ | ○ |
| I find the subject of human embryology interesting. | ○ | ○ | ○ | ○ | ○ | ○ |
| I find the subject of human embryology difficult to understand. | ○ | ○ | ○ | ○ | ○ | ○ |
| I find answering exam questions on human embryology to be more stressful than answering those on gross anatomy. | ○ | ○ | ○ | ○ | ○ | ○ |
| I feel confident enough in my knowledge base of human embryology to teach it to others. | ○ | ○ | ○ | ○ | ○ | ○ |
| I personally would like to have more human embryology incorporated into the anatomy laboratory. | ○ | ○ | ○ | ○ | ○ | ○ |
| I personally would prefer if the anatomy course did not teach human embryology. | ○ | ○ | ○ | ○ | ○ | ○ |
| I personally would prefer to have a separate course specifically for human embryology. | ○ | ○ | ○ | ○ | ○ | ○ |
| I personally would prefer to not be required to learn human embryology in medical school. | ○ | ○ | ○ | ○ | ○ | ○ |

**12. List 10 words that you associate with human embryology. They may be vocabulary, anatomic terms/processes, affective/emotional terms, etc.**

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

**13. What do you find most interesting about human embryology?**

**14. What do you find most confusing about human embryology?**

At the end of the human embryology course (or course component(s)) in which you are enrolled, you will be asked to complete an End-of-Course Survey regarding these same topics.

Appendix C:  Student End of Course Student Survey

## Study Information

The purpose of this survey is to investigate students' attitudes and beliefs regarding human embryology in the curriculum. The researchers are specifically looking for individuals' responses who are currently enrolled in a learning experience in human embryology in the classroom. If your institution does not have a stand-alone human embryology course, please answer the following questions in this survey regarding the course(s) at your institution in which components of human embryology are taught.

This survey is voluntary will be anonymized after data collection. This survey will take approximately 10-15 minutes to complete.

This research is being conducted by individuals at Indiana University, and is approved as an exempt study #1303010942 through the Indiana University Institutional Review Board. Please contact Keely Cassidy (xxxxxxxx@xxxxxxx.xxx) with any questions or comments.

**1. I acknowledge that this is the End-of-Course Survey about my study approaches, attitudes, and beliefs regarding human embryology.**

- Yes

**2. Please enter your seven digit phone number (NOT including area code). This information will only be used to link your Beginning-of-Course Survey and End-of-Course Survey**

#
#
#
#
#
#
#

**3. Please select your gender.**

- Male
- Female
- I prefer not to answer

**4. How did you study for the human developmental anatomy component of this course? Estimate the percentage of time that was spent on each method.**

| | 0-20% | 21-40% | 41-60% | 61-80% | 81-100% |
|---|---|---|---|---|---|
| By myself | | | | | |
| With a partner | | | | | |
| With a group | | | | | |

**5. What resources did you use to study for the human embryology components of this course? (Check all that apply)**

- Required textbook
- Additional textbooks
- Lecture notes
- Online embryology animations
- Laboratory models and dissections
- Self-generated materials (drawings, flowcharts, mnemonic devices)
- Other (please specify)

**6. If you are a medical student (M.D. or D.O.), is there a clinical specialty that you are particularly interested in pursuing at this time? (Check up to 3)**

- ☐ Allergy and Immunology
- ☐ Anesthesiology
- ☐ Dermatology
- ☐ Emergency medicine
- ☐ Family medicine
- ☐ Internal medicine
- ☐ Neurology
- ☐ Obstetrics and Gynecology
- ☐ Ophthamology
- ☐ Orthopaedic surgery
- ☐ Otolaryngology
- ☐ Pathology
- ☐ Pediatrics
- ☐ Plastic surgery
- ☐ Radiology
- ☐ Surgery
- ☐ Urology
- ☐ Not sure at this time
- ☐ Other (please specify)

**7. If you are not a medical student (D.O. or M.D.), what field are you pursuing?**

- ☐ Physical therapy
- ☐ Occupational therapy
- ☐ Dentistry
- ☐ Nursing
- ☐ Other (please specify)

**8. Please read carefully and rate your responses to the following questions by indicating your level of agreement.**

| | Strongly agree | Agree | Neutral | Disagree | Strongly disagree | N/A |
|---|---|---|---|---|---|---|
| An understanding of human embryology is essential to understanding gross anatomy. | | | | | | |
| An understanding of human embryology helps me to better understand certain clinical ailments. | | | | | | |
| The study of human embryology is an important and necessary part of medical training. | | | | | | |
| The subject of human embryology is applicable to modern medicine. | | | | | | |
| I think that I will use human embryology practically as a healthcare professional. | | | | | | |
| I find the subject of human embryology interesting. | | | | | | |
| I find the subject of human embryology difficult to understand. | | | | | | |
| I find answering exam questions on human embryology to be more stressful than answering those on gross anatomy. | | | | | | |
| I feel confident enough in my knowledge base of human embryology to teach it to others. | | | | | | |
| I personally would like to have more human embryology incorporated into the anatomy laboratory. | | | | | | |
| I personally would prefer if the anatomy course did not teach human embryology. | | | | | | |
| I personally would prefer to have a separate course specifically for human embryology. | | | | | | |
| I personally would prefer to not be required to learn human embryology in medical school. | | | | | | |

**9. List 10 words that you associate with human embryology. They may be vocabulary, anatomic terms/processes, affective/emotional terms, etc.**

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

**10. What do you find most interesting about human embryology?**

**11. What do you find most confusing about human embryology?**

**12. Do you have any suggestions or ideas for how to improve the teaching and/or learning of the human embryology course or course component(s) at your institution?**

**13. Email address**

**14. If you are willing to participate in a follow-up focus group (small group interview with fellow students) regarding these topics, please check the box below and enter your email address. The interview will take no more than 30 minutes and will be via telephone or Skype, depending on your personal preferences and logistics. The interview will take place at a day and time convenient for you.**

Yes, you may contact me to schedule a focus group.

Email address

## Appendix D: Faculty Interview Questions

### Faculty/Instructor Interview Script

The following are general questions that may be addressed during the interviews. The order and specifics will be based on the conversational flow and upon individuals' survey responses that could use a detailed explanation or that have already been addressed.

Approximately how many course hours are devoted to embryology/embryological topics in your course (program/department)?

- Do you think that is too many, too few, or just right?
- Do you know what factors go into deciding that number, and who makes that decision?

I see from the survey that your department has a ________ curriculum (briefly describe).

- What does the placement of embryology look like within that framework?
- Do you think this does or does not work well?

Describe to me what a typical day looks like in the classroom when you are teaching embryology content.

- Do you ever have a lab component to embryology? (or anything else?)
- Tell me about your mindset when you are teaching embryology.
  - What influences your level of confidence when teaching embryological content?
- What is your rationale for deciding whether or not a certain topic should be included, and the time spent on it?
  - Are any subjects avoided (purposefully or not)?
  - What types of human birth defects do you teach?
  - What social and ethical issues associated with embryology do you teach?
    - (If they can't think of any examples: screening fetuses, abortion, in-utero surgery)

What importance do you think your department places on the teaching and learning of embryology as related to medical education?

What importance do you think the medical profession places on embryology?

- Do you see it as being a foundational anatomical subject or as more specific to certain specialties (e.g., ObGyn, Peds, Neo)?

Is there anything else you would like to say about the teaching and/or learning of embryology within your experiences in (medical) education?

## Appendix E: MSCI M300 Course Proposal

### MSCI M300: Topics in Medical Sciences (3 credits)
### "From Cell to Infant: Human Embryology"
### Course Proposal for Fall 2013

I, Keely Cassidy, would like the opportunity to serve as instructor for an undergraduate level course (M300: Topics in Medical Sciences) starting the fall semester of 2013 titled "From Cell to Infant: Human Embryology". This course would focus on human embryology – the study of the formation, growth and early development of the human – utilizing both lectures, a research paper, and active learning activities to convey the required knowledge in an engaging and rigorous manner. This course must have A215: Basic Human Anatomy as a prerequisite, as the subject matter in the proposed course requires a solid foundation of typical mature human anatomy.

Qualifications and Teaching Experience

I am currently in my second year of the Anatomy (Educational Research) doctoral program, and have served as an Associate Instructor (A.I.) at the university level each semester for the following courses:

- A215: Basic Human Anatomy Fall 2011, Spring 2012, Summer 2012, Fall 2012, Spring 2013; Responsibilities: introducing laboratory material; providing students assistance in structure identification on models, histology slides, and donors; providing students with guidance in study skills for anatomy; running review sessions and forming sample exams; demonstrating structures on male and female donors; setting up and proctoring exams; grading at least two exams per semester
- A550 and A551: Gross Human AnatomyFall 2012, Spring 2013; Responsibilities: complete prosection of one donor for the A215 course; assisting in dissection and structure identification of the laboratory donors in a regional approach; assisting graduate and medical students with learning skills in anatomy; grading three exams per semester

In addition to my experiences at Indiana University, I received my Masters of Science in Anatomy from Des Moines University in 2011. There I had the experience of enrolling in and excelling in a Human Development course, which told the story of human embryology from the fertilization of an ovum and the way through the birthing process. This experience was so valuable for me in understanding so many of the "Why?" questions regarding why normal adult anatomy is the way it is, and undergraduate students could benefit greatly from this knowledge as well.

Here at Indiana University I have gained pedagogical training in multiple education courses, weekly educational research seminar meetings, and practically as an A.I. These experiences are enabling me to identify strengths and weaknesses in my teaching, as well as options and plans for continual improvement. This spring 2013 semester, I will be taking MSCI M620: "Pedagogical methods in health sciences," during which I will gather additional information about teaching and learning styles, grading rubrics, and also have the opportunity to work with fellow graduate students and instructional consultants to refine the proposed M300 syllabus and course plan. The opportunity to instruct a course in embryology is one that I hope to utilize to bring this exciting subject matter to the undergraduate population. Guidance from my graduate student colleagues who have already developed and taught their own courses, as well as very experienced faculty advisors, will be a valuable resource on this journey. I am very enthusiastic on the topic of human embryology, as I plan to use it as a major part (if not the basis) of my doctoral dissertation. In fact, this course was first envisioned during literature searches regarding the lack of an adequate focus on embryology in the medical curriculum. It is my hope to get more students interested in this topic earlier in their careers, to foster the mindset that embryology is an essential part of anatomic studies.

Course Description and Justification for the M300 Designation

This course is designed to provide students with a deep understanding of the development of human anatomy, from the fertilization of a cell all the way to the infant and the birthing process. As embryology is the foundation to human anatomy, having a clear understanding of the complex processes that lead to the final human organism will enable students to understand why human anatomy appears the way that it does, as well as to gain knowledge regarding human birth defects and their origins. Students will gain an appreciation for the intricacy and delicate balances that exist in the embryological development of humans. The course will include traditional lectures and exams as well as the viewing of human donor bodies, brief case studies, team-based learning, and other active learning exercises. This course is designed to be three credits and eligible to count as an upper-level course for the students pursuing a minor in Medical Sciences. Any laboratory-type activities will take place during the already scheduled class time and would not require a special location.

Human embryology is traditionally a very difficult subject matter for undergraduate students, and therefore the designation of a 300-level rather than 100-level is beneficial for several reasons. First, it will clearly convey to students that they must have successfully completed A215: Basic Human Anatomy before enrolling in this course. This is to ensure that they possess knowledge of common anatomic terminology as well as the appearance of structures before trying to figure out where and how these structures develop. Another benefit of establishing this as a 300-level course is that the rigorous nature of the course will be reflected on student transcripts rather than being perceived as an introductory course. In addition, this will enable the Medical Sciences department to offer one more upper-level course for the minor in Medical Sciences. Embryology is a fascinating subject, and this course will encourage students to disregard the unfortunate label of anatomy as "just a memorization class" and enable them to think critically about human embryology and the potential for human birth defects. With a positive classroom experience in M300: From Cell to Infant: Human Embryology, it is hoped that students will become more well-rounded in their knowledge, continuing to develop an interest in the anatomic sciences as well as integrating embryology with other experiences in the medical and biological coursework.

Formal Request to the Undergraduate Education Committee

I propose to teach M300: From Cell to Infant: Human Embryology as one course in the fall session of 2013. The benefits of this proposal are many. Undergraduate students who successfully complete the course will leave Indiana University with a rich understanding of the ever-changing anatomy of the developing human. This course could serve as an upper-level elective for the Medical Sciences minor, providing an additional source of undergraduate credit revenue for the department as well as an additional option for students seeking this degree. It will also present the ability to continue to develop as an instructor and a mentor for students early in their educational careers, which will be seen as a positive and unique aspect of the Anatomy (Education Research) doctoral program here at Indiana University.

Thank you for your consideration, and I look forward to meeting with the Undergraduate Education Committee to discuss this proposal and to address any questions you may have.

Sincerely,

Keely M. Cassidy

Appendix F: MSCI M300 Syllabus

Indiana University
School of Medicine
Medical Sciences Program
Fall 2015

| | |
|---|---|
| Course Number: | MSCI M300 (3 credits) |
| Course Title: | Topics in Medical Sciences: Human Embryology |
| Instructor: | Keely M. Cassidy, MS |
| Class Meeting Place: | Jordan Hall 001 |
| Class Meeting Time: | Monday/Wednesday/Friday 1:25 – 2:15 pm |

<u>What will I get out of this course?</u>

This course is designed to provide students with a deep understanding of the development of human anatomy, from the fertilization of a cell to the time just prior to the birthing process. As embryology is the foundation to human anatomy, having a clear understanding of the complex processes that lead to the final human organism will enable students to understand why human anatomy appears the way that it does, as well as to gain knowledge regarding human congenital malformations and their origins. Students will gain an appreciation for the intricacy and delicate balances that exist in the embryological development of humans. The course will include traditional lectures and exams as well as an intensive research project, daily quizzes, brief problem-based learning activities (case studies), and other active learning exercises.

<u>By the end of this course, what will I be expected to be able to do?</u>

1. Recognize and define the embryology vocabulary necessary to communicate effectively in both embryological research and clinical fields
2. Explain the three-dimensional development of the embryo/fetus, and the relationships of structures to one another throughout development
3. Interpret and find patterns in the simultaneous, codependent nature of development
4. Analyze the origins and effects of incorrect developmental processes
5. Monitor and explain your study approaches, attitudes, and beliefs regarding embryology

<u>What is the required textbook?</u>

*Before We Are Born: Essentials of embryology and birth defects*. Keith L. Moore & T.V.N. Persaud. Saunders Elsevier, Philadelphia, 2011, 8$^{th}$ edition (7$^{th}$ edition or e-book also acceptable)

If I have questions about the course, what should I do?

Consult the syllabus and ask your classmates. If your question can be answered this way, great! If your question is regarding an individual issue and cannot be found in the syllabus, ask before/after class or email Keely.

If I have questions about the content, what should I do?

If we are sitting in class, then raise your hand and ask so that everyone can benefit from hearing the answer.
If we are not sitting in class, then post questions and comments (even resources that you find!) to a new thread in our course's Canvas Discussions page. Do not email content questions to Keely because you will not receive a response via that medium. Keely will check the Discussions page a few times per week, but will not post the correct answer unless at least one other classmate has already attempted to answer the question or contribute to the discussion.

How will my course performance be evaluated?

1. Surveys: Students will complete two online surveys (one pre- course and one post-course) regarding their study approaches, attitudes, and beliefs about embryology. Students will be provided with the link to the surveys when needed. These are both required for completion of the course.

