Temporal Visualization of Body Cavity Partitioning: An Interactive Timeline

BY

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THESIS

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SUMMARY

This research presents a possible solution to help users sort through complex embryonic information quickly and efficiently, while uncovering relationships between developing structures in the form of a web-accessible, interactive timeline through Articulate Storyline 360. Body cavity partitioning was chosen as the area of focus, as the development of the organ systems are directly related to the spaces in which they grow, and embryology is typically taught by body system. In total, 34 biomedical visualization and dental students evaluated the interactive timeline, with mixed results. With both the interactive and static resources, knowledge of embryology increased; however, the interactive was slightly more effective at helping users find information quickly and efficiently for two of six given tasks. Generally, subjects were satisfied with the timeline, finding it useful for navigating embryonic relationships, but felt that timeline text and images could use improvement, along with a few aspects of the layout. This resource has the potential to be improved and expanded to include other body systems in human embryology to provide a reference for students studying human embryology.
INTRODUCTION

A. Overview of research problem

Embryology presents a unique challenge to learn and teach due to the continuously evolving nature of both structures and terminology. Systemically, the developmental timing of different structures are variable, as some may take several weeks to develop, while others are complete in only a few days. Development is not only dependent on chemical signaling from surrounding cells, but also spatial relationships between neighboring structures. Understanding embryonic defects is essential for future physicians, and understanding how each structure develops in relation to surrounding spaces would facilitate learning clinically significant material.

Embryology is typically taught as an integrated subject within gross anatomy courses with a focus on its relationship to adult anatomy and the clinical significance of developmental structures, through the use of textbooks and lectures (Drake, McBride, Lachman, & Pawlina, 2009). Information is organized and separated by body systems, which prevents learners from becoming overwhelmed, and allows them to learn embryology in portions (Sadler, 2012). This form of systemic teaching, however, creates a barrier to understanding how structures affect each other temporally and spatially, resulting in a disconnected perception of relationships. In order to understand the broader picture, students need to vacillate between chapters on organ systems, refer back to generalized reference timeline that may not include the requisite detail to accurately grasp linked events, or rely on poorly-designed websites for more information.

To organize the vast amount of temporal data, which spans weeks 3-7 in the embryonic period, a visualization can be employed to provide the learner with a general overview of how
developmental events affect and relate to each other. It can also allow for further exploration of embryonic development and facilitate quick, efficient learning.

An interactive, web-based and accessible timeline was designed as a resource for first year medical or dental students, who often struggle to understand developmental complexities. The timeline includes three key features: ability to select events for more information, highlight representations of structure with visual cues when they are related to each other, and reveal malformations as an alternate event. The interactive enables the user to discover relationships between developing structures more quickly and effectively as compared to searching through detailed textbooks or utilizing online resources. Understanding the relationships between organs and the spaces in which they arise is aided by recognizing developmental landmarks at specific points in time.

B. **Significance of the problem**

A major trend in medical education has been a decrease in time spent on anatomical and embryology education in favor of increased clinical exposure, and over the past 50 years, the number of course hours dedicated to embryology has declined from 60 hours to just below 20 hours (Drake et al., 2009). With the amount of information necessary for medical students to learn steadily increasing and a curriculum more focused on clinical relevance, the amount of time students can apportion to embryology is diminished (Scott, Charles, & Holland, 2013). Discovering embryonic relationships is not a quick process; to recognize important connections, students need to understand how several body system structures interact with each other over specific periods of time.

Spontaneous abortion occurs in 50% of embryos, while birth defects and prematurity are
the leading causes of disability and infant mortality (Sadler, 2012). Out of 146 students surveyed about their confidence and perceived difficulty learning embryology, 65% felt unconfident in embryology, while 82% found learning embryology to be difficult (Hamilton & Carachi, 2014) although 81% felt that embryology should be included in the medical school curriculum due to clinical significance (Hamilton & Carachi, 2014). Cassidy (2016) examined what parts of embryology were most confusing. Of 94 students, 67% mentioned that the most confusing thing about embryology was understanding the content; 20% had difficulty with visualization. Of those who thought the content was most difficult, 58% believed understanding the processes of development was most difficult due to the fact that there were so many events “all happening at the same time” (p. 191). Despite clinical significance, embryology education in medical schools has still decreased (Cassidy, 2015; Hamilton & Carachi, 2014; Scott et al., 2013).

Because the amount of time devoted to embryology during class time has been reduced, much of this material must be self-taught. Given the decreased number of qualified anatomy teachers and the increased need for quality anatomy education, which medical students are expected to retain for the rest of their careers, educators and students have turned to the Internet and technology-enhanced education to meet their needs to obtain information efficiently (Zucker, White, Fabri, & Khonsari, 1998). It is important to provide effective and engaging tools to supplement class material and allow students to learn the material efficiently; however, due to the lack of quality embryology education and resources, students struggle to find reliable and usable references online (Cassidy, 2016).