2. Quizzes: There will be a quiz at the beginning of class every day (except exam days) covering the material learned in the previous class meeting. Each quiz will be worth two points: one for attendance and one for the correct answer.

3. Examinations: Four unit/block exams will include multiple choice, fill-in, labeling, and short answer questions. The second, third, and fourth exams will include one cumulative/comprehensive short answer question. Several possible topics for this question will be announced prior to the exam.

    a. Exam reference card policy: Each student is allowed to use a single notecard (3 x 5 inch) during the exam with notes of the student's choosing on one side. Text size is required to be visible with the unaided eye (excepting prescription eyeglasses), and no visual aid devices (i.e., magnifying glasses) will be permitted. Notecards must be approved and initialed by the instructor prior to the start of the exam, and will be collected with the exam when complete.

    b. Optional review sessions: The Wednesday evening before each exam, there will be an optional review session from 5-7 pm in either JH 001A or JH 111 (TBA). There will be no formal or structured review activities, and is a question-and-answer session where you may come and go as you please.

4. Problem-based learning (PBL) assignments: Students will complete three problem-based learning activities, or case studies, on embryological clinical correlations. The blog prompt and any necessary materials will be provided one week prior to the due date for each blog.

5. Congenital anomaly research project: Students will choose a human congenital anomaly with an anatomical basis on which to complete a research project. Topics will be approved on an individual basis. The intention is for each student to become a budding expert on their chosen topic, from the perspective of a healthcare professional. Students will submit their topic and a paragraph explaining why they chose that topic on September 16th, which will then be approved or changes requested. An outline of the project will be due on October 9th. The final product, due November 20th (the Friday before Thanksgiving break!) will be a hypothetical dialog of a conversation between the student/expert and expectant parents of an individual with the chosen congenital animaly. Further details, pointers, and a rubric will be provided.

   Indiana University Plagiarism Certification Test (IUPCT):
   1. Go to this website via the IU School of Education to learn about definitions and examples of plagiarism: https://www.indiana.edu/~tedfrick/plagiarism/
   2. When you feel that you understand what plagiarism is, take the test and receive your certification: https://www.indiana.edu/~istd/test.html If you have already done this for another course at IU, skip to Step 3.
   3. Print your certificate and bring to class by September 16th. You will not receive a grade for any part of your Research project until you have provided proof of this certificate.

What is the point breakdown for my course performance?

| | | | |
|---|---|---|---|
| 1. Quizzes | 2 points | x40 | = 80 points |
| 2. Examinations | 100 points | x4 | = 400 points |
| 3. PBL Assignments | 25 points | x3 | = 75 points |
| 4. Congenital malformation research project: | | | |
| Research topic and reason paragraph | 5 points | | |
| Research project outline | 25 points | | |
| Final research project | 200 points | | = 230 points |

TOTAL points in course = 785 points

What is expected in the classroom to encourage a great learning and teaching environment?

1. Students should be prepared for class to start at 1:25 pm.
2. Students should have cell phones and any electronic devices turned off or on silent during class. If a phone call is required, then it needs to be addressed with the instructor prior to the class. Texting during class is not acceptable. Any student found texting will asked to leave and will not receive credit for attending that day.
3. Students are expected to attend all classes. In the case of an emergency, illness, or other serious situation the student is expected to inform the instructor prior to the absence (if possible) or upon returning to class. Any students who are forced to miss class due to a college-approved event are required to inform the instructor prior to the event (see below).
4. It is the obligation of the student to obtain information regarding a missed class.
5. Assignments are considered late if they are not turned in by class time on the due date. A late assignment will receive a 25% reduction for each day it is late.
6. All assignments must be typed, except in-class work or when stated otherwise.
7. All course participants are expected to maintain respect for and professionalism regarding the content and each other at all times. Lapses will result first in a verbal warning, and if the behavior continues in a required meeting with Keely. If further issues arise, then further actions may be taken.
8. If you will miss a scheduled exam due to an approved, university-sanctioned event (for example, you are a student-athlete traveling for an away game), then you must provide documentation establishing this in writing to Keely by class time at least one week prior to the exam. If you missed a scheduled exam due to an illness or unavoidable emergency, then you must provide documentation establishing this in writing to Keely as soon as possible. Make-up exams will not be given, but the missed exam will not be factored into the student's final course grade. This only applies to missing one exam. If a student misses two or more exams during the semester,

If I will or did miss an exam, what should I do?

Consideration of rescheduling a quiz or examination will occur only if the student provides documentation for the reason for the absence. A reason must be provided, although details (e.g., exact nature of the illness) need not be stated. If the student knows ahead of time that there will be a conflict with an exam, the documentation must be in the instructor's hands by 1:25 p.m. one week before the exam. The student will be advised the following Monday if he/she will be allowed to reschedule the exam, and if so, what the .

What topics will we cover AND What is due each day?

| AUGUST | | | | | |
|---|---|---|---|---|---|
| **WEEK** | **Monday** | **Tuesday** | **Wednesday** | **Thursday** | **Friday** |
| **1** | 24<br>Introduction to embryology | 25 | 26<br>Week 1 of development | 27 | 28<br>Week 1 of development |

| SEPTEMBER | | | | | |
|---|---|---|---|---|---|
| **WEEK** | **Monday** | **Tuesday** | **Wednesday** | **Thursday** | **Friday** |
| **2** | 31<br>Week 2 of development | 1 | 2<br>Week 2 of development | 3 | 4<br>Week 3 of development |
| **3** | 7<br>*no class* | 8 | 9<br>Week 3 of development | 10 | 11*class in JH 009*<br>Intro to Congenital Malformations |
| **4** | 14<br>Weeks 4-8 of development | 15 | 16<br>Weeks 4-8 of development<br>Research topic due<br>IUPCT due<br>Optional Review | 17 | 18<br>**EXAM I** |
| **5** | 21<br>Research activity in-class | 22 | 23<br>Week 9 of development-Birth | 24 | 25<br>Placenta and Fetal membranes |

| OCTOBER | | | | | |
|---|---|---|---|---|---|
| **WEEK** | **Monday** | **Tuesday** | **Wednesday** | **Thursday** | **Friday** |
| **6** | 28<br>Placenta and Fetal membranes | 29 | 30<br>Body cavities and Mesenteries<br>PBL 1 due | 1 | 2<br>Body cavities and Mesenteries |
| **7** | 5<br>Respiratory system | 6 | 7<br>Respiratory system | 8 | 9<br>*no class*<br>Research outline due |
| **8** | 12<br>Musculoskeletal system | 13 | 14<br>Musculoskeletal system<br>Optional Review | 15 | 16<br>**EXAM II** |
| **9** | 19<br>Cardiovascular system | 20 | 21<br>Cardiovascular system | 22 | 23<br>*no class* |
| **10** | 26<br>Cardiovascular system | 27 | 28<br>Research activity in-class<br>PBL 2 due | 29 | 30<br>Digestive system |

| NOVEMBER | | | | | |
|---|---|---|---|---|---|
| **WEEK** | **Monday** | **Tuesday** | **Wednesday** | **Thursday** | **Friday** |
| **11** | 2<br>Digestive system | 3 | 4<br>Digestive system | 5 | 6<br>Digestive system |
| **12** | 9<br>Urogenital system (on Exam IV) | 10 | 11<br>Urogenital system (on Exam IV)<br>Optional Review | 12 | 13<br>**EXAM III** |
| **13** | 16<br>Urogenital system | 17 | 18<br>Urogenital system | 19 | 20 *class in JH 009*<br>Nervous system<br>Research paper due |
| | 23<br>*no class* | 24 | 25<br>*no class* | 26 | 27<br>*no class* |

| DECEMBER | | | | | |
|---|---|---|---|---|---|
| **WEEK** | **Monday** | **Tuesday** | **Wednesday** | **Thursday** | **Friday** |
| **14** | 30<br>Nervous system | 1 | 2<br>Nervous system | 3 | 4<br>Head and Neck |
| **15** | 7<br>*no class* | 8 | 9<br>Head and Neck<br>PBL 3 due | 10 | 11<br>Head and Neck |
| **16 (Finals)** | 14 | 15 | 16<br>Optional Review | 17 | 18<br>**EXAM IV** |

OFFICIAL INDIANA UNIVERSITY POLICIES (deleted for Appendix)

## How to Succeed in M300: Human Embryology

You have chosen to study a foundational and challenging area of anatomical education: embryology and fetal development. Whether you are taking this course because it fulfills an upper-level Medical Science minor requirement, it relates to your future plans in the healthcare professions, due to an interest and curiosity about the subject matter, or a combination of these and other reasons, here are a few tips for how to succeed in (and enjoy) M300: Human Embryology. Best wishes!

Keely Cassidy

If you have taken IUB's A215 course, then most of the anatomic vocabulary and structures should be familiar to you. You may still need to review certain topics, and for this I recommend the A215 textbook, *Human Anatomy* by McKinley and O'Loughlin, and your A215 course notes.

If you have not taken IUB's A215 course, then refer to the A215 *Human Anatomy* textbook or a similar resource throughout the course so you become familiar with the anatomic terms we will use on a daily basis (i.e., directional terms, general tissue types) and during body systems units (i.e., cecum versus ascending colon, soft palate versus hard palate). Pay particular attention to the images of adult gross anatomical structures, as these are the "final goal" of all the primordial and/or transient developing structures we will talk about in M300.

When thinking about your schedule and study plans, remember to…

- Keep track of the course schedule (details in syllabus), as this will tell you when exams, PBL assignments, quizzes, and your research project are due.
- Let Keely know right away if you feel lost or start to have issues affecting your performance. Office hours are as noted earlier in the syllabus or by arranged appointment, so email or discuss after class to set up a meeting.
- Make a study schedule and hold yourself accountable. Studying in small chunks of time often throughout the week is better than trying to learn everything in one day – this is especially true for a topic like human embryology which requires learning many vocabulary terms and an understanding of time progression.
- Study in groups or pairs (at least some of the time). Other students may have more complete notes on a topic or be able to explain concepts in a different way than the instructor. Also, teaching others is one of the best ways to learn a topic – if you can explain it well to a fellow student, you will be able to explain it clearly on the exam!

**When studying for M300, remember to…**

- Keep up and pay attention in class. Embryology follows a very specific timeline, and if you do not understand what was covered in Week 5 of development you will have a difficult time understanding what happens in Week 6 of development. Ask clarifying questions in class – chances are many other students have the same question.
- Actively read the textbook. A good routine to follow is: read chapter before lecture (pay particular attention to key words and images), listen to lecture and take good notes, re-read chapter after lecture to clarify anything you missed and add to notes. Active reading means that you are not mindlessly highlighting, but that you are making notes, checking in at certain points to ensure you understand the material, and writing things in your own words for better understanding.
- Organize the vocabulary. Anatomy is considered by many to be similar to a foreign language and you are responsible for learning many new terms which often have Greek or Latin roots. Keep a running list and continually add root words and their meanings (i.e., cyto- means "cell" or "container"). Link terms to one another to show relationships, as structures are continually changing and evolving in development.
- Use active learning techniques! We will be doing some of these during class, but also use and adapt them for your studying. They will help you to figure out the major links between concepts and to remember long series of information. Below are a few examples of active learning techniques that may help you.
    - Flowchart – To understand the progression of structures through time
    - Concept map – To understand how structures and systems relate
    - Memory matrix – To remember long lists of material, or to be able to tell the differences between similar topics
    - Mnemonic device – To remember key traits or long lists
- Do not blindly memorize facts/figures. See them as small parts of a much larger story – our goal is not mere memorization of facts and figures, but rather a clear understanding of the essential processes and interrelationships between structures in the developing human.
- Remember the 38 week timeline. Many things we will talk about (especially in the body systems) will be occurring simultaneously. Refer to large figures and timelines (i.e., Figure 1-1 in *Before We Are Born*) to keep this in perspective.
- Use provided web resources and find your own. If you come across a great website/video/mnemonic, please let Keely know so others can benefit and so it can be added to the Canvas resources page.

Appendix G: MSCI M300 Research Project Materials

**Due dates:** Topic and paragraph (via Assignments) & IUPCT certification (paper copy to Keely) Wednesday, September 16th
One topic per student, no repeats in the class, "first come, first served".
Instructor will either approve or you will be notified via email to choose another topic by Friday, September 18th.
Monday, September 21st → Research activity (role-play group work) in-class
Outline (via Assignments) Friday, October 9th
Submit an outline of your project. Instructor will look at the organization and overall plan of the document and give light feedback.
Wednesday, October 28th → Research activity (TBA) in-class
Final project/plan (as Word doc via Turnitin.com) Friday, November 20th
After submission to Turnitin.com, email instructor with confirmation.

**Format:** 12 pt. Times New Roman font, 1" margins on all sides, must use citations (style is up to you), style is hypothetical dialogue of a conversation between the expert (some type of healthcare professional) and the expectant parents of the individual(s) with the chosen birth defect
**Length:** 10-12 pages double-spaced (not including title page, table of contents, images, or appendices)
**Points:** 230 (or 29% of your entire course grade)

**Goals:**

- For each student to become a budding expert on their topic of choice
- Choose a human birth defect or disorder about which you are interested in learning more
- Research and design a plan for expectant parents on a birth defect, including how to avoid and how to treat the birth defect
- Address your topic with scientific clarity and clinical compassion

**Audience:** Expectant parent(s)/family of an individual with your chosen birth defect

**Final project/plan must include:**

- Explanation of the embryological basis of the birth defect including etiology, anatomical structures and processes, and relationships to other structures
- Description of the signs and symptoms of individuals with the defect, both as newborns and as children and adults (if applicable)
- Plan for expectant parents on how to avoid this defect (if not possible, explain why)
- Plan for expectant parents on how to treat this defect (if not possible, explain why)

- 2 or more original color images (hand drawn and scanned or computer generated) showing the embryological processes that lead to the defect
- Use 6 or more peer-reviewed journal article sources (can also use textbooks, website, etc. but they will not count toward the 6 required peer-reviewed journal article sources)
- Tone of scientific clarity and clinical compassion/empathy to the audience

Strategies/Resources for getting started and writing:

- Choose a topic you are very interested in, as you will be spending a good amount of time on this project.
- Websites that list many different human birth defects:
  http://www.cdc.gov/ncbddd/index.html
  http://www.cdc.gov/ncbddd/jump/pregnancy.html
  http://www.birthdefects.org/
  http://www.marchofdimes.com/baby/birth-defects.aspx?gclid=CIO7rqKEl7kCFcU7MgodAUYASg
- Make appointments or walk-in to IU's Writing Tutorial Services – they will assist you at any stage of your writing process from brainstorming to polishing the final draft. This is a free service! http://www.indiana.edu/~wts/
- Suggested general plan: First, write an outline that includes all the required parts of this assignment (See "Final project/plan must include:" on the previous page). Collect resources (textbook, etc.) and a few of your 6 required peer-reviewed journal articles. A good way to find these is to search the IU library's database (http://www.libraries.iub.edu/) through "Resource Gateway." They may be reviews of the birth defect, case studies, etc. Then start gradually filling in information within your constructed outline. If you follow this general plan your outline will naturally and quickly grow to become a decent rough draft. Leave it for a few days and come back to proofread, so you can see it with fresh eyes. Share your paper with other M300 students or people willing to look at it, reading aloud to help you catch mistakes you otherwise may not.
- Always keep in mind that compassion and empathy must be heard in your project – write in a way that explains the scientific facts clearly while not being brutal or pessimistic. Think of how you would want a nurse or physician to break this news to your family.

Consider going above and beyond by doing these types of things:

- Refer the parents to support groups or counseling services geared toward the specific birth defect. Provide details and contact information.
- Interview a family member or friend of a person with the same birth defect (or a physician, support group leader, etc.).
- If there are currently no preventative measures or treatment, hypothesize what the prevention or treatment could be in the future (can involve biochemistry, genetics, environmental reforms, etc – be creative!). If you want to go a step further and your birth defect already has preventions and treatments, then hypothesize more.
- Include images of people with the birth defect and label the common or hallmark features of these individuals.

M300: Human Birth Defect research project/plan Rubric

| | Does not meet expectations | Meets minimum expectations | Meets expectations adequately | Excellently executed Above and beyond! |
|---|---|---|---|---|
| Explain embryological basis of birth defect (etiology, anat. structures/processes, relationships to other structures)<br>40 pt | | | | |
| Describe signs/symptoms<br>30 pt | | | | |
| Plan for how to avoid or why this is not possible<br>45 pt | | | | |
| Plan for how to treat or why this is not possible<br>45 pt | | | | |
| 2+ original color images showing embryological processes<br>10 pt | | | | |
| 6+ peer-reviewed journal article sources, Cited<br>10 pt | | | | |
| Tone of scientific clarity and clinical compassion/empathy<br>10 pt | | | | |
| Grammar, Organizational flow<br>10 pt | | | | |

Additional comments:

## Appendix H: Faculty Word Association Data

Difficult
development
development
patterning
models
development
mis-information
Progressive
development - the 4th dimension of time
Development
mesoderm
fascinating
fascinating
3D
development
development
Informative
challenging
Growth
Development
blastocyst
development
dynamic
gastrulation
development
developmental
birth defects
development
anatomical variation
Defect
essential for comparative anatomical dissections
Pathogenesis
congenital defects
dynamic
Abstract
gastrulation
congenital
differential gene expression
congenital abnormalities
anatomy
congenital anomalies
Rapid growth
Congenital
endoderm
universal
complex
derivates
conceptual
interesting
Explanatory
4-dimensional
Development
Folding
morula
neural tube
spatial relationships
congenital
omphalocele
fundamental
organogenesis
transcription factors
anomaly
anomaly
essential for understanding the human body's mechanics
pediatrics
integrative
Interesting
neurulation
neural crest
epithelial-mesenchymal interaction
neural crest
evolution
neural crest
Cell movement
Anomalies
ectoderm
branchial cleft
relevant
clinical relevance
difficult
complex
Clinical relevance
congenital defects
Embryogenesis
In utero
syncytiotrophoblast
somites
folding
implantation
organogenesis
causitive
induction
notochord
malformation
Hernia
anatomy
Branchial arch
anatomy
epiphany
Germ Layers
differentiation
embryonic remnant
differentiation
pharyngeal arch
structure
congenital anomalies
Challenging vocabulary
Partruition
neural crest
blasts
important
interesting
teratology
dynamic
Variability
teratogens
Organogenesis
Neural tube defects
cytotrophoblast
rotation
gastrulation
neurulation
ultrasound
diagnostic
difficult
limb bud
teratogen
Cleft
physiology
anatomy
yolk sac
challenging
Origins
induction
gut rotation
cell migration
heart tube
movement
epigenetic
Errant development - birth defects

Pregnancy
mesenchyme/mesenchymal cells

revealing
difficult to visualize
confusing
gastrulation

rotation
Congenital
Gastrulation
cardinal
fetal tissues
malformation
teratogen
hedgehog
helpful
placenta
boring
atresia
TEF
chemical pathways
relational anatomy
endoderm
amazing
Anomalies
proliferation
heart defects
epithelium-mesenchyme transformation
half-assed
morphogen
imprinting
Amazing complexity, amazing beauty
Clinical
epimere

foundational
Moore: The Developing Human
interesting
fascinating

pharyngeal arches
Defects
Days past conception
implantation
mesoderm
understanding
rotation
congenital

difficult
development
embryo
tetralogy of fallot
Atresia
pathology
congenital
mesoderm
bridging
Visualize
germ layers
gastrulation
complex
problematic
genetics
morphogenesis
Adult structures make more sense
Anatomical
hypomere

clinically applied
Moodle Course
gastrulation
neurulation

signaling
Maturation
Somites
development
endoderm
implantation
neural crest
teratogen
enjoyable
implantation
apoptosis
horseshoe kidney

surgical care
genetic
ectoderm
foundational
Animations
organogenesis
pharyngeal arches
continuum
difficult
teratogen
gastrulation

Relevance
somite/somitomere

essential

neurulation
four-dimensional

neurulation
Fetal
Blastocyst
ductus
ectoderm
celom
germ layers
tube
misunderstood
gastrulation
gestation
duodenal atresia

medical care
malformation
gonadal ridge
explanation
Neurulation
foundation
neural tube
timeline
memorize
syndrome
neuralation

Organizational
cytotrophoblast

critical

trilaminar disc
syncytiotrophoblast

gastrulation
Remnants
Ectopic
mesoderm
foregut
diaphragm
fundamental
rotation
de-emphasized
neurulation
anatomy
neural tube defect

essential fo reserach to new interventions and cures

deformity
mesonephric duct
miraculous
Rotation
body plan
umbilical
maturation
low-yield
pregnancy
notochord

Dermatomes
syncytiotrophoblast

organized

blastocyst
teratoma

surgical correction
Primitive
Placenta
lanugo
hindgut
heart
complex

yolk sac
side-lined
genetics
stem cells
teratoma

essentuial for new
technical and industrial
reserach
dissection
surgery
essential

# Appendix I: Faculty Most Interesting Data

I like relating it to Gross Anatomy, to facilitate student understanding of why things are where they are and why they look that way. It provides a bit of context for the anatomy that they see in lab. Congenital defects are also quite interesting to study.

the integration of biochemistry, histology, anatomy, physiology that are involved in understanding developmental processes; the basis it provides for understanding the adult condition; clinical applications are also interesting but I am most interested in the evolutionary and developmental aspects of the field.

it helps to explain the basis for congenital heart defects or conditions such as omphalocele.

the processes by which a single cell can become a unique, complex, multicellular individual

when time is taken to understand something properly, it DOES explain adult anatomy

Applications to clinical scenarios

The realization that deviation from the event studied leads to congenital anomalies.

The challenge of learning and understanding the material well enough myself so I can highlight and emphasize the most important and key information to the students in a way they can comprehend and use the material.

Its relevance to anatomy (dermatomes, branchial arches, etc) and its clinical relevance (tetralogy of fallot, ileal diverticulum, horseshoe kidney).

Heart development and associated malformations. I also like neural development

It is the foundation for understanding adult anatomy and many congenital disorders.

Knowing what the difficulties are and being able to address them.

It is such a complex process with so many different things occurring at the same time it is a miracle anybody comes out "normal". I also find it very interesting how embryology can account for the organization and appearance of bodily structures.

Embryology helps us understand the adult anatomy - almost every question a student has about the adult anatomy can be answered with understanding the development

"if it doesn't make sense, we blame embryology"

Explaining how anomalies are not uncommon and that they often of little clinical significance even though they can seem rather drastic

it explains why the anatomy looks the way it does

being able to explain what specific congenital anomalies are and why they occur

I like the fact that it is a challenging subject to learn, so, as a teacher, I find that I'm actually able to get points across that students fail to get form textbooks.

How simple beginning structures are transformed into complex adult anatomy

Understanding embryo helps make sense of structures/concepts in gross anatomy that otherwise appear odd or random.

Further explanation of normal and pathological adult structures

processes of metamorphosis/loss/apoptosis

The transformation from a single cell to a complex organisms with many cell, tissue and organ types. The challenge of conveying this understanding to students.

helping students understand how the adult body forms and how common congenital problems arise

interesting congenital conditions caused by improper development in utero

That all terms change names every time that one thing gets to change it's name. It is also very helpful in understanding how structures end up in their adult positions

organogenesis

1. When taught the correct way, it helps students understand anatomical patterns (innervation,

arterial supply, lymphatic drainage).

2. Physicians need to be aware of and understand common congential anomalies.

3. Neural crest cells.
Its relationship to medical ailments.
Relating the comparative and historical basis for the medical care we deliver.
the story.  This is how relational anatomy develops
Using development to explain definitive morphology

# Appendix J: Faculty Most Confusing Data

The developmental processes happen early on and on a minuscule scale, so they are difficult to visualize. There are not enough good animations to depict to students what is actually happening, and they are left to imagine, which can be confusing. In addition, unlike Gross Anatomy, many of the terms used do not have an intuitive origin, and so seem like nonsense words which are harder to remember (on the other hand, many Gross Anatomy terms describe structure or function, for example "erector spinae").
The genetics. it's difficult to keep up with all the current research. embryology is a field that is constantly changing, in terms of what we know about it.

development is a dynamic process, so things are happening over time

many things are happening at the same time in different developing systems

when models substitute for a real understanding, the exercise is impoverished.

Explaining temporal and spatial relationships during development

Head folding
How best to incorporate and how much detail to go into in integrating embryology into our gross anatomy course.

Three dimensional folding during gastrulation.
Embryo folding and explaining concepts like the heart and diaphragm begin in the cervical region. The cardinal system of veins and associated venous malformations is also a tough concept to teach.
Keeping up with the newest trends and information in cellular and molecular aspects of development.

To what extent do students need signaling pathways?
Maybe not confusing, but it is very difficult to conceptualize development of some areas. Animations help tremendously but there are so many terms unique to embryology that change names throughout development-i understand why students get frustrated.
I wish i had a better grasp of the molecular signaling going on in embryology. For my students, they find it difficult to juggle the complex vocabulary, picturing the 3-dimensionality, and understanding how this all changes over a 4th dimension of time.
Conveying the idea that many things are occurring concurrently and that terminology is constantly changing
4-dimensional aspect of it

confusing, unclear textbook text and diagrams

there are lots of unknowns in the field
It is challenging to teach the 3-dimensional (4-dimensional) aspect of human embryology, but that is what makes it enjoyable.

The mechanisms that cause cellular transformations

The temporal aspect. There is so much happening at the same time.
1) 3-D relationships

2) concurrent timelines

impact of some genetic developmental modifiers
Relating our 2D slices of human embryonic and fetal material to 3D structure in a way that the students can understand.
elucidating complex three dimensional processes such as gut formation and rotation, and cardiac development

the genetics

That all terms change names every time that one thing gets to change it's name. Plus any molecular biology and genetics. That's way beyond my expertise.

movements of tissues and rudiments

Formation of the inferior vena cava.

Terminology

Generatiing interests among the students

Alternate theories, variations

Describing 3-D development

# Appendix K: Faculty Suggestions for Improvement

n/a
High quality animations seemed a required component to learning embryology.
I wish there was more embryology in my course textbook. I refer to supplements they may not have purchased. I use simple modeling with tubes and paper for some explanations.
PLEASE have more, better quality animations! Currently we use the book Before We Are Born, which has some, but the videos have no sound which can be frustrating for students trying to follow along.
incorporation of comparative anatomy might be good considering so many studies are conducted in non-humans; there are tons of animations and videos available, 3-D models or 3-D activities would really help for certain topics.
more integration between embryology and gross anatomy. At my institution, there is absolutely no integration between these two subjects.
A colleague and I are creating an interactive timeline so that students can tract the continuity of development through multiple system-base units
I think it's crucial to have a couple of champions/experts who understand and can explain embryological processes and who have a strong grasp of adult anatomy. All materail should be vetted by clinicians--we should not cover material that does not inform regular clinical practice--there just is not the time...
Better availability of animations
Get curriculum administrators on board.
I think more time needs to be given to it so that it represents a greater component of the curriculum and therefore gets a larger share of the assessment as well. Otherwise, students don't take it as seriously as they should when it represents only a small portion on an exam.
The hardest thing to do with embryology is to figure out which course does early embryology/early embryonic period fit. It seems to be a struggle for students when it is introduced in an anatomy course.
Incorporate more electronic visual media into embryology education in order to demonstrate complex processes (e.g., body and heart folding).
Better integration into Anatomy course
I think animations, when done well, can be very powerful learning tools. For me personally i think it is important to start slow to get a good foundational understanding of the terms and processes and then build on that. This works well in a stand-alone course but is difficult in integrated curricula. In the latter, students tend to learn isolated pieces of embryology without really understanding how the embryo got to that stage. e.g., the understand limb development but don't have a good grasp on development of the trilaminar disc.
Faculty need to do a better job of emphasizing the clinical relevance of embryology and appreciating its significance. I have seen some instructors who were overwhelmed with the subject either dismiss embryology or transfer their negative feelings to their students. Embryology is challenging to understand, but when you start to get the basic concepts, it is fascinating!

rah rah, embryology!
I think a strong embryology course combined with a equally strong cadaver dissection might be more instructive than many medical gross anatomy courses. If you understand embryology you will understand anatomy.
more helpful animations

better, clearer textbooks
Have people who are more knowledgeable about modern embryology teach it.
more animations available that can be interacted with (ie "label"some cells and see "where" they go

Software solutions to the problem of relating 2D structure to 3D

explanatory videos

we have a "teach only what they need to know to understand the adult anatomy" philosophy, which I hope is successful in preparing the students for their future careers.

None

no

Instructors need to have a strong background in anatomy and a good understanding of which anomalies are most commonly seen in the clinic.

Some 3d animations would be really helpful (pharyngeal arteries/arches, midgut rotation, etc).

N/A

Create innovative ways that utilize today's technology to grab our students' interests.

How can we convince administration to allot more time with students for embryo ?