Embryology information curated within a web-based, interactive timeline provides the user
an accessible way to interact with developing structures in context and to determine which events occur simultaneously, recognize their effects on each other, and observe how a disrupted event could result in a defect.
LITERATURE REVIEW

A. The Importance of Studying Human Embryology

Although human embryology continues to be an important subject for learning clinical correlations and enhancing understanding of normal human development in medical school curricula, medical students have experienced a decline in the amount of embryology being taught (Hamilton & Carachi, 2014). The amount of time allocated for gross anatomy and embryology has been steadily decreasing, though anatomy faculty (Cassidy, 2015) and medical students (Hamilton & Carachi, 2014) assess embryology as being clinically relevant for future physicians. Students have noted that supplemental interactives, models, and animations for teaching complex anatomical material would have been beneficial for understanding temporal relationships (Cassidy, 2016).

Body cavity partitioning was chosen as the section of embryology to visualize due to the incorporation of all three germ layers and the relationship between developing structures in both the thoracic and abdominal cavities. In addition, the integration of several different body systems makes this portion of embryology particularly ideal for visualization as current resources separate information by body systems.

B. Gastrulation

Gastrulation, or the formation of the three germ layers, is essential for providing context for the processes of lateral and craniocaudal folding, which create both the spaces for the body cavities, and the inner tubes of the gastrointestinal and respiratory systems (Sadler, 2012; Schoenwolf, Bleyl, Brauer, Francis-West, & Larsen, 2015). The development of embryonic germ layers provides a concrete starting point for embryonic derivatives, and was therefore included
as the starting point for the timeline during week three. Gastrulation occurs during the third week of development and is the process by which the trilaminar disc is formed from the bilaminar disc (Sadler, 2012). The epiblast (next to the amnion) and the hypoblast (next to the yolk sac) are two membranes forming the bilaminar disc, which give rise to embryonic and extraembryonic structures, respectively (Sadler, 2012). The process is initiated with the formation of the primitive streak, a small groove on the surface of the epiblast, which extends towards the oropharyngeal membrane (Sadler, 2012). Three germ layers are formed as cells from the epiblast migrate through the openings of the primitive pit and streak, displacing the hypoblast to form the endoderm and middle layer, or mesoderm. The remaining cells from the epiblast become the ectoderm (Sadler, 2012).

1. **Ectoderm**

Exposure to fibroblast growth factor (FGF) results in inhibition of bone morphogenic growth protein (BMP4) and transforming growth factor- β (TGF-β) (Sadler, 2012). Exposure to BMP4 results in induction of the epidermis and lateral and intermediate plate mesoderm (Sadler, 2012). In the region protected from BMP4 exposure, ectoderm forms a thickened region called the neural plate, which undergoes neurulation to form the developing nervous system (Sadler, 2012). Derivatives of the ectoderm include: The central nervous system, the peripheral nervous system, sensory epithelium of the ear, nose and eyes, the epidermis, including hair and nails, subcutaneous glands, mammary glands, pituitary gland, and enamel of the teeth (Sadler, 2012). During closure of the neural tube, neural crest cells dissociate from the ectoderm (Sadler, 2012). Specific disorders, or neurocristopathies, are directly correlated with the embryonic derivatives that develop from neural crest cells: connective tissue and bones of the face and
skull, cranial nerve ganglia, C cells of the thyroid gland, conotruncal spetum in the heart, odontoblasts, dermis in face and neck, spinal (dorsal root) ganglion, sympathetic chain and preaortic ganglia, parasympathetic ganglia of the gastrointestinal tract, adrenal medulla, Schwann cells, Glial cells, meninges (forebrain), melanocytes, smooth muscle cells to blood vessels of the face and forebrain (Sadler, 2012).

2. **Mesoderm**

The mesoderm differentiates into the paraxial, intermediate, and lateral plate mesoderm, medially to laterally (Sadler, 2012). The paraxial mesoderm forms somites, which in turn form the sclerotome (tendon and bone), myotome (muscle) and dermatome (dermis of the back), each with a separate nerve component (Sadler, 2012). The intermediate mesoderm forms the urogenital structures, and the lateral plate mesoderm splits into parietal and visceral layers. The split creates an intraembryonic body cavity, which will house internal organs (Sadler, 2012). The visceral layer covers the future pleura, peritoneum, and pericardium, while the parietal layer lines the body wall (Sadler, 2012).