# Appendix L: Student Word Association Data

## BCS survey

| | | | | |
|---|---|---|---|---|
| Difficult | Confusing | Intricate | Detailed | Fetus |
| Development | Strange | Complicated | Round-about | Process |
| difficult | necessary | blastocyst | bilaminar disc | fertilization |
| development | gastrulation | neurulation | birth defects | neural tube |
| development | fetus | gastrulation | morula | blastocyst |
| Complicated | Blame | Rushed | Facinating | Necessary |
| fetus | fertilization | embryo | blastocyst | neural tube |
| Fertilization | Folding | Epiblast | Caudal Tail | Tetralogy of Fallot |
| difficult | detailed | tiring | interesting | essential |
| Embryo | Weird words | Difficult | Lengthy | Process |
| beginning | complex | frustrating | confusing | necessary |
| growth | development | fetus | embryo | mutation |
| Confusing | Frustrating | Complex | Interesting | Amazing |
| small | delicate | stressful | tedious | detailed |
| Embryo | Epiblast | Defects | Tri laminar Disc | Endocardial Cushions |
| required | boring | slow | development | fetus |
| Pregnancy | Fetus | Umbilicus | Development | Birth Defects |
| Development | Clinical | Defect | Cranial | Caudal |
| Germ Layers | Amnion | Chorion | Development | Notochord |
| Frustrating | Embryo | Development | Sonic Hedgehog | Interesting |
| development | germ layers | placenta | notochord | lateral folding |
| Notochord | Paraxial | Germ | Trilaminar | Disc |
| inner cell mass | hypoblast | epiblast | fertilization | implantation |
| Fetus | Placenta | Intricate | Tetrology | Congenital abnormalities |
| Development | Association | Notochord | Mesoderm | Neural Crest Cells |
| In-depth | Difficult | Memorization | Low yield | Partially relevant |
| Fertilization | Dorsalization | Birth Defects | Development | Reproduction |
| development | endoderm | ectoderm | mesoderm | folding |
| Babies | folding | congenital | sex | development |
| Difficult | Stressful | Painful | Interesting | Cranial folds |
| trophoblast | zygote | sperm | oocyte | meiosis |
| development | fertilization | zygote | meiosis | genetics |
| baby | nonsense | goopy | complicated | weird locations |
| Inner Cell Mass | Epiblast | Hypoblast | Ectoderm | Mesoderm |
| inner cell mass | hypoblast | epiblast | mesoderm | endoderm |

| | | | | |
|---|---|---|---|---|
| Begining | Folding | Development | Gastrulation | Implantation |
| morula | coelom | notocord | zygote | blastocyst |
| Fascinating | Sonic hedgehog | gastrulation | mesoderm | endoderm |
| gastrulation | difficult | notocord | folding | development |
| inner cell mast | blastocyst | trophoblast | hypoblast | epiblast |
| Difficult | Stressful | Interesting | Annoying | Complex |
| Oocyte | Zygote | Blastocyst | Placenta | Umbilical Cord |
| Ectoderm | Endoderm | Mesoderm | Neural Tube | Neural Crest |
| Foregut | Hindgut | Mesoderm | Endoderm | Ectoderm |
| Hypoblast | Fetus | Pregnancy | Notochord | Mesoderm |
| babies | layers | development | tiny | pregnancy |
| stressful | difficult | in need of more resources | abstract | complicated |
| fetus | umbilical cord | trimester | stem cells | endoderm |
| generation | complex | visuals | patterns | conception |
| babies | tetrology of fallot | vestigial organs | confusing | animations |
| development | memorization | fertilization | interesting | spermatogenisi s |
| primitive | DREM | challenging | interesting | allantois |
| spatial reasoning | interesting | evolution | diverticulum | folding |
| mesentery | lateral folding | yolk sac | vitelline vein | neural tube |
| folding | weird | crazy | interesting | complicated |
| fetus | embryo | development | baby | pregnancy |
| baby | changes | teratogen | growth | zygote |
| Alien-like | Universal | Allantois | Umbilical cord | Feta circulation |
| baby | teratogens | development | conception | folate pathway |
| mnemonics | videos required | color-coded drawings | confusing | faculty disagreance |
| development | blastula | morula | placenta | endoderm |
| baby | fetus | bilaminar disc | pink | growth |
| zygote | human rights | abortion | birth defects | baby |
| Development | Embryo | Zygote | Germ layers | Notochord |
| stressful | baby | other | anatomy | physiology |
| Embryo | Fetus | Development | Reproduction | DNA |
| Difficult | Foundational | Essential | Initial | Relevant |
| embryo | zygote | notochord | neural crest | fetus |
| Start | Origin | Complex | Blast | Parasite |
| embryo | fetus | development | growth | differentiation |
| Spatial | Neuroscience | Development | Gastrulation | Neurulation |
| fetus | embryo | zygote | blastocyst | morula |
| Fetus | Embryo | Development | Difficult | Extensive |
| baby | embryo | growth | complicated | difficult to |

| | | | | |
|---|---|---|---|---|
| | | | | visualize |
| babies | ovaries | mesoderm | ectoderm | endoderm |
| development | difficult | germination | fetus | intricate |
| chorion | mesoderm | ectoderm | endoderm | epiblast |
| development | differentiation | uterus | placenta | amnion |
| Development | defects | fetus | pregnancy | female health |
| blastocyst | gern layers | notochord | neurotube | hypoblast |
| Very complicated | Difficult | Disorganized curriculums | Interesting | Biology |
| Development | Neurulation | Tube-within a tube | Embryogenesis | Neural folds |
| spatial | vocabulary | fetus | chorion | gastrulation |
| beginning | growth | manifestation | structures | gestation |
| Rigorous | Confusing | Abstract | Dynamic | Baby |
| Development | Germ Layers | Embryogenesis | Gastrulation | Zygote |
| Notochord | Ectoderm | Endoderm | Mesoderm | Neural plate |
| Development | Gastrulation | Neuralation | Morula | Fertilization |
| complex | development | embryo | fetus | fertilization |
| blastomere | uterus | fallopian tube | embryo | trophoblast |
| Development | Malformation | Congenital | Complicated | Dynamic |
| tube within a tube | notochord | mesoderm | ectoderm | endoderm |
| Trilaminar Disc | Gastrulation | Neurulation | Embryo | Fetus |
| uninteresting | bloated | theoretical | tiresome | fluff |
| morula | babies | pregnancy | abortion | congenital defects |
| abstract | difficult | conceptual | babies | pediatrics |
| Development | Germ layers | Baby | Differentiation | Notochord |
| blastocyst | zygote | complications | stem cells | abortion |
| ectoderm | mesoderm | endoderm | embryo | fetus |

| | | | | |
|---|---|---|---|---|
| Embryo | Allantois | Ductus Arteriosus | Amniocentesis | Birth Defects |
| Intricate | Small | Frustrating | Confusing | Interesting |
| spina bifida | zygote | cleavage | amnion | chorion |
| germ layers | differentiation | genes (Hox, etc) | cell signaling | primitive streak |
| mesoderm | notochord | endoderm | exoderm | baby |
| Teratomas | Gametes | Scary | Rapid | Trilaminar |
| notochord | birth | egg | sperm | labor |
| Induction | Stem cells | Cardiac Tube | Urogenital Fold | Teratology |
| extensive | perplexing | heart-breaking | insane | overwhelming |
| Life | Human | Abstract | Art | Jumble |
| interesting | life | important | relevant | difficult |
| disability | syndrome | miracle | somite | endoderm |
| Surprising | Difficult | Illogical | Boring | Fetus |

| | | | | |
|---|---|---|---|---|
| complicated | drawings | process | life | sequence |
| Fossa Ovalis | Yolk Sac | Neurogenesis | Teratogens | Fetal |
| embryo | fertilization | placenta | neonatal | growth |
| Germ layers | Ectoderm | Endoderm | Mesoderm | 22 days |
| Supply | Rotation | Change | Weeks | Normal |
| Wnt | BMP | Sonic Hedgehog | Dorsal | Ventral |
| Distant | Gastrulation | Notochord | Neural crest cells | Stem cells |
| blastula | implantation | mesoderm | pluripotent | birth defect |
| Ectopic | Pregnancy | Fetus | Embryo | Birth |
| meroencephaly | spina bifida | somite | blastocyst | notochord |
| Uterus | Migration | Gradual | Embryonic period | Important |
| Diploidy | Aneuploidy | Chromosomes | Nutrients | Umbilical |
| easily forgettable | challenging | visual | boring | strange |
| Obstetrics | Complicated | Overwhelming | Detailed | Pregnancy |
| disappearance | detailed | signalling | control | time-consuming |
| pregnancy | uterus | amnion | egg | fetus |
| Neural plate | Primitive streak | Congenital defects | Anencephaly | Scary |
| placenta | morula | complex | stages | mitosis |
| mutations | baby | hormone | placenta | sex |
| development | fascinating | animations | larvae-like | detail |
| Endoderm | Development | Gastrulation | Notocord | Caudal |
| ectoderm | nuchal cord | calcification | development | complex |
| Fetus | Growth | Placenta | Efficient | Complex |
| differentiation | mitosis | mesoderm | yolk sac | endoderm |
| ectoderm | BMP | genetic gradients | primitive streak | notochord |
| three-dimensional | heart development | trilaminar disk | hypoblast | zygote |
| notocord | mesoderm | ectoderm | edoderm | paraxial mesoderm |
| Intricate | Fascinating | Boring | Abstract | Aggravating |
| Yolk Sac | Conserved | Tail | Amniotic Cavity | Embryonic Folding |
| Notochord | Pharyngeal Arch | Neuralation | Gastrulation | Somite |
| Embryo | Acromosomal process | Beginnings | Egg | Fertilization |
| Parietal | Yolk Sac | Epiblast | Blastocyst | Gestation |
| growth | cavities | deformities | birth defects | teratogens |
| important | theoretical | necessary | daunting | fearful |
| ectoderm | mesoderm | foregut | hindgut | placenta |
| seeds | malformations | unified | human | spiritual |
| apoptosis | embryology | umbelical | notochord | neural tube |
| oogenesis | sequences | nerulation | zygote | fetus |

| | | | | |
|---|---|---|---|---|
| connecting stalk | epiblast | hypoblast | invagination | morulla |
| movement | complicated | stages | developmental anomalies | individualism |
| primitive pit | omphaloenteric duct | ductus venosus | somite | ectoderm |
| confusing | relevant | challenging | cranial | caudal |
| woman | period | ovulation | gastrulation | neurulation |
| oocyte | fertilization | organogenisis | cool | yes |
| Quad screen | Pregancy | Wonder | Mysterious | Limb buds |
| spina bifida | placental development | abortion | neural tube | immunity |
| illustration | teratology useful in learning normal | should be taught along side anatomy | difficult | slightly boring |
| mesoderm | ectoderm | neural tube | notochord | abortion |
| neural crest | neural tube | gastrulation | fertilization | congenital |
| politics | neurulation | development | evolution | homology |
| Growth | Differentiation | Animations | Neurulation | Folding |
| process | time | study | pregant | teratogen |
| Zygote | Differentiation | Complicated | Mysterious | Miraculous |
| Required | Conceptual | Tiring | Visual | 3-D |
| uterus | blastula | amnion | yolk sac | ectoderm |
| Risky | Amazing | Notochord | Fast | Cool |
| pregnancy | difficult | umbilical cord | newborn | uterus |
| Blastocyst | Ectoderm | Mesoderm | Endoderm | Notochord |
| amnion | chorion | stressful | complex | folding |
| Complex | Interesting | Fast-paced | Concerted | Long |
| trilaminar | mesoderm | multi-faceted | spina bifida | birth defects |
| yolk sac | sex | development | gastrula | blastocyst |
| birth defects | mesoderm | ectoderm | endoderm | fertilization |
| hypoblast | yolk sac | cytotrophoblast | ductus arteriosus | gastrulation |
| fertilization | zyote | ovary | implantation | cell division |
| gastrulation | organogenisis | meiosis | somites | neural plate |
| epiblast | somites | neural crest cells | amnion | yolk sac |
| Fetus | Germ layers | Gestation | Fertilization | Gastrulation |
| COmplicated | Folding | Mushing | Invagination | Lumps |
| frustrating | unorganized | complicated | neurulation | organogenesis |
| etiology | small | significant | anatomy | basics |
| Necessary | Straining | Muscles | Transcription factors | mesoderm |
| Neural Plate | Notochord | Development Abnormality | Trilaminar Disc | Medicine |
| Folding | Amniotic | Chorionic | Yolk sac | Epiblast |
| Ectoderm | Mesoderm | Endoderm | Amniotic | Blastocyte |
| blastocyst | morula | amnion | chorion | notochord |

| | | | | |
|---|---|---|---|---|
| gastrulation | not applicable | notocord | neurulation | yolk |
| Evolution | Indirect Clinical Relevance | Transformation | Fetus | Conceptus |
| zona pellucida | zygote | syncitiotrophoblast | fetus | baby |
| Neural Tube | Folic Acid | Implantation | Organogenesis | Miracle of life |
| specific | inadequate | rushed | fetuses | disks |
| frustrating | overwhelming | interesting | complicated | uncertain |
| neonatal | genetics | anatomy | fetus | embryo |
| Spina bifida | Growth | Blastula | Gastrulation | Neurulation |
| differentiation | germ layers | placenta | miracle | trimester |
| fertilization | complicated | unknown | new | differentiation |

## ECS survey

| | | | | |
|---|---|---|---|---|
| endoderm | mesoderm | ectoderm | somites | neural tube |
| rotation | embryo | tiny | nerves | dermatomes |
| spina bifida | mesoderm | neural crest cells | blastula | fertilization |
| fetus | neonate | rotation | babies | placenta |
| Human | embryology | fun | memorize | memorize |
| Difficult | Frustrating | Interesting | Annoying | Fetus |
| confusing | illogical | evolution | aperts | thalidomide |
| development | fetus | genetics | vestigial structure | homologous |
| foundational | challenging | nerulation | fertilization | confusing |
| birth | heart | breathing | crying | emotion |
| Embryo | Growth | Change | Development | Genetics |
| gastrulation | blastula | neural crest cells | embryogenesis | fertilization |
| embryo | fetus | pharyngeal arch | growth | development |
| development | morphogenesis | differentiation | neural tube | gastrulation |
| interesting | integrated | essential | foundation | development |
| Germ layer | Derivative | Ectoderm | Endoderm | Mesoderm |
| confusing | complex | neural crest cells | arches | folding |
| babies | congenital malformation | development | complex 3D | multiple things happening at once |
| bilaminar | trilaminar | dermatomes | 12 week | heart |
| neural tube | notochord | mesoderm | endoderm | ectoderm |
| folding | budding | conceptual | spatial | timing |
| understandable | clear | fun | interesting | easy |
| Endoderm | Ectoderm | Mesoderm | Mesentery | Cloaca |
| Complex | Interesting | Frustrating | Gastrulation | Essential |
| Origin | Derivative | Development | Congenital | Malformation |
| difficult | confusing | new | simultaneous | interesting |
| development | anatomy | embryo | fetus | placenta |

| | | | | |
|---|---|---|---|---|
| Confusing lectures | Folding | gastrulation | wish it was more clear | cardiac development |
| embryo | fetus | blastocyst | yolk | gastrulation |
| Development | Notochord | Embryogenesis | challenging | three dimensional |
| Development | Fetus | Timeline | Folding | Mesoderm |
| development | malformations | trilaminar | signal gradient | limbs |
| Gastrulation | Ectoderm | Mesoderm | Endoderm | Neural crest |
| ICM | Fascinating | Fetal | Neural crest | Complex |
| pharyngeal arch | fetus | development | congenital abnormalities | blastocyst |
| endoderm | mesoderm | ectoderm | congenital | urachus |
| cardiac cushions | ureteric bud | mesonephric ducts | vitilline vein | urachus |
| epiblast | hypoblast | ectoderm | endoderm | mesoderm |
| germ layers | folding | development | complex | important |
| Conceptual | Difficult | Random | Exetensive | Arbitrary |
| germial | gut tube | endoderm | ectoderm | mesoderm |
| painful | Interesting | time consuming | baby | development |
| Neural Crest | Arches | Cloaca | Urogenital Sinus | Primordial |
| Development | Origin | Evolutionary History | Ontogeny Recapitulates Phylogeny | Vestigial |
| Amazing | Logical | Coordinated | Fragile | Complex |
| yolk sac | cytotrophoblast | embryo | cell | zygote |
| Inner cell mass | Cleft lip/palate | endoderm | mesoderm | ectoderm |
| Folding | Trilaminar Disc | Endoderm | Mesoderm | Ectoderm |
| Gastrulation | Organogenesis | Origin of disease | germ layer | Fertilization |
| meckel's cartilage | trophoblast | epiblast | gastrulation | endoderm |
| endoderm | mesoderm | ectoderm | how | interesting |
| syncitiotrophoblast | epiblast | foramen cecum | cytotrophoblast | morula |
| Development | Trilaminar disc | Notocord | Neural crest | Pregnancy |
| Development | Primordial | Induction | Calender | Endoderm |
| story | progress | time | space | distribution |
| neural crest cells | foldings | layers | pouch | arch |
| pharyngeal arches | sex determination | sex differentiation | bilaminar disc | trilaminar disc |
| Child | Birth | Abnormality | Pain | Cure |
| Mullerian | Gut tube | Ambiguous | Cleft palate | Unclear |
| Interesting | Development | Human | Amazing | Complex |
| Pharyngeal arch | Umbilicus | Development | Gut rotation | Appendix |
| Difficult | Non-applicable | Heart | Lungs | Odd |
| development | movement | dense | vestigial | glossotracheal |

| | | | | |
|---|---|---|---|---|
| embryogenesis | development | morphogenesis | pharyngeal arch | primordial |
| difficult | confusing | Visual | yolk | conceptual |
| fetus | growing | abnormalities | blastocyst | embryo |
| mobile | obliterated vessels | temporally dependent | visually difficult | causative of disease |
| development | allantois | pharyngeal arch | umbilicus | transformation |
| rudimentary | patent | persistent | developmental | necessary |
| Stressful | confusing | complicated | fetus | heart |
| fetus | Tetrology of fallot | Round ligament | urachus | limb bud |
| embryo | development | arches | rotation | somites |
| fetus | development | dynamic | complicated | sophisticated |
| developmental flaws | trilaminar disc | pharyngeal arch | ductus | defects |
| Growth | Development | Tiny | Ductus arteriosus | Obliterated |
| confusing | complicated | poor explanation | irrelevant | terrible |
| Somites | Mesentery | Rotation | Anular Pancreas | Notochord |
| movement | development | nonesense | tiny | not able to see |
| Obliterated | Vitelline duct | Falciform ligament | Tetralogy of Fallot | Umbilical folds |
| gut rotation | gut tube | stem | fistula | frustration |
| Fundamental | Origin | Weird | Challenging | Elusive |
| Conceptual | Difficult | Descriptive | Enlightening | Fossa |
| fetus | mushy | colors | movement | logic |
| foreign | different | venosum | remnant | persist |
| boring | difficult | time consuming | annoying | fetus |
| fistula | ductus arteriosus | remnant | ligamentum venosum | persistance |
| Fontanelles | Pharyngeal cleft | Pharyngeal pouches | Ductus arteriosum | Ductus venosum |
| development | Endoderm | Mesoderm | Ectoderm | embryologic |
| foramen cecum | spina bifida | situs inversus | rotation | wnt signaling |
| important | human | adult | related | relationships |
| Pharyngeal | Arches | Sacs | Ductus | Obliterated |
| Complicated | Dynamic | Interesting | Gastrulation | Pouches |
| Early | Gastrulation | Caudal | Ectoderm | Mesoderm |
| obliterated | umbilical | hindgut | foregut | rotation |
| remnant | ductus arteriorus | ligamentum teres | annoying | confused |
| Ductus arteriosus | Development | Foramen cecum | Patent | Shunt |
| neural crest | neural fold | primitive node | umbilical vein | primitive streak |
| brings | me | to | my | knees |
| Development | Change | Ductus | Venosum | Arteriosum |
| Challenging | Interesting | Evolving | Connected | Detailed |
| Fun | Complex | Difficult | Incredible | Contradictory |

| | | | | |
|---|---|---|---|---|
| development | defect | preaxial | postaxial | teratogen |
| eyes | placenta | layers | change | growth |
| development | embryonic | tetragen | fetal circulation | organogenesis |
| aortic arch | amniotic fluid | prenatal | mesoderm | ectoderm |
| memorize | week | number | memorize | rotation |
| Baby | Pain | Waiting Room | Pregnant | Lack of Sleep |
| limbs | arches | pouch | membrane | pharyngeal |
| teratogen | stem cells | lineage | differentiation | HOX genes |
| interesting | fascinating | primitive | explanatory | babies |
| long term | difficult | family | mother | baby |
| Blastocyst | Somite | Notochord | Gestation | Zygote |
| pharyngeal pouch | differentiation | mesoderm | endoderm | ectoderm |
| neural crest | endoderm | mesoderm | ectoderm | notochord |
| Hox genes | notochord | pharyngeal arches | blastocyst | implantation |
| dermatome | pathophysiolo gy | malformation | difficult | 3-dimensional |
| Lateral plate mesoderm | Notochord | Neural tube | Bud | Induced |
| gastrulation | weeks | endoderm | ectoderm | mesoderm |
| epithelial-mesenchymal interactions | tissue reorganization | tiny | interesting | helpful to know |
| lung bud | urogenital system | chanals | aorta | gut tube |
| mesenchyme | lateral plate | paraxial | gut tube | lung bud |
| unclear | random | germ layers | complicated | growth |
| 3D | trilaminar | pluripotent | tubes | ductus arteriosus |
| Arch | Congenital | Omentum | Vitelline | Ligamentum |
| Foundation | Development | Congenital | Weinhaus | Folding |
| Disease | Anomaly | Structure | Orientation | Genetic |
| complex | language | days | relevant | imagination |
| trilaminar disc | blastocyst | embryoblast | epiblast | hypoblast |
| ligaments | omentum | x should do all the lectures | Ensure all of the figures used for the lectures are consistent in terms of colors used for the layers | Very useful to understand abdominal arterial/venous supplies and automatic nervous system |
| development | umbilical | foregut | midgut | hindgut |
| abstract | simultaneous | unorganized | challenging | growth |
| Origins | Congenital | Signaling | Germline | Embryo |
| craniofacial | neural crest | folding | umbilichus | fertilization |
| Pharyngeal arches | Zygote | Embryo | Somite | Invagination |

| | | | | |
|---|---|---|---|---|
| Endoderm | Mesoderm | Ectoderm | Yolk sac | Allantois |
| gut rotation | neural crest cells | urachus | umbilical vein | ductus vernosus |
| pharyngeal arch | limb | development | weeks | embryo |
| interesting | applicable | urogenital sinus | pharyngeal arches | sacular stage |
| neural tube | neural crest | foregut | midgut | hindgut |
| fragile | trophoblast | interlinked | clinical | congenital |
| Unfamiliar | Complex | Illuminating | Integrative | Challenging |
| folding | fetus | craniofacial | pouch | arch |
| twisting | tube | confusing | alien | parasite |
| Germ cell | Placenta | Herniation | Urachal Fistula | Embryology |
| Congenital | Mythology | Parasite | ligament | collapsed |
| Confusing | Layers | Red | Yellow | Blue |
| folding | timing | gastrulation | neural tube | neural crest |
| Paraxial mesoderm | Intermediate mesoderm | Growth | Pharyngeal pouches | Epaxial |
| Development | Pharyngeal arches | Notochord | Ontogeny | Phylogeny |
| clinical correlations | tissue interactions | patterning | morphogenesis | fascinating |
| mesoderm | ectoderm | lateral somitic frontier | brachial arch | apoptosis |
| heart | hormones | transcription | expression | weeks |
| blastocyst | endometrium | ampulla | pharyngeal pouch and arch | hard to understand - sometimes |
| Intermediate mesoderm | Lateral plate mesoderm | Paraxial mesoderm | Obliterated structures | Congenital abnormalities |
| Ectoderm | Mesoderm | Branchial arch | memorize | relationship |
| explicative | animals | interesting | conceptual | visualization |
| foregut | midgut | hindgut | mesoderm | endoderm |
| ureteric bud | urogenital sinus | lateral folding | neural crest cells | notochord |
| Medicine | Pediatrician | Genetics | Trimester | Neural crest |
| Undefined | Irrelevant | Abnormality | Formation | Stressful |
| Endoderm | Mesoderm | Ectoderm | Notochord | Invagination |
| Interesting | Inter cell mass | Uterus | Fallopian tube | Cleft palate |
| Head | Pharyngeal arches | Viteline duct | Yolk Sac | Umbilical vein |
| diagrams | notochord | somites | neural crest cells | fold |
| blastocyst | germ cell layers | stem cell | gastrulation | differentiation |
| overwhelming | weird | awful | boring | arch |
| problems | defects | miscarriage | confusing | complicated |
| organ bypasses | variation | reabsorption | reason for adult structure | frustrating |
| embryo | rapid | organized | informative | rotation |
| organs | structure | difficult | boring | fetus |

| | | | | |
|---|---|---|---|---|
| lungs | GI tract | brain | endoderm | ectoderm |
| lung bud | ductus venosum | foregut | midgut | hindgut |
| fold | ventral | dorsal | pharyngeal | blastocyst |
| coordinated | poorly named | laint names | gut tube | pharyngeal arches |
| origin | somite | neural crest | folding | buds |
| Difficult | Pharengyl Arch | Thymus Gland | Fossa Ovalis | Foramen Ovale |
| somite | cleft palate | pharyngeal groove | Seifert | Hades |
| Folding | Bulbus cordis | Truncus arteriosus | Ligamentum venosum | Aortic arches |
| gubernaculum | embryo | notocord | ectoderm | pancreas |
| Ligamentum arteriousum | Ostium secundum | Foregut | Meckels diverticulum | Oh shit I didn't learn that |
| irritation | development | distraction | overwhelming | confusing |
| Helpful | Crest cells | Pharyngeal arches | Trilaminar disk | Gut rotation |
| Canal | Remnant | Long lectures | Frustrating | Charts |
| blurry | remnants | development | malformations | cool |
| rotation | foregut | hindgut | axis | neural crest cells |
| liver | heart | circulation | ligamentum venousum | thyroglossal duct |
| cyst | diverticulum | sulcus terminalis | development | daunting |
| Ligamentum teres | Median folds | Lateral folds | Heart conditions | Development |
| frustrating | confusing | interesting | arches | twisting |
| development | tetralogy of fallot | patent foramen ovale | organogenesis | sulcus terminalis |
| concepts | structures | helpful | difficult | complicated |
| Umbilical | portal | shunt | retroperitoneal | Peritoneal |
| Arches | Obliterated structures | Helpful | Unnecessary | Neural crest cells |
| Endoderm | Enbryo | Fetus | Spina bifida | Pharyngeal pouch |
| ligament | shunt | ligamentum arteriosum | ductus venosum | pharyngeal arches |
| lost | thyrocervical | sulcus terminalis | descend | pharyngeal arches |
| Ductus venosus | Pharyngeal arch | Thymus | Branchial | Limb bud |
| WNT | HOX | pharyngeal folds | notocord | neural crest cells |
| difficult | hard | cool | blah | baby |
| Fold | Rotate | Ovale | Embryo | Egg |
| Folding | Regions | Steps | Derived | Initial |
| Illogical | Fetus | Pregnancy | Scary | Surprising |

Appendix M: Student Most Interesting Data

## BCS survey

Birth defects, the process

how small simple things turn in to the diverse and complicated machinery of our bodies

How errors in embryology lead to serious defects; and the process in general

cell signalling and the role the notochord plays in induction

How fully developed humans originate

The way that all the tissues develop from three germs layers

Seeing how the development of structures influences their location in the body.

The utter integration of innumerable, highly complex processes happening simultaneously thanks to molecular signaling.

How we learned all of it

I like learning about the specific clinical correlations associated with embryological abnormalities

I enjoyed learning about birth defects and their embryonic origins.

How our bodies all have such a complex developmental process.

The process is so complicated and yet the majority of the time it goes off without a hitch. It's very regulated and interesting

How it can lead to disease when specific processes don't work

Where everything comes from

Discovering the mix of development that is advantageous for the fetus vs after birth

Understanding how the complexity of the human body arises from a single cell.

The complexity of the development

The fact that so many things can go wrong along the way makes the birth of a healthy baby seem like a miracle. Also, I feel that knowing more about germ layers and differentiation can be key in discovering how things in the adult body interrelate and about perhaps lead to new treatment ideas.

The applications to disease

It's amazing how we progress from one cell to a fully developed human...and even more amazing that all these really important steps happen correctly for the majority of us. I think it is very interesting and sad where the process goes wrong.

How it explains specific aspects of post-natal anatomy

It is the time of our lives during which we develop the most.

Clinical relevance...example: Fossa ovalis

How developmental processes influence gross structures after birth

The clinical side- the things that can go wrong

Just seeing how the baby develops and seeing life in each stage is pretty amazing.

The seeming whirlwind of steps and gene expression is absolutely astounding--and complex. Also, this is--truly--how life begins, so that is quite fascinating.

It's basically about where we are from and how we go from essentially two cells into an entire human being.

The migratory patterns of organs and tissues

How stem cells know which type of cell/tissue to differentiate into.

I think the most interesting thing about embryology is the similarities with other mammals. It is really cool to see how similar we all are until the end of development.

I find it very interesting to study where life begins in human terms. It gives me a new appreciation for the human body considering the complexity of embryological development and the low rate of birth defects.

weeks 0-3

Molecular aspects

Gastrulation and folding.

That different layers can be mapped to specific organs/components of the adult body.

I think it's just fascinating how we can indirectly "observe" (through pictures/animations) the development of a human being from a zygote to a newborn!

Its consistency across different species

Its implications for congenital defects.

All of it.

The differentiation of different cells and structures from a single cell

how something so small and simple becomes something so big and complex

when you can see how it relates to a clinical ailment

the differentiation of cells and organs

It is very elegant, and kind of divine.

I have enjoyed learning about the developmental process in relation to the different birth defects or abnormalities that can arise at different points of the developmental process.  It helps put the different processes in to context.

learning how embryology relates to anatomical differences among people and to developmental diseases

How mistakes in embryologic development leads to clinical pathologies in children and adults. How it explains the organization of grown human bodies. How it  reveals the history of our evolution.

It is interesting to see how an entire organism develops from such small chromosomal material.

understanding how we went from one cell to a entire functioning person

The course of formation

How teratogens affect development

teratology

How we can pick out stages of development and see how they effect a newborn and that person later in life.

discovering how some adult anatomical structures unexpectedly arise from embryology (why diaphragm is innervated by C3,4,5 but is located much more inferiorly)

The fact that organs/systems can be functional at such a small/early stage.

The coordination of so many steps and processes.

Baby development

How complicated human development is, yet how it all makes sense.

That it is the beginning of everything that we become.

How drastic changes are to the embryo as it develops

The 3D changing and growing, how things start and then move around.

Just the overall development from a embryo that looks like any other vertebrate, to our very recognizable human form.

I like the developmental, stepwise aspect of the course and content

The ability to understand how an egg and a sperm can unite to create a zygote which will undergo changes and develop into a person.

The fact that the process starts as a cell and ends as a human being.

How one fertilized cell can turn into an entire human being through many many processes all happening at the same time. And that it happens inside a woman's body!

Tissue and structure development

How intricate the process is and what small changes can cause various diseases.

The correlation to clinical pathology

Knowing where different body parts come from and how they developed

Hard to pick a certain aspect. Pregnancy and fetal development is fascinating as a whole. When the professor points out clinically relevant points in development it really grabs my attention.

The developmental defects in newborns.

Complexity of processes that lead to fully-formed human fetus.

That it's the development of humans

Clinical correlations with conditions we may see as future providers

the organized advancement of the structures

The cell to cell signaling to form an appropriate 3D organism

Learning how a fully formed human is developed from only two cells.

It is amazing how a human forms from a single cell.

Anatomically differentiation

I find potential abnormalities in development and their effects to be the most interesting.

the process of development

It's an amazingly complicated process that works most of the time more or less perfectly.

how the zygote knows exactly how to differentiate its cells and how the zygote/fetus is fully human even though it looks like something else

It is amazing to see how human life develops! This is the third embryology class I have had and it is always interesting. Extremely relevant to understanding many clinical conditions as well as a basic, unifying event in the human experience.