3. **Endoderm**

The endoderm mostly forms the inner lining of the gastrointestinal tract separated into the foregut, midgut, and hindgut, but also gives rise to the epithelial lining of the respiratory tract, the parenchyma of the thyroid, parathyroids, liver, and pancreas, the reticular stroma of the tonsils and thymus, the epithelial lining of the urinary bladder and urethra, as well as the tympanic cavity and auditory tube (Sadler, 2012).

C. **Body Cavity Partitioning**

Schoenwolf et al. (2015) state that as the embryo develops, several events occur during
weeks 3-7 that separate body cavities and their organ systems. Heart development occurs first, simultaneously with lateral and craniocaudal folding (Schoenwolf et al., 2015). External features of the heart are developed through the process of cardiac looping by day 28, or the end of week four (Schoenwolf et al., 2015). By this point in time, the respiratory diverticulum has just begun to bud from the proximal, ventral foregut, and is not obstructing the heart; however, as the lung bud branches into primary and secondary bronchi, pleuropерicardial folds grow coronally and medially from the body wall, in order to prevent the growing lungs from encroaching on the developing heart (Schoenwolf et al., 2015).

Schoenwolf et al. (2015) also state that the septum transversum, or future central tendon of the diaphragm, initially develops cranial to the heart, but by the fourth week, lateral and craniocaudal folding have also been completed, which translocates the septum transversum below the heart and the future thoracic cavity. Pericardioperitoneal canals, which connect the thoracic cavity and abdominal cavity, are open while the lungs are developing (Schoenwolf et al., 2015). In order to form the pressure difference between thoracic and abdominal cavities, an essential component of respiratory physiology after birth, the pericardioperitoneal canals must be closed off; however, closure will occur after lungs have had time to develop a substantial percentage of the conducting portion of the respiratory system, during weeks 5 – 7, with the ingrowth of the pleuropерitoneal membranes from the posterior body wall (Schoenwolf et al., 2015). By the middle of week 6, the rib cage has formed the inferior thoracic aperture, and myoblasts from the body wall form the seal around the rim of this space to anchor the developing diaphragm to the lateral body walls (Schoenwolf et al., 2015). Posteriorly, the vertebrae have already formed the spine by the middle of week 5, which allows the diaphragm
to be anchored by the dorsal mesentery of the esophagus, which forms the right and left crura attaching to L1-L3 and L1-L2, respectively (Schoenwolf et al., 2015).

According to Schoenwolf et al. (2015), the dorsal mesentery suspends the descending aorta, inferior vena cava, and developing gastrointestinal system, which traverse the thoracic and abdominal cavities. The diaphragm forms around the structures, as opposed to the structures piercing through an intact diaphragm (Schoenwolf et al., 2015). The aorta and inferior vena cava are formed by vasculogenesis, posterior to the gut tube, and eventually fuse with vessels connected to the heart (Schoenwolf et al., 2015). Fusion of the paired dorsal aortae create a single descending aorta during the fourth week, along with the development of the cardinal veins, which become the future inferior vena cava (Schoenwolf et al., 2015). Formation of this important vasculature takes place before the diaphragm has partitioned the thoracic and abdominal cavities (Schoenwolf et al., 2015).

Schoenwolf et al. (2015) also explain that the rapidly developing gastrointestinal tract will herniate into the yolk sac during week seven, where the gut tube will complete rotation around the superior mesenteric artery from the descending aorta by the start of the fetal period (weeks 10-12). Closure of the diaphragm likely facilitates this normal herniation (Schoenwolf et al., 2015). Failure of the diaphragm to develop properly during GI tract development can result in congenital diaphragmatic hernias, as the easiest space for the intestines to occupy is the thoracic cavity (Schoenwolf et al., 2015).

1. **Formation of the diaphragm**

The diaphragm partitions the peritoneal and thoracic cavities and is formed from four parts. The septum transversum develops first, forming the central tendon of the diaphragm.
Muscular contributions from somites 3-5, which eventually migrate away from the centrally-located septum transversum onto two posteriorly-placed pleuroperitoneal membranes, close off the pericardial-peritoneal canals. Myoblasts from the lateral body wall also contribute by forming a muscular seal around the edge of the diaphragm. The dorsal mesentery suspending the foregut, descending aorta, and inferior vena cava forms the diaphragmatic crura (Sadler, 2012). It is important to note that the diaphragm does not form as one structure, in order to allow important vasculature to traverse both peritoneal and thoracic cavities and to provide adequate space for organs to grow during development, before physiological pressure differences across body cavities is essential for respiration (Schoenwolf et al., 2015).

Sadler (2012) outlines several congenital defects that can occur if the diaphragm has formed improperly. If pleuroperitoneal folds fail to close off pericardioperitoneal canals, abdominal viscera can herniate into the thoracic cavity, compressing the lungs and heart (Sadler, 2012). If the muscular contributions from the lateral body walls do not completely seal the rim of the diaphragm and close off the inferior thoracic aperture, a parasternal hernia can form, which can also allow intestinal loops to enter the thoracic cavity (Sadler, 2012). An esophageal hernia, in which the stomach is constricted at the esophageal hiatus, can form from shortening of the foregut (Sadler, 2012).