Clinical correlates

How mature anatomical structures are formed

Everything

The level of organizational complexity and concurrent processes.

That a single cell can somehow give rise to an entire organism

## ECS survey

all of it

learning the long-term effects that come from specific defects in development

Helps to map out the adult body and understand how systems work together. It is astonishing to learn all the nuances and things that can go wrong/create variation.

I enjoyed being able to connect a dynamic developmental process with something more static, like identifying structures in a dissection.

I like when it correlates to the final structure in adults.

That our bodies development is so complex, yet most people are born without abnormalities.

The changing of the heart pumping when breathing begins

Its capacity to explain why adult anatomical structures exist where they are and function as they do.

Even though I think the abnormalities in anatomy are the most challenging part to comprehend, they really do help explain a lot of clinical phenomena. (like the testes referring pain to the T10 dermatome, because that is where they developed, etc.) I also really enjoyed learning about the congenital defects.

Its relevance to clincal medicine

The development of the cardiovascular system.

How defects in embryological development lead to disease and disorders

It's relationship to anatomy and congenital deformities.

The complexity - that an enormously intricate process takes place with little variation for every embryo

It is interesting once I am able to understand visually what is going on with the embryo.

I think it is pretty incredible that one cell, through a variety of different signaling pathways, division, and differentiation, can become an entire tiny human.

I find the stages of development most interesting.

the divisions of different organ systems from ecto-, endo-, and mesoderm

The clinical correlations presented about how normal development goes wrong

The clinical correlations

Seeing how terminal structures develop in anatomy lab.

Ways in which development can be disrupted and the clinical manifestations

It adds context to the adult structure of anatomy

So many things happen so quickly and precisely to form a functional human being.

Most of it as a whole was interesting

It really helped me better understand cardiac and abdominal anatomy

I am most interested by so much development occurs in such a short time

I think it is interesting to learn about how a human develops

How complex yet amazing human development can be

learning why certain syndromes have the various symptoms and how those symptoms are all related via embryological developmetn

Neural development

Understanding how complex organisms develop from conception to birth and beyond

The linkage between embryonic development abnormalities and human congenital disorders.

Embryo folding

applying it to cardiac defects

Clinical applications - malformations, etc.

How so much of what we are is determined so early in development and how so much could go wrong--but usually doesn't!

When portions of anatomy integrated with other classes, it really helped me learn and remember things for those courses.

Clinical correlations

Body formation

The associated malformations and diseases.

I think it is incredibly elegant that the appropriate signals, gradients, cilia motion, cell surface receptors, asymmetric divisions provide sufficient information for one cell to differentiate into an entire organism. It is so amazing to me that these simple signals can provide so much information and variety.

Folding

It relates to anatomy.

I was particularly interested in the various points in development at which minor changes to a regulating factor would change the shape or layout of the embryo. It made the differences between humans and their ancestors seem minute.

I found learning how everything is developed from one cell very interesting. I loved seeing how the pattern is established and how cells differentiate to form different organs and tissues. I also loved learning about the development of the heart and the gut tube.
linking the embryology to the structure. For example knowing that the v3 of trigeminal nerve goes with everything from the first pharyngeal arch.
I liked how embryology answered many of the 'why' questions I developed throughout anatomy. For example, embryology answered 'why' there were so many confusing structures in the heart and 'how' the heart came to look the way it did.
I truly enjoy to learn how the embryo is able to attached to the endometrium. Also, I enjoyed to lear about the development of the face and neck.

Knowing the different stages of development and what is taking place at a given time
Learning about the vestigial parts of the human body. Also pathology, although we were not tested on pathology so it was not high yield studying.

The molecular side of things--the spatial-temporal gradients of paracrine signaling, etc.
the clinical applications to a lot of genetic conditions, and just why certain things in are body are where they are and function the way they do
I found human embryology interesting when I could make connections with anatomy and SMP. After midterms, once I learned about the signaling pathways, I gained a better understanding of embryology. Embryology also facilitated my understanding of anatomy.

Clinical correlations
The molecular signaling pathways involved (i.e. 2-cilia model, Wnt signaling pathway, ectoderm/mesoderm interactions)

Pretty much everything
Building on an understanding of gross anatomy, it can strengthen an understanding for locations and relationships in gross anatomy.

It does provide a nice comprehensive picture of how structures arise.
Embryology was important for understanding some structures in the body, especially the relationships of certain structures.

- helped understand why the adult organs, etc were the way they are

the complexity with which our bodies are able to develop and how cells communicate
I like that I can understand how organs get their different characteristics instead of memorizing it.

How structures begin to develop and form various structures.

Heart and lung malformations

The relevance to developmental abnormalities.

Correlation to clinical patholgies when human embryology goes wrong.

How complicated the process is and how frequently things actually turn out correctly.

I like finding how how humans develop and the different defects that can happen.

How it relates to adult embryo

honestly not much. The pathology is kind of interesting.
It was great when it helped explain why the gross anatomy was a certain way. It helped explain some of the relationships.

How all the processes eventually produce a real human

It works! (Most of the time)  Development into the mature structures

Clinical applications- Understanding origins of conditions in adults, i.e. Meckels diverticulum.
It enriches understanding of human anatomy by adding a "why" component to otherwise rote learning.

How it affects us as adults so much
It explains why certain anatomical things ended up the way they did, or why certain diseases/malformations occur.

See how it causes what we see now in born babies and adults
I find it interesting to understand the origins of certain developmental disorders after understanding what should occur normally.
I think it's interesting how much changes in so little time. I also find it fascinating that all the changes are coordinated so well.
I really enjoyed learning the devleopment of the heart and the nervous system - it is especially interesting when it is related back to clinical correlates.

It is a complicated field.

The coordinated growth of different organ systems.

The stepwise fashion of development

A more complete understanding of how things develop.
Learning about development is cool and the fact that it is such a complex process. It is amazing that we all turn out to be fairly normal.

Nothing

It is a miraculous feat and beyond imagination how it could happen.

How something so complex comes from almost nothing

The remnants still left in the body.

How the embryo changes

The details that help to explain why certain structures appear in a certain way in the body.

I find the complexity of developmental processes most interesting

Appendix N: Student Most Confusing Data

## BCS survey

figuring out what everything looks like

Processes that happen that have no functional value

Very difficult to visualize (and thus understand) without the aid of videos/props

visualizing developmental processes, and timelines

some of the layer differentiation around wk 2-4

The time frame is complex and can be easily confusing.

I can't visualize things!

3-D conceptualization of anatomical development

How did we learn all of these minute details about how we developed?

Use of vocabulary that is specific to embryology that is not really used in everyday life.

So far, the processes after gastrulation (lung buds, small intestines, etc.) has been the most confusing. The drawings and animations help, but there's just so much going on at once that it's a little overwhelming.

I find the topic of GI development the most confusing.

The process is so complicated- all the little details that are involved with regulation, and looking at everything that can go wrong can be overwhelming.

When single structures form multiple structures in the adult and vice versa. Lots of terms and name changes too.

Where everything comes from/ how names are constantly changing

Understanding the mix of development that is advantageous for the fetus vs after birth

Being able to visualize these processes in three dimensions. It would be exceedingly helpful to have a realistic 3D model of these events, rather than simple cartoons.

Trying to learn the complexity of development through either a PowerPoint or from an incomprehensible book.

Picturing development.

There are a lot of terms that are solely used in embryology, it is like learning yet another language

How from week to week the names of the structures and equivalent parts change as development progresses

multiple changes that occur in the same tissue with different names for each stage

It's not the topics so much that are confusing, it is the pace at which we are expected to learn everything. It would be more beneficial, I believe, to either introduce it before beginning beginning gross anatomy or require reading for it before the overload of classes begin. Maybe even a summer online class.

layers on layers on layers on layers

When things disappear or transform into other things

the initial (first trimester) development

When we got to the notochord and the divisions and folds, I have been confused ever since...the foldings and what they turn into in the adult body is hard to visualize and understand.

I really could not understand the formation of the primitive streak; I wasn't able to visualize the changes occurring during gastrulation. When the epiblast cells proliferate, I can't visualize the formation of the streak, notochord, or the lateral folding that occurs later. It's very difficult to conceptualize and visualize these changes in 3D when we only see them in two dimensions--on paper or a computer screen.

Notochord development. More generally, transmitting what is written in words to a spatial perspective or picturing the processes in my head.

Hard to visualize in 3d

The constant evolution and disappearance of structures and recalling which weeks they are in.
I think the most confusing thing is the contradictions--more than once a lecture has contradicted a text book or resource.
It is oftentimes difficult for me to visualize what we are talking about. Gross lab is helpful for me to further understand concepts, so maybe a lab with embryological specimens could help to ease confusion?

the detail intricacies of foldings and separations of new spaces

Visualizing some of the folds

The development of the organs.
Hard to say. We have online modules and I am just never sure of the depth I should get out of what I am learning. They go into great detail and then we barely are tested on it. If I had to choose I would say how the different layers fold is confusing to me.
Trying to visualize 3D structures in 2D, keeping track of all of the structures, and thinking about how and where they move during development. Also, a lot of the terminology is really difficult to keep straight.
Understanding the three-dimensional structures and processes represented by two-dimensional pictures.

Learning about something that is so abstract.

The different views of the zygote.

The interactions of various structures and the overall physical orientation of the embryo

how all of the different layers form, develop, and interact

the abstractness of the subject

when things happen and the terminology that overlaps/changes for certain structures

So many steps! Do I really have to memorize all of it? Let's be real.
It is oftentimes difficult to follow where developing structures migrate to (eg when something develops near C3 and ends up around T10 like the diaphragm). Similarly, remembering the sequence of when certain structures are renamed can be challenging.

the developmental process, spatial reasoning, understanding/recognizing slides of embryo

All the spatial reasoning and understanding of 3D events that had to be taught in 2D.

Spatial relationships, 3-D arrangement of structures and their migration

Learning structures do not yet resemble a human.

understanding how we went from one cell to a entire functioning person

All of the very many morphogens and keeping them straight

Complexity of growth signals

gastrulation

How things separate out and where they end up in the body- the different lineages of things.
certain developmental processes may be difficult to visualize without plenty of images/animations from various angles

Development and splitting/fusion of tissue layers.

Keeping track of concurrent events in different systems.

the structures

The multiple steps occurring at the same time.

Folding.

How unlike a grown human the embryo is at first

The terms.

The first few weeks of development and differentiation.
I think it is very difficult to spatially understand development and the different things occurring together
The complexities of the many cellular differentiation and cell migration steps and the many structures that develop and regress throughout the course of fetal development.
The fact that so many things happen at the same time, I am a sequential learner so jumping around is a little difficult for me.
It is really difficult to visualize what is happening, and many processes are all happening at the same time, so it is challenging to wrap your head around what is happening when and where and what that would look like.

folding of the embryo

keeping track of what tissues become particular structures.

All the twisting and turning of cell layers.

Picturing everything

Remembering time frames especially since a lot of stuff happen simultaneously.

How the adult structures that are given by specific embryonic parts.
The sheer amount of changes that the embryo undergoes in such small time frame. Also, tracing the derivatives of each germ layer, etc.

Many things happen at the same time and it is hard to keep them all straight
Understanding the different processes that are occurring simultaneously and spatial orienting myself while maintaining a hold on the vocabulary.

the overlapping timelines

cell to cell signaling

The terminology.

The developmental process of the tube within a tube.

The timeline and everything that is happening at the same time.
So far I struggle with visualizing things in a 3D manner (i.e. from different angles or through different cross-sections) to be the most difficult.

all the vocabulary
The dynamic nature of the topic can be hard to follow, especially when figures in text books aren't clear about what plane you're looking in. Well made animated videos would be very very useful, but most of them online are not quite up to the standards of the textbook.
the concerted efforts that happen throughout the process. it is difficult to visualize multiple complex processes happening at the same time.

Translating info from 2D renderings to a real world 3D understanding can be tricky.

It can be quite abstract.
3D geometry is hard to teach, and while I consider myself to be a spatially oriented person I've always found this difficult

So many things happening simultaneously over a relatively short period of time

The differentiation of layers and regions in the first 4 weeks.

How cells differentiate into different tissue types

## ECS survey

heart

Imagining the 3D changes that are occurring during development when looking at 2D pictures
Timelines--understanding how different aspects of development are progressing at simultaneously. Also hard to imagine development in 3D since texts mostly use simplistic pictures.

Visualizing very early development can be difficult; online animations helped. I am still confused with ventral/dorsal mass muscles changing orientation with limb rotation.

Why memorizing the weeks is useful.

Why certain things grow at different rates.

currently- the rotation of limbs on their axis

The subject's abstract nature and lack of intuitive actions.
There are several 'abnormalities' in embryology (things that aren't intuitive). Memorizing these abnormalities can be difficult.

Detailed structural names irrelevant to clinical medicine

Visualizing development spatially, especially when there is rotation involved
It is taught in a 2-dimensional format whereas it is a very visual and 3-dimensional subject, so I feel that I would better understand the content if it were taught in a different way than a lecture format.
Orienting myself to where in the embryo processes are taking place, how they are related to other processes, what times different processes are happening.

There are do many different processes all going on at the same time that are all related.
All of the different processes happening at the same time. It is very difficult to envision where the different processes are happening and what that would look like.

most of renal development
the lateral plate/ paraxial, intermediate mesoderm and difference between mesoderms and mesenchyme
It seemed scattered and the method of teaching by different professors/physicians made consistency difficult. Also understanding the simultaneous nature of the course was difficult

the first few weeks
Vocabulary, as well as keeping development of certain systems/regions of the body straight on a timeline (conception to birth).

The timing of events and how they interact.

Cardiac development is confusing without good figures.
It is difficult to understand the topic quickly because many things are happening at once, and the language that is used is new to me.

The 3D representation of how things developed was confusing

Folding (gastrulation).

I am confused about how some of the signaling works
Three dimensional thinking and comprehending everything that happens simultaneously when you are learning about it in isolation from each other

Folding and combining different systems on the same timeline

the first folding part before it has adult like landmarks

Heart formation

Spatial orientation
The constant change of the structures and organs. Also the timing of the development of different structures and organs.

Diaphragm development

the early early stages of development

The general timing of things and the turns/folds that occur to form adult structures

Visualizing all of the different things going on and keeping track of what was happening when.
The beginning portion seems random and arbitrary. By organogenesis, things start to meld a little better and you have more "oh that makes sense because of X and X," where in the beginning you just think, "okay you said that so I'll just memorize it and believe you."

3D structures are very hard to picture

tube within a tube formation

The pathways.

See above.

Folding

All the things that are going on at the same time.
The number of new words that were often very similar to each other often confused me, I needed a very deep understanding of the meaning of each word in order to keep the terms straight.
It was hard for me to picture the 3D development of structures some times. The videos that we were provided were very helpful to picture how things develop in space.

3D rotation
I find making the connections between all the things that are happening at the same time to be difficult.

The folding of the embryo is sometimes confusing.

Lateral rotation of the upper extremities
Following the course of development in terms of structures rotating as well as pinning specific days and weeks to a period of development.

Understanding and remembering the timeline of events--what's happening when with what.
the first head and neck lecture was awful. I had to read my Langman's and my board book multiple times to figure out what was going on.
I found some of the clinical correlations confusing. However, once I studied embryology more and learned the biochemical pathways, I understood it.

Heart development

Heart formation

the 4D visualisation (time, 3d space) of how things happen during the first trimester

Nothing in particular

The time-based process of certain limbs and internal structures' development.
I do not have a strong grasp on any human embryology, but I would say the shifting of structures from their original locations was difficult to grasp.

It was difficult for me to picture the processes in motion and in 3D.

can be very detailed and numerous steps (e.g., heart tube folding and septal formation)

hard to see
visualizing the changes in structure when presented 2D static images and expected to understand it in much more complex relationships
It is difficult to visualize the three dimensional structure of embryological structures without seeing them in three dimensions.

Visualizing the embryo in three dimensions.

Just remembering in what order things happen.

The different pictures and how sometimes things did not seem to match up or seemed irrelevant
3 dimensional development hard to visualize with a presenter teaching from 2 dimensional diagrams

The naming system using latin is pretty awful.
It is very hard to really teach embryology in such a clear and concise manner and make it come together when it randomly appears in the course.

The formation/disappearance of certain organs
Everything. It's a 3-D topic that is very complex yet it is taught with verbal explanations using overly busy and poorly made illustrations. Add to this the fact that our course text, Thieme, doesn't even include embryology, so we have to get it from BRS which has even crappier drawings than what are in the lectures or Moore's, which is way more complex than what we need for this course.

The folding/rotation. It was difficult for me to put the whole story together.
All the movements of structures & how primordial structures give rise to what we have in live humans

Foreign vocabulary
It seems like a whole different world than our normal 70kg man we spend so much time learning about. Seems cryptic at first.

Many of the things are just so conceptual that its frustrating to understand it all!
The fact that lots of things move around a lot, so certain structures can be far displaced from their origin, causing them to have a different blood or nerve supply than the rest of their neighboring tissue in the adult body.

The words and all the dynamic changes
The terms are typically ones that we have not heard before. In anatomy, while there are some terms we haven't heard before, many of them we have been exposed to from childhood to this point since we had to take classes that taught us about the human body. The majority of terms in embryology seem completely foreign.
I find all of embryology to be confusing. I feel like the professors don't understand it well enough to teach it.
our lecture notes are difficult to get through; most of the time I have gone to youtube to create my own notes and then find my clinical correlates to relate it back to class material.

There are few concepts to tie the information together.

Rotations in space and orienting myself while looking at the pictures.

The dynamic nature - nothing is constant

The 3D aspect.

The development has so many stages that it is difficult to remember everything.

Too many structures and terms I have not seen before
The amazing amount of simultaneous growth, rotations, shunts and the like. Specifically I find somitogenesis and neurulation to be the most visually/ conceptually challenging. Organ development is easier

Visualization of the processes

How things change so much or move.

The specifics

The many different steps of each process of development.

I find the GI system most confusing.

## Appendix O: Student Suggestions for Improvement

### ECS survey

nope, the animations are great
Devote a whole block or class to embryology. Use more models or videos to help students picture the processes.

animation videos for limb development

No.

The more animations/pictures, the better.

no
The more animations, the better. This really helps me visualize the structural changes that are happening during development.

Keeping the material related to clinical medicine only
We had a lecture on the clinical applications of embryology but the lecturer was not at all convincing - whereas some of our regular lecturers brought us more clinical applications...so that one I really felt was unnecessary.

Supplying more animations and videos
I think 3-dimensional models, small group discussions would be more helpful than lectures and slides.
X's lectures were very clear and straightforward. I believe I would have learned more if X had given more of the lectures or if the other lectures had been presented in ways similar to X's.
I think there should be one embryology professor who teaches us the entire course. That way they know what we do and do not know and they can design a course that teaches us everything we need to know. Also, correlating the embryology with the ultimate adult anatomy and with interesting clinical correlations helps us to understand why it is so important!
Offer the course as a separate class, and have professors teach the course who are genuinely interested in Embryology.

Have X teach everything.
More uniform presentation of material and uniform handouts/additional resources. Some of the lectures were very dense and difficult to follow.

maybe have only one professor, like just X.

Don't treat it s a course that is just thrown on top of anatomy.

Use more figures from langman in lecture. They are very clear.
I would have one professor teach the course. Every professor used different kinds of photos/tables/diagrams/outlines etc. and this made learning some topics more difficult. I really liked X and the photos X used. Embryology is difficult to understand via words so I think good photos and videos are essential.

Could have professors who are more prepared in presenting the materials teach it.

Better teachers, better pictures
I think X should teach all of the embryology lectures. The other professors did a good job, but I think continuity would be very helpful.

More 3D graphics and organization
Better teachers - ones that will incorporate clinical connections only after we have a base of what goes on during development

Keep the same instructor for all lectures.
I have taken developmental biology before, and in my opinion foundational orientation was not emphasized enough in this class. It was often difficult to decipher where in space lecture material was derived from, and without this concept firm, it made learning the material difficult. I think more attention needs to be paid to the presentation specifically of this material - I love embryo as

a class/concept, but the lectures were often so nutty or convoluted it was hard to know what was what! The lecture on Urogenital development stands out as a highlight, as well as X's lectures in SMP on development.

Just have the best embryo teachers (not physicians) to teach us. They are much better at building a firm foundation of embryology for the students. We had several guest embryo lecturers who are great physicians/surgeons but they are not necessarily good at teaching.

Have consistency with how lectures are presented.

Cross sections are very difficult to understand when they are just slices. Removing a quarter of the "pie" if you will would make it easier to put into 3d context

Create lecture outlines ahead of time to give to students in the anatomy course packet; perhaps use more videos to explain concepts

Yes, I think it should be taught by one faculty member, rather than a new and different surgeon every week so that there is more continuity with learning.

I really recommend the textbook. I think the Langmans was a really linear way to absorb the material and the pictures were fantastic. I would recommend that the book be more integrated with the lectures, so that a student is getting two presentations of the same resource, which would make studying easier. Instead of going to lecture then ALSO have to read the book. But I understand that other have different learning styles.

Lectures that include both words and pictures with summaries.

More in depth materials

X should have X teach almost every embryological course.

N/A

More animations during lecture

No.

It would have helped my learning if the lectures were more complete and contained more of the information on which we were tested. Some study groups or small group discussions of the material might have helped in synthesizing the information as well.

I think it is very important that terminology is explained well and, as much as possible, explain how things are developing in space.

Perhaps more integration with anatomy during the anatomy lecture in addition to the embryology lectures. For example while learning the stapedius m. it could be thrown in that it is innervated from the second arch.

I think greater consistency would have helped. We only had a few embryology classes scattered throughout the semester. I would have liked more classes that didn't only focus on the specific development of a system, but also incorporated that system into the greater picture of what was happening during development those weeks.

Is all fine in our institution. I think one thing may be changing the time in which the course is given.

N/a

Do not make lecture at 5:30. X was by far the best presenter of the material and X should be delivering all the lectures.

Just let X teach everything!

The test banks, videos, and additional handouts were helpful. I thought some lecture were more organized than others, having a summary table or slide. Possibly having that for all the lectures.

The heart course needs to be simplified

Do not try to fit so much information into such a minor aspect of HSF, it took away study time from more important subjects.

more animations and more biochemistry

Better organized lectures

The more advanced 3D models and videos that can be shown would aid in the process of understanding.

When incorporating human embryology into a unit, present it at the beginning of the unit.

The diagrams were generally very difficult to follow. I'm not sure if that's just the nature of the material, but clearer (perhaps more simple) imagery could be very helpful.

Incorporate it for each organ system/body region
use more videos and/or incorporate more images, especially ones that can be rotated or controlled in 3D

Show videos of all embryologic events that we are expected to know.

I think embryology should be emphasized more and may require its own course.
To incorporate more videos showing the process. I think it would be helpful to show videos during almost every lecture to target those that learn visually.

Should spend more time on it.
Separate course, or at least specifically outlined material on embryology for students to use as a reference.

Incorporate more videos - it's so dynamic 2D images don't do it justice.
Make a separate embryology course. It doesn't have to be a whole semester, but it feels like an afterthought where it is randomly put in some sections of the course.

I think X does a great job.
As stated above, the explanations are usually bad and overly complex. X tries, but just fumbles the ball with busy diagrams and jargon-y explanations. Recommendations: 1) Make short, Khan Academy style videos about discrete topics that can be put on youtube and watched and rewatched (and rewatched, and rewatched). Best if these include animations or 3-D objects similar to the way Acland's anatomy videos pan in and out and rotate around an actual, 3-D skull. 2) Teach embryology in a unit or all together in a lecture or two (but dear god, not a whole class of it!). Spreading it out across the course doesnt' work for me. I'd rather start or end with it and have it all at once to master the terminology and integrate it all together. I don't remember how the gut rotates now that were on head, but I suspect that it would have been useful to learn concurrently with the pharyngeal arches. 3) Better, more down-to-earth explanations. It's an incredibly dense, jargon-filled discipline. Recognize that most med students don't care about embryology b/c we don't think it's relevant to medicine. We might be wrong but that's what we think. Cut the jargon and focus on the concepts that we can carry forward and apply if we go into an embryology-heavy field. For example, the embryology of the heart could have been distilled down to the relevant pathology that we will see on boards/in real life and still achieved the same thing. Most of the normal processes are long forgotten. 4) Case studies to convince us it's relevant. Tell me how I will use this when I'm a Family Medicine doctor treating a kid in my clinic and I'll pay more attention than just telling me about how this thing with some crazy name migrates over by this other thing with an equally crazy name.

More time would help. I think it should be its own course.
Start from the beginning to give a basis instead of just throwing embryology in at random times (i.e. just embryolgy of the heart or abdomen during those units--no context to understand them w/o base knowledge)

Stick to the stuff that's critical for understanding the clinical applications/presentations.
Eliminate it from gross anatomy, put in it's own separate course. If it must be in gross, give a complete primer of it, rather than disjointed bits and pieces in different units… difficult to understand in a discontinuous form.

I think that it should receive a stronger treatment in gross or a separate course.
Show more YouTube videos at the end of lecture to bring it full circle. Also, when lecturing on a difficult topic such as embryology, put (at least) a few words on the slide. If you just talk for literally 30 min on one slide, you don't get everything written and you can't really process the information!
I like it the way it is. It's usually sort of mixed in with whatever relevant structure we're learning about, which makes it interesting and easier to make logical connections. It's hardest when there's a big chunk of embryology material presented by itself, because it doesn't feel as relevant.
Organize it better in the course It seems like it is thrown in the lecture order randomly/sporadically

Lecturing more slowly than the other lectures would help since the terms are more foreign. Showing more supplementary videos of what is going on would also help in visualizing everything.

I find the study of embryology during an anatomy course to be confusing. I would much rather have a course dedicated only to embryology where the professor specializes in embryology.

I wish we had our own embryology course instead of just a couple extremely difficult lectures thrown into an already hectic and involved anatomy course. I think this knowledge is extremely critical, and I wish we had an entire course devoted to development.

No.

Yeah completely change the material provided on the thorax embryology. The pictures and descriptions were very hard to understand.

I think the current approach strikes a nice balance; there is enough coverage to help understand adult structures but not an emphasis on learning embryo for the sake of embryo.

More animations.

Focus only on the major points of embryology, not on the minor details.

There should be a separate embryology course. Or we need better illustrations/videos/models

Make it more dedicated rather than interspersing here and there. Like at the end of the course take a week just for embryology

More animated resources

Simplify it.

Actually teach it

I feel that videos are very helpful in learning embryology.

I think it is taught very well. X is one of the most knowledgeable professors I have ever had.

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**CURRICULUM VITAE**
Keely Marie Cassidy

EDUCATION

**Doctor of Philosophy**: Anatomy and Cell Biology June 2016
Minor: Education
Indiana University
Indianapolis, Indiana
Dissertation: *Embryology in Medical Education: A Mixed Methods Study and Phenomenology of Faculty and First Year Medical Students*

**Masters of Science**: Anatomy 2011
Des Moines University
Des Moines, Iowa

**Bachelor of Arts**: Athletic Training (cum laude) 2009
Buena Vista University
Storm Lake, Iowa
University College Cork
Cork, Republic of Ireland

PROFESSIONAL WORK EXPERIENCE

**Indiana University, Center for Innovative Teaching and Learning** 2013-2016
Graduate Assistant to Instructional Consultants

- Collaborate with instructional consultants and university faculty to procure Institutional Review Board approval and produce research in the scholarship of teaching and learning, as the Research Project Manager.
- Co-facilitate workshops for faculty and associate instructors (e.g., How to Write a Course Proposal, Teaching Portfolios, Statements of Teaching Philosophy, Biology Associate Instructor training, Leading Discussions).
- Maintain organization and assist in design of campus-wide events focused on teaching at the university level (e.g., New Faculty Orientation, Associate Instructor Orientation, Classroom Climate Workshops).

**Indiana University School of Medicine, Medical Sciences Program** 2015, 2012
Gross Anatomy Cadaver Prosector

- Independently perform one complete body cadaveric prosection; complete an extensive report on the donor's body habitus, physical state, and pathologies; conduct weekly meetings with laboratory director regarding prosection progress; mentor high school student observing in the laboratory.

**Indiana University, College of Arts and Sciences** 2014-2015
Assistant Webpage Developer

- Transfer content to the webpage of the university-wide required undergraduate course, Traditions and Cultures of Indiana University (X112); sustain communications between course instructors and technological consultants.

GRANTS, HONORS, and AWARDS

**Outstanding Associate Instructor Award** 2016
Indiana University School of Medicine, Medical Sciences Program

**Influential Instructor Award** 2016
Indiana University, Adam W. Herbert Presidential Scholars Program

**Finalist for Senior Class Award for Teaching Excellence in Biology and Dedication to Undergraduates** 2016
Indiana University

**American Association of Anatomists Anatomy (AAA) Education Platform Oral Presenter** 2016
AAA annual meeting; San Diego, California

**American Association of Anatomists Student/Postdoctoral Travel Award**
2016, 2015, 2014, 2013

**American Association of Anatomists/*Anatomical Sciences Education* Student/ Postdoctoral Education Research Poster Award Finalist** 2015

**Human Anatomy and Physiology Society Graduate Student/Postdoctoral Travel Award** 2014, 2013

**Indiana University Provost Women in Science Travel Award** 2014

PROFESSIONAL ORGANZATION MEMBERSHIPS and COMMITTEES SERVED

**American Association of Anatomists (AAA)** 2011-present
AAA Board of Directors Student/Postdoctoral Director 2015-present
Committee Structure Task Force 2015-present

**Human Anatomy and Physiology Society (HAPS)** 2012-present
*Synapse!* Creator and Coordinator 2015-present
*HAPS-Educator* Committee Editorial Board 2013-present

**Association of American Medical Colleges (AAMC), Central Group on Educational Affairs** 2013-present

**National Athletic Training Association** 2005-2009

TEACHING EXPERIENCE

**Indiana University, Medical Sciences Program**

Course Creator & Instructor of Record

Topics in Medical Sciences: Death, Donation, Dissection 2016

- MSCI M300, 3 cr.
- Responsibilities: Designed curriculum and course objectives based on best practices in current educational research about discussion courses; chose texts and course materials; designed assignments and in-class activities to stimulate discussion about end-of-life issues, body donation programs, and the history of medical dissection; provided formative and summative feedback on individual research notebooks; facilitated intellectual debate on course topics; graded all assignments; managed the course grade book; oversaw logistics with respect to the course.