2. **Pericardial Cavity and Cardiovascular System**

Sadler (2012) states that the cardiovascular system starts to form in the middle of week three as progenitor heart cells start to form a horse-shoe shaped ring of mesoderm around the cranial end of the embryo, called the cardiogenic region (Sadler, 2012). Due to lateral folding, a tube is formed and the two endocardial tubes merge medially (Sadler, 2012). By the end of
week 3, the heart begins to beat (Sadler, 2012; Schoenwolf et al., 2015). Although interatrial septation, atrioventricular septation, and aorticopulmonary trunk formation is significant, internal heart development will not be addressed in the deliverable, as this complex part of development is marginal to body cavity partitioning.

3. **Pleural Cavity and Respiratory System**

In adults, within the thoracic cavity the respiratory system and lungs are separated from the heart by a series of fibrous and serous membranes, and from the abdominal cavity, housing the gut. Separation of these body cavities arises from fusion of four parts of the diaphragm, separating the pleural and peritoneal cavities, and the pleuropericardial folds that grow inwards from the mesodermal lining of the body cavity and fuse medially to form the fibrous pericardium (Sadler, 2012). The fibrous pericardium, with the root of the lung, separate the lungs and the heart (Sadler, 2012).

According to Schoenwolf et al. (2015) the respiratory system forms from the proximal gut tube, as a respiratory diverticulum buds during the fourth week. The internal lining is formed from endoderm, while splanchnic mesoderm forms the cartilage, muscle, and connective tissue surrounding the growing trachea (Schoenwolf et al., 2015). The diverticulum branches into the primary lung buds that will eventually branch into secondary and tertiary bronchi, which expand and grow towards the pericardioperitoneal canals (G. C. Schoenwolf et al., 2015). Sadler (2012) states that in order to separate the lungs from the esophagus, tracheoesophageal ridges grow in between the two tubes, and eventually meet, forming the tracheoesophageal septum (Sadler, 2012). During the embryonic period and body cavity partitioning, the lungs remain in the pseudoglandular phase, in which terminal bronchioles are
continuing to form, but no respiratory alveoli or bronchioles are present (Schoenwolf et al., 2015).

Several embryonic defects can occur if the position of the tracheosophageal septum forms too high or too low in relation to the gut tube or if the tracheoesophageal ridges fail to develop or fuse with each other (Sadler, 2012). These defects are tracheoesophageal fistulas, which are abnormal connections between the trachea and esophagus and esophageal atresia, in which the gut tube or trachea ends in a blind-pouch (Schoenwolf et al., 2015).

4. Peritoneal Cavity and the Digestive System

Sadler (2012) states that during lateral folding, two folds of mesoderm and ectoderm fuse in the midline of the embryo, which forms the anterior body wall (Sadler, 2012). The embryo remains connected to the yolk sac by the vitelline duct, which is continuous with the developing gut tube (Sadler, 2012). The gut tube is sectioned into three parts: the foregut, midgut, and hindgut; each of which is associated with different organs and portions of the digestive system (Sadler, 2012; Schoenwolf et al., 2015).

Schoenwolf et al. (2015) states that the foregut will develop into the stomach, liver, gallbladder, pancreas, and first portion of the duodenum (Schoenwolf et al., 2015). The midgut forms most of the duodenum, ileum, and jejunum, along with the cecum, ascending colon and proximal 2/3rds of the transverse colon (Schoenwolf et al., 2015). The hindgut forms the distal 1/3 of the transverse colon, along with the descending colon, sigmoid colon, and anus up to the pectinate line (Schoenwolf et al., 2015).

Schoenwolf et al. (2015) states that in relation to the developing body cavities, several embryonic defects can occur if primary intestinal loop herniation or rotation do not occur
correctly (Schoenwolf et al., 2015). Omphalocele occurs when the gastrointestinal tube does not return to the abdominal cavity after herniation, and is similar in many ways to gastrochisis, which occurs when the anterior body walls fail to close in the abdominal region (Schoenwolf et al., 2015). Gastrochisis is an anterior body wall defect, as the body walls do not fully fuse during lateral folding, which exposes the abdominal cavity contents to amnionic fluid (Schoenwolf et al., 2015). Abnormal rotation can also occur, in which the cranial limb returns after the caudal limb, resulting in the colon becoming positioned on the left side of the body, as opposed to the right, which may have implications for gut motility (Schoenwolf et al., 2015).

5. Inferior Thoracic Aperture and Rib Development

Additionally, Schoenwolf et al. (2015) explain that sclerotomes from somites form the vertebrae. Somites undergo segmentation, and then recombine to enable the spinal nerves to exit between vertebrae and allow muscular components from the myotomes, to span multiple sclerotomes (Schoenwolf et al., 2015). Ribs begin to elongate starting from day 35, and by the middle of the 6th week, or day 45, true ribs have formed (Schoenwolf et al., 2015). Simultaneously, mesenchymal condensations (sternal bars) begin to merge medially and connect laterally with the costal processes, cranially to caudally (Schoenwolf et al., 2015). This allows myoblasts from the body wall to migrate inwards towards the developing diaphragm and form a seal between the lower ribs and the septum transversum (Schoenwolf et al., 2015).

6. Descending Aorta and Inferior Vena Cava Development

Schoenwolf et al. (2015) describe the formation of the descending aorta by vasculogenesis, which merges with the aortic sac during week 4. The major arteries of the gut tube arise from the vitelline arteries of the yolk sac, and fuse with the descending aorta caudal
to the diaphragm between weeks 6-7. The celiac artery initially joins the aorta at the 7th cervical vertebrae, but descends to the 12th thoracic level (Schoenwolf et al., 2015). The superior mesenteric artery, around which the midgut will rotate 270 degrees clockwise, forms next and descends from T2 to L2. The inferior mesenteric artery forms last, descending from T12 to L3 (Schoenwolf et al., 2015). The inferior vena cava arises from the fusion of the right vitelline, supracardinal, and posterior cardinal veins (Schoenwolf et al., 2015), which fuse between weeks 7-8. The subcardinal portion of the inferior vena cava develops between weeks five and six, and is suspended by dorsal mesentery (Schoenwolf et al., 2015).

**D. Interactivity**

Interactive computerized modules have a positive effect on learning and are well received as supplemental learning tools for medical education concepts (Bryman, 2008). In addition, computer-based visualization can be used for integrating large amounts of data in an understandable way (O’Donoghue et al., 2010). Online course material is an effective method of improving learning for undergraduate and graduate medical education (Bernardo et al., 2004; Ruiz, Mintzer, & Leipzig, 2006; Sisson, Hughes, Levine, & Brancati, 2004). Due to differences in individual learning preferences, benefits from interactive, web-based tools include the ability to tailor material to suit educational needs, supplement existing educational material, and provide users a self-directed method of learning (Cook & Dupras, 2004).

**E. Learning Theory**

Enhanced motivation and self-directed learning are key benefits provided by web-based interactive educational material (Kettanurak, Ramamurthy, & Haseman, 2001). Interactive education can improve user attitude regarding learning, which is beneficial for motivating
students and improving performance (Kettanurak et al., 2001). Improved scores are noted when interactive media and instruction are tailored to fit student learning styles, as the ability to control the pace of material is useful for meeting student needs (Bahçeci & Gürol, 2016; Carlson, 1991).

Web-based interactive media provides a method of active learning, which actively engages students, as opposed to passive learning, where students are simply given the information (Prince, 2004). Students are seen to retain more information with active learning methods, as they are more motivated and interested, with research suggesting that individual learner involvement in organization of learning concepts improves recall (Huggett & Jeffries, 2015).

F. Usability

Steve Krug (2014) outlines his definition of usability with several bullet points to consider when developing interactive or web-based devises, stating that the deliverable should be “useful, learnable, memorable, effective, efficient, desirable, and delightful” (p. 9). With these objectives in mind, the interactive was designed to ensure that the product was easy for users to navigate and would not distract from the most important information.

Peter Morville’s usability honeycomb also outlines features of interactives that contribute to good user experience: useful, usable, valuable, desirable, accessible, credible, and findable (Morville, 2004). To ensure a good experience with the interactive, these facets of user experience were addressed during initial designs and tests with the committee.

G. Display of Temporal Data

1. Timelines

Timelines can be used to chronologically organize relationships between types of events
such as social interactions, history, movie narratives, data or information visualization, and
court or medical cases. Advantages of using interactive timelines include providing a larger
context for events, which enables users to compare and analyze potential relationships (Allen,
1995). Timelines are useful teaching tools that allow vast amounts of history to be distilled and
taught to students in a visually appealing and meaningful way. Recently, interactive, web-based
timelines have been seen to index systems and provide a historical summary (Rosenberg,
Grafton, & Staff, 1996) to be used as reference. The ability to graph and organize vast amounts
of temporal data in a clear way allows users to make comparisons, while an interactive
environment allows the information to be accessible (Plaisant et al., 1998).

Timelines are well suited for displaying relationships and helping users track change over
time in “knowledge-rich domains”, where a variety of interrelationships exist between events
(Kumar, Furuta, & Allen, 1998). Including interactivity in a timeline allows users to zoom into a
specific point in order to reveal more detailed information and control exploration (Allen,
1995). Possibilities for timeline interactivity include “semantic zooming,” in which the large
context for the event is still included, scaling the x-axis, highlighting attributes, revealing more
information about an event by clicking, including text, graphics, or video (Allen, 1995) and the
ability to resize, rotate, and scale graphics (Kumar et al., 1998). More recent developments of
interactive timelines allow for the inclusion of filtering and navigation features like the ability to
pan through the timeline or select by type of data (Plaisant et al., 1998).

2. Timeline Design and Types

Several options for timeline display exist, the most common of which is horizontal display,
as information and events can be organized into sets that are usually placed onto a horizontal
line representing time (Nguyen, Xu, Walker, & Wong, 2015). Vertical timelines are mobile-friendly and allow users to continuously scroll through events; however, they limit the amount of information shown at one time and do not provide overall context.

3. **Existing Interactive Timeline Creation Software:**

Interactive timelines are not a new concept and numerous web-based programs exist for creating interactive timelines. The most popular is TimelineJS, software developed by the Northwestern University Knight Lab, which has been used by media outlets like Time and CNN for journal articles and historical events. A common practical application of interactive timelines are their use in litigation to illustrate sequences of event to juries (Rosenberg et al., 1996).

H. **Research gap**

At the moment, only sparse resources exist for displaying embryonic timelines. The most accurate and recommended are in-text sources from Sadler’s Medical Embryology (Figure 1) and Larsen’s Human Embryology (Figure 2). Although the content is accurate and reliable, the timelines do not show developmental relationships and, instead, show development split systemically. Sadler’s timeline is not comprehensive enough to provide students with an understanding of how the systems relate to each other during development.

A few web-based timelines do exist, but they are unresponsive to different device sizes, and are difficult for users to interact with. Figure 3 is a screenshot from the Visible Embryo, which has a unique spiral organization of content; however, the colors and website design make interaction with the website difficult. Figure 4 is a screenshot from the Interactive Prenatal Development Timeline, which allows the user the ability to filter which body systems to display, and has three modes of difficulty tailored to users’ preferences. Figure 5 is a screenshot from
Timeline Human Development on the UNSW Embryology website by Hill (2017). The content is reliable, but the listed, weekly format makes accessing specific information difficult. The three interactive websites referenced have several useful features, but none has the feature to view key developmental relationships with a visual representation.

Figure 2. Examples of chapter timelines of body systems. Reprinted from *Larsen’s human embryology* (p. 341-342) by Schoenwolf, Bleyl, Brauer, Francis-West, & Larsen. 2015, Location: Churchill Livingstone. Reprinted without permission.

RESEARCH SIGNIFICANCE

A. Significance of research study

Embryology is typically taught with textbooks and integrated within gross anatomy courses to focus on the relationship to adult anatomy and the clinical significance of developmental defects (Drake et al., 2009). Material is separated by organ system, creating a disconnected perception of relationships and a barrier to understanding how the growth of organs effect each other temporally and spatially (Cassidy, 2016). To understand the broader picture, students need to spend their limited time referring back to generalized reference timelines in order to infer relationships.

Students need to know a small amount of embryology for professional medical and dental licensing exams (Joint commission on National Dental Examinations, 2017; Federation of State Medical Boards of the United States & Examiners, 2016), but because the amount of time devoted to embryology during class time is reduced, much of this material must be self-taught. Providing effective supplements to class material would allow students to learn more efficiently.

Lack of quality visuals is a persistent problem in embryology education (Cassidy, 2016) and, currently, there are no useful systems to organize the vast amount of material and allow a learner to discover embryonic relationships quickly and efficiently. Embryology information curated within a web-accessible, interactive visualization would allow for further exploration of both normal and abnormal embryonic development and could facilitate quick, efficient learning.

The proposed method of addressing a big data visualization problem is an interactive timeline. A visual solution can provide the user with an accessible way to interact with
developing structures in context, determine which events occur simultaneously, recognize their effects on each other, and observe how a disrupted event could result in a defect. There is a lack of research in embryology data visualization, and no research has been performed in which an interactive timeline has been used to address organizational issues associated with embryology education.

\[ \text{B. Hypothesis} \]

Central: Utilizing an interactive timeline displaying temporal relationships of body cavity partitioning during human embryogenesis will decrease the amount of time needed for students to identify key developmental landmarks and their connection to embryonic defects.

Sub-hypothesis: Additionally, the interactive timeline will increase user knowledge of embryonic relationships and congenital defects.
METHODS

A. Research study design

Both qualitative and quantitative data were collected on the interactive timeline in a mixed method study design, in order to gather more support for findings and conclusions (Cresswell & Plano Clark, 2007). This integrated approach provides support for findings that one type of data collection alone cannot answer (Chowdhury, 2015; Cresswell & Plano Clark, 2007). The main method of task analysis utilized a crossover study design in which subjects were given both treatments in a randomized order, to control for individual variation and between-subject variability (Stoney & Lee Johnson, 2012). Specifically, subjects were either given tasks to complete with the static resource that contained just the content (text and images) from the timeline displayed on a website to control for format, or supplied the intervention (the interactive timeline) to complete three different tasks (Stoney & Lee Johnson, 2012).

To determine the amount of prior knowledge about embryonic development, a short pre-test featuring general overview questions about embryonic relationships was distributed to each group for a post-test comparison. Subjects were then instructed to use the first resource to complete a set of three tasks, such as uncovering a developmental relationship between two body systems or describing its clinical significance. Users were timed to evaluate how long they took to complete the task. To reveal whether the interactive timeline decreased the amount of time needed to discover embryonic developmental relationships, the amount of time taken to complete a similar set of tasks with the second resource was compared to that of the first.

After each task was completed, the subjects were instructed to recap or walk through what they did to arrive at the final outcome with a brief, semi-structured interview (Given, 2008).
Responses were audio recorded for transcription and analysis. A post-test with different questions from the pre-test was distributed to the user after the first set of tasks to determine which resource was more effective for increasing embryology knowledge. To gather data about what features of the interactive timeline make the site usable and effective, a short usability survey was distributed at the end of testing (U.S. Department of Health & Human Services, 2006).

Subjects were randomly assigned to one group of four for the testing series, so that each set of tasks was tested with each intervention (the interactive and static control). Each group was given a packet on a clipboard containing various tasks and forms listed in the appendices. All groups were given the Informed Consent Form as the first portion of their packet.

**Group A:** Pre-test, Interactive (task set 1), walkthrough, post-test, Static control (task set 2), walkthrough, survey.

Packet: Appendix C (informed consent form p. 59), Appendix J (Data collection form, p. 74) Appendix D (Pre-test, p. 66), Appendix F (Task set 1, p. 68), Appendix E (Post-test, p. 67), Appendix G (Task set 2, p. 70), Appendix I (Usability Survey p. 73).

**Group B:** Pre-test, Static control (task set 1), walkthrough, post-test, Interactive (task set 2), walkthrough, survey.

Packet: Appendix C (informed consent form p. 59), Appendix J (Data collection form, p. 74) Appendix D (Pre-test, p. 66), Appendix F (Task set 1, p. 68), Appendix E (Post-test, p. 67), Appendix G (Task set 2, p. 70), Appendix I (Usability Survey p. 73).

**Group C:** Pre-test, Interactive (task set 2), walkthrough, post-test, static control (task set 1), walkthrough, survey.
Packet: Appendix C (informed consent form p. 59), Appendix J (Data collection form, p. 74)
Appendix D (Pre-test, p. 66), Appendix G (Task set 2, p. 70), Appendix E (Post-test, p. 67),
Appendix F (Task set 1, p. 68), Appendix I (Usability Survey p. 73).

Group D: Pre-test, Static control (task set 2), walkthrough, post-test, Interactive (task set 1),
walkthrough, survey

Packet: Appendix C (informed consent form p. 59), Appendix J (Data collection form, p. 74)
Appendix D (Pre-test, p. 66), Appendix G (Task set 2, p. 70), Appendix E (Post-test, p. 67),
Appendix F (Task set 1, p. 68), Appendix I (Usability Survey p. 73).

This research study design was approved by the Institutional I Review Board (IRB) on

B. Stimulus design plan

1. Pre-Production

The interactive timeline was designed to incorporate aspects of interactivity, learning
theory, and usability. The key feature of this timeline included the ability for users to highlight
buttons and lines to showing event relationships in order to help subjects find relationships
quickly and efficiently. By including this interactivity, user control is enhanced to actively
engage users in the material, increasing motivation and excitement. A navigation bar with
additional information about the timeline, such as the Introduction, About, and Filters section,
was included to provide users more control over what type of content they would like to view
to increase usability and accessibility (Morville, 2004). The Introduction section gives users a
brief overview of the timeline structure and provides background about body cavity
partitioning. To increase usability and findability, unnecessary facts were eliminated. This streamlined content to avoid overwhelming users after the researcher garnered feedback that including information not directly related to body cavity partitioning made the most essential information difficult to access.

a. Initial design

Originally, the timeline was designed to be a freely available, online website that could be accessed on mobile or desktop devices. Due to difficulties with the website’s JavaScript functions during production, the final deliverable was created in Articulate Storyline 360. The goals of the timeline were still addressed, as the interactive resource provided users additional information about the developmental event, displayed the relationships between different developmental events, and presented alternate events as embryonic defects.

Users were presented with an overarching context of the events overlapping in the timeline, but were also given options to explore an event further by clicking on the event button. This provided more information given both as text, and as illustrated visual references or representations (Figure 6). As the user explored the timeline, relationships between events were emphasized with visual cues like highlighted lines (Figure 7). Clinical significance and birth defects were incorporated as alternate events on the timeline, which could be selected with the defects tab under “Filters” (Figure 8).

The ability to filter categories in the timeline gave the user more control over what they wanted to see and explore. This includes filtering by structures, defects, or spaces.
Figure 6. Overview and images of the developmental event

Figure 7. Relationship between events

Figure 8. Developmental defects from malformations
b. Workflow Overview

Figure 9. describes the workflow for the development of the deliverable, from planning and organizing the information with prototypes and wireframes, to the creation of assets and user interface elements, and ending with the construction of the interactive timeline with Articulate Storyline 360, a software for developing interactive, e-learning modules.

![Workflow and list of programs used for timeline creation](image)

Figure 9. Workflow and list of programs used for timeline creation

c. Website Outline

Key concepts of body cavity partitioning were first mapped out with CMapTools. Concepts were color-coded by germ layer accordingly and were connected with lines to illustrate relationships as seen in Figure 10, Appendix K, p. 76. This information was placed in the format of a linear timeline in Adobe Illustrator (Figure 11, Appendix K, p. 76), so that events that overlapped temporally could be clearly delineated. These concept maps included all events and extraneous information about body cavity partitioning. From these concept maps, information was strategically eliminated, until only the most essential events of body cavity partitioning were included.

d. Website Design

Composition thumbnails were first sketched to explore options for event layout, as seen in Figure 12, Appendix K, p. 75. Two possible outlines were created in Adobe Illustrator to
experiment with a potential look and feel for the website (Figures 13-14, Appendix K, p. 75-76). The researcher and committee decided on the organic arrangement (Figure 14, Appendix K, p. 76), which uses curved lines to illustrate structure development and corresponded with the organically evolving structures.

A site map was sketched to determine the flow of pages within the website, which included key features like an introduction to body cavity partitioning with an overview of the site and a filters tab for the components “structures”, “defects”, “spaces”, and “all”, which highlights both spaces and structures (Figure 15, Appendix K, p. 76).

The initial wireframe sketch (Figure 16, Appendix K, p. 77) was based on the concept of an organic event arrangement. This was further refined by eliminating extraneous details not directly related to body cavity partitioning, like the development of the hepatic diverticulum and greater/lesser omentum. This created the finalized wireframe sketch (Figure 17, Appendix K, p. 77), which was placed in Adobe Photoshop, and a layer was created for each potentially selectable event (Figure 18, Appendix K, p. 78). This allowed the researcher to plan which lines would be highlighted when the user clicked on an event and where the defects would be placed. This Adobe Photoshop file also included sketches of the embryonic events and provided a guide for determining the path of the highlight on the button select function (Figure 18, Appendix K, p. 78).

A vector version of the events, relationships, and highlights was created in Adobe Illustrator, with each object clearly named as a connection, button, text, or highlight (Figure 21, Appendix K, p. 79). This early vector map created the foundation for the scalable vector graphic (SVG) elements that were exported and placed into the HTML index file for the website. The
naming conventions in Adobe Illustrator were imported into the code, creating classes and IDs, which could be referenced by both CSS and JavaScript for function (Figure 21, Appendix K, p. 79).

Color composition was determined in conjunction with highlighted lines to streamline workflow. From nine initial color compositions (Figure 19, Appendix K), the most popular three were chosen based on feedback from classmates and committee members. The colors were refined, so that the hues corresponding to the germ layers were cohesive (Figure 20, Appendix K, p. 79). The intraembryonic space was assigned the color purple, as opposed to blue or green, representative of the internal mesodermal lining (Figure 20, Appendix K, p. 79).

e. Website Prototype

An early prototype was developed in Articulate Storyline 360 (Figure 22, Appendix K, p. 80), in which all lines were created in Storyline and coded to highlight with a button press. This system only used Storyline buttons lines and outside images/ text. Early during development, the interactive timeline was initially designed for development from scratch with HTML, CSS, and JavaScript. A simple website utilizing the Bootstrap 4.0 framework was created (Figure 24, Appendix K, p. 81). The navigation bar and image card for the content were placed in the website along with the timeline wireframe created in Adobe Illustrator. The timeline was aligned to the left of the content card with each separate component imported as code for a scalable vector graphic of all possible buttons and relationships without highlights.

Two key functions were necessary for the timeline to operate properly: 1) ability to toggle stroke color on button click, and 2) ability to toggle the image and content in the image card on button click. The first function ran