Topics in Medical Sciences: Human Embryology 2015, 2014, 2013

- MSCI M300, 3 cr.
- Responsibilities: Designed curriculum and course objectives based on best practices in current scientific and educational research; wrote and delivered all lectures on stages of human embryology and developmental anatomy from the gross anatomical perspective; designed in-class activities; arranged trips to the medical gross anatomy laboratory to demonstrate embryological structures on cadavers; provided formative and summative feedback on intensive congenital anatomic anomaly research project; designed and graded all exams, quizzes, and assignments; managed the course grade book; oversaw logistics with respect to the course.

Instructor of Record

Disease and the Human Body 2016

- MSCI M131, 3 cr.
- Responsibilities: Collaborated with 3 faculty members to teach course; designed endocrine system unit learning objectives based on best practices in current scientific and educational research; wrote and delivered all lectures on the endocrine system and related disease states; designed in-class activities; designed endocrine system unit exam and quizzes.

Study Skills in Anatomy 2014

- MSCI M100, 1 cr.
- Responsibilities: Designed and delivered all lectures on anatomy study strategies; designed in-class activities; wrote and graded all assignments; managed the course grade book; oversaw logistics with respect to the course.

Associate Instructor

Human Tissue Biology 2015

- ANAT A464, 4 cr.

- Responsibilities:  Guided students in the laboratory with daily laboratory content lectures and use of virtual microscopy; wrote and delivered lectures on the special senses, eye, and ear; assisted in the interpretation of images; designed, set-up, and graded laboratory exams; facilitated review sessions.

Basic Human Anatomy 2011-2014

- ANAT A215, 5 cr., 9 sections total
- Responsibilities:  Co-taught the laboratory by administering half of the introductory lectures; taught and guided student content knowledge using cadaveric specimens and models; set-up and graded half of the laboratory exams; set-up eight practice exams per semester; facilitated review sessions; supervised and mentored an undergraduate teaching assistant for each laboratory section.

**Indiana University School of Medicine**

Associate Instructor

Medical Neuroscience 2014, 2015

- M555, 5 cr.
- Responsibilities:  Assisted the course instructor and students in the laboratory with cadaveric specimens and interpretation of models and medical imaging; delivered lectures on the brainstem and language and aphasia; set-up and graded laboratory exams; graded quizzes; facilitated review sessions; delivered one lecture, "Language and aphasia."

Gross Human Anatomy 2012-2013

- A550, A551, 8 cr.
- Responsibilities:  Assisted the course instructor and students in the laboratory with dissection of cadaveric specimens and interpretation of models and medical imaging; designed, set-up and graded laboratory exams; graded quizzes; facilitated review sessions; delivered four lectures, "Autonomic nervous system," "Posterior abdominal wall," "Head and neck embryology," and "Introduction to and development of the limbs."

**Des Moines University College of Osteopathic Medicine**

Teaching Assistant

Neuroanatomy 2010-2011

- ANAT 1501, 5 cr.
- Responsibilities:  Co-taught in the laboratory by assisting students in cadaveric nervous system dissection and comprehension of course material specifically as it related to the study of physical therapy.

Gross Anatomy 2010

- ANAT 1101, 6 cr.
- Responsibilities:  Performed daily prosections upon a sample cadaveric donor and assisted in video recording the daily introduction of the donor; worked with various faculty members to co-teach inter-professional groups of students (medical, physical therapy, podiatry, and graduate) as they dissected all body

systems; set-up and facilitated review sessions and practice exams; proctored laboratory exams.

**Buena Vista University, School of Education and Exercise Science**

Undergraduate Teaching Assistant & Tutor 2007-2009

Exercise Physiology (EXSC 352, 4 cr.)

Upper-extremity Evaluation and Orthopedic Physical Assessment (EXSC 350, 4 cr.)

Lower-extremity Evaluation and Orthopedic Physical Assessment (EXSC 450, 4 cr.)

Functional Human Anatomy (EXSC 140, 3 cr.)

- Responsibilities: Administered weekly review sessions; provided tutoring services; provided human subjects and opportunities for hands-on review of the material.

Invited Guest Teaching Experience

**Indiana University School of Medicine**

- Problem-Based Learning (PBL) facilitator for Medical Physiology (P532) 2015
- "Head and neck development" & "Limb development and introduction to limbs" lectures for Gross Anatomy (A551) 2013

**Indiana University, Medical Sciences Program**

- "Reproduction and meiosis" lecture for Basic Human Anatomy (A215) 2013
- "Heart rate and blood pressure" laboratory for Anatomy and Physiology I (APHY 101) course, Ivy Tech Community College 2013

RESEARCH EXPERIENCE

**Dissertation: *Embryology in Medical Education: A Mixed Methods Study and Phenomenology of Faculty and First Year Medical Students*** 2011-2016

- Principal Investigator and Dissertation Committee Chair: Valerie Dean O'Loughlin, PhD (Indiana University)
- Role: Co-Principal Investigator/student/fellow
- Description: Design and defend research proposal; complete Institutional Review Board approval; recruit participants; monitor data collection; complete analysis and written manuscript.

**Histo Happy Hour: Evaluation of an interactive histology review session** 2015-2016

- Co-Principal Investigators: Valerie Dean O'Loughlin, PhD (Indiana University), Barbie Klein (Indiana University)
- Role: Co-Principal Investigator/student/fellow
- Description: Design intervention prior to the National Board of Medical Education histology subject examination to assist in review of the material;

complete Institutional Review Board approval; recruit participants; monitor data collection and analysis; resulted in publication in progress.

**Abstract or concrete? The art of writing a strong abstract** 2013-2016

- Principal Investigator: Katherine Dowell Kearns, PhD (Indiana University)
- Role: CITL research assistant
- Description: Administer research materials; maintain research materials and participant confidentiality; design database and codes; assist in rubric design and norming session facilitation.

**Geological time, biological events and the learning transfer problem** 2014

- Principal Investigator: Claudia Johnson, PhD (Indiana University)
- Role: CITL research assistant
- Description: Conduct extensive literature search; contribute written portions of manuscript and revisions; resulted in publication in the *Journal of the Scholarship of Teaching and Learning.*

**Evaluating mental workload of two-dimensional and three-dimensional visualization for anatomical structure localization** 2010-2011

- Principal Investigator: Jung-Lee Fu, PhD (Iowa State University)
- Role: Research assistant for Iowa State University's Virtual Reality Application Center
- Description: Recruit participants; investigate the utility and efficacy of clinical imaging software in anatomic education; resulted in publication in the *Journal of Laparoendoscopic & Advanced Surgical Techniques.*

**The effects of omega-3 fatty acids on neurocardiogenic syncope** 2008
**Psychosocial aspects of home monitoring systems** 2008

- Principal Investigator: Paul Nyugen, MD (Provena Saint Joseph Hospital)
- Role: Research intern for Provena Saint Joseph Hospital, Department of Cardiology and Electrophysiology in Elgin, Illinois
- Description: Assist in patient interviews and clinical presentations during the development of studies; conduct weekly case studies and present to research team.

## SERVICE

**American Association of Anatomists (AAA)** 2011-present
AAA Board of Directors Student/Postdoctoral Director 2015-present
Committee Structure Task Force 2015-present

**Human Anatomy and Physiology Society (HAPS)** 2012-present
*Synapse!* Creator and Coordinator 2015-present
*HAPS-Educator* Committee Editorial Board 2013-present

**Indiana University School of Medicine**

Tour guide in the gross anatomy laboratory for graduate-level, interdisciplinary guests to the facilities 2013-2014

**Des Moines University College of Osteopathic Medicine**

Student Senate, Student Representative 2010-2011

Biomedical Sciences Coordinating Committee, Student Representative 2010-2011

Des Moines University Senior Health Fair Coordinator 2009-2010

PROFESSIONAL DEVELOPMENT

2016

- Preparing Future Professors: *Whistling Vivaldi* faculty learning community

2015

- "An Introduction to Evidence-Based Undergraduate STEM Teaching" faculty and graduate student learning community
- Daily guest instructor observation in Medical Physiology (P531) course
- Preparing Future Faculty Conference participant

2014

- LeanIn Circle "Female STEM scholars" member (-present)
- Preparing Future Faculty Conference participant
- "Publish Your First Book" presentation participant

2013

- Course Development Institute participant

2012

- "Paths to the Professoriate" graduate student learning community (-2013)

2011

- Indiana University Associate Instructor Orientation participant
- Indiana University Associate Instructor in Biology Orientation participant

PRESENTATIONS (INVITED):

2016

**Active learning in A&P: Play to your students' strengths**

Indiana Physiological Society 6$^{th}$ annual conference, DePauw University

2015

**How to perform an effective online search for educational research articles**

With Brian Winterman, Indiana University Library Sciences

Pedagogical Methods in the Health Sciences (M620) course, Indiana University

2014
**Anatomy panelist for Indiana University Hudson & Holland's "Science and Math Success Week"**

**Embryology in the medical curriculum: Striving for an effective balance**
Indiana University-Purdue University Indianapolis monthly graduate seminar

**Gastrointestinal system and abdominal vasculature**
Indiana University Center for Anatomical Sciences Education's Anatomy Education Science Camp

**Embryology in the medical curriculum**
Indiana University School of Medicine Anatomy statewide retreat

**Head and neck development**
Gross Anatomy (A551), Medical Sciences Program, Indiana University

2013
**Annual Indiana University A.I. Supervisors' Meeting graduate student panelist**

**Embryology in the medical curriculum: student study approaches, attitudes, and beliefs**
Indiana University School of Medicine Anatomy and Cell Biology Fall Research Forum

2012
**Anatomic variations of the dorsalis pedis artery: A cadaveric study**
Indiana University School of Medicine Anatomy and Cell Biology Fall Research Forum

**Reproduction and meiosis**
Basic Human Anatomy (A215) course, Indiana University

**Heart rate and blood pressure laboratory**
Anatomy and Physiology I (APHY 101) course, Ivy Tech Community College

PRESENTATIONS (REFEREED):

2016
**The embryology educator experience: A comprehensive survey of faculty and the generation of a phenomenology of embryology education**
Anatomy Education Platform 2: Evidence-Based Approaches to Anatomy Education
American Association of Anatomists annual meeting; San Diego, California

**"Death, Donation, and Dissection": The development of an undergraduate course about human body donors in education** (poster)
Human Anatomy and Physiology Society annual meeting; Atlanta, Georgia
**Evaluation of an interactive histology review session for medical student statewide exam preparation** (poster)

Indiana University – Purdue University Indianapolis Edward C. Moore Excellence in Teaching Symposium; Indianapolis, Indiana
2015
**Tubes and twists: A hands-on activity to teach development of the digestive system** (workshop)
Human Anatomy and Physiology Society annual meeting; San Antonio, Texas

**Embryology in the medical curriculum: The perceptions and opinions of current anatomy faculty** (poster)
American Association of Anatomists/*Anatomical Sciences Education* Student/ Postdoctoral Education Research Poster Award Finalist
American Association of Anatomists annual meeting; Boston, Massachusetts

**Development of a pre-medical embryology course using backward course design and student career goals** (oral presentation)
Indiana University – Purdue University Indianapolis Edward C. Moore Excellence in Teaching Symposium; Indianapolis, Indiana

2014
**Let their goals be your guide: How to develop a writing exercise using student career plans in healthcare** (workshop)
Human Anatomy and Physiology Society annual meeting; Jacksonville, Florida

**Development of a pre-medical embryology course using backward course design** (poster)
American Association of Anatomists annual meeting; San Diego, California

2013
**Embryology in the medical curriculum: student study approaches, attitudes, and beliefs** (poster)
Human Anatomy and Physiology Society annual meeting; Las Vegas, Nevada

**The pyramidal lobe: Connecting a case study with lymphatic system topics in gross anatomical education** (poster)
American Association of Anatomists annual meeting; Boston, Massachusetts

**Learning communities for graduate students: Supporting scholarly teaching**
Indiana University – Purdue University Indianapolis Edward C. Moore Excellence in Teaching Symposium; Indianapolis, Indiana

2012
**The unhappy triad of the knee: Quest for a conclusive definition** (poster)
American Association of Anatomists annual meeting; San Diego, California

2011
**Anatomic variations of the dorsalis pedis artery: A cadaveric study** (poster)
American Association of Anatomists annual meeting; Washington D.C

2010
**Anatomic variations of the dorsalis pedis artery: A cadaveric study** (poster)
Des Moines University Research Symposium; Des Moines, Iowa

PUBLICATIONS

Manuscripts:

- **Cassidy, K.** 2015. Synapse HAPS: A Rapid, New Form of Knowledge Transmission. *HAPS-EDucator, 19*(3): 13-14.
- Johnson, C.C., Middendorf, J., Rehrey, G., Dalkilic, M.M., Zhu, C., & **Cassidy, K.** (2014). Geological time, biological events and the learning transfer problem. *Journal of the Scholarship of Teaching and Learning, 14*(4): 115-129. doi: 10.14434/josotl.v14i4.4667.
- Foo, J., Martinez-Escobar, M., Juhnke, B., **Cassidy, K.**, Hisley, K., Lobe, T., & Winer, E. (2013). Evaluating mental workload of two-dimensional and three-dimensional visualization for anatomical structure localization. *Journal of Laparoendoscopic & Advanced Surgical Techniques, 23*(1): 65-70. doi:10.1089/lap.2012.0150.

Book chapters:

- **Cassidy, K.** Authenticity in the classroom. In *Voices from the Classroom: Graduate Students' Reflections of Evidence-based Teaching*. J. Meta Robinson, V. O'Loughlin, K. Kearns, and L. Plummer (Eds.). (in press)
- **Cassidy, K.**, Clapper, L., & Lederer, A. Professional and personal learning communities: The lasting impact of an interdisciplinary network of graduate students. In *Voices from the Classroom: Graduate Students' Reflections of Evidence-based Teaching*. J. Meta Robinson, V. O'Loughlin, K. Kearns, and L. Plummer (Eds.). (in press)

Abstracts presented at national meetings:

- **Cassidy, K.** (2016)."Death, Donation, and Dissection": The development of an undergraduate course about human body donors in education. *HAPS-Educator 20*(3) (in press).
- **Cassidy, K.** (2016). The embryology educator experience: A comprehensive survey of faculty and the generation of a phenomenology of embryology education. *FASEB J 30* (in press).
- **Cassidy, K.** (2015). Tubes and twists: A hands-on activity to teach development of the digestive system. *HAPS-EDucator 19*(3): 106.
- **Cassidy, K.** (2015). Embryology in the medical curriculum: The perceptions and opinions of current anatomy faculty. *FASEB J 29*: 695.1.
- **Cassidy, K.** (2014). Let their goals be your guide: How to develop a writing exercise using student career plans in healthcare. *HAPS-EDucator 18*(3): 49.
- **Cassidy, K.** (2014). Development of a pre-medical embryology course using backward course design. *FASEB J 28*: 534.1.

- **Cassidy, K.** (2013). Embryology in the medical curriculum:  student study approaches, attitudes, and beliefs. *HAPS-EDucator, 17*(3):  56.
- **Cassidy, K.** (2013). The pyramidal lobe:  Connecting a case study with lymphatic system topics in gross anatomical education. *FASEB J 27*:  958.3.
- Canby, C.A. & **Cassidy, K.** (2012). The unhappy triad:  Quest for a conclusive definition. *FASEB J 26*:  lb24.
- **Cassidy, K.** & Khan, M.A. (2011). Anatomic variations of the dorsalis pedis artery:  A cadaveric study. *FASEB J 25*:  lb2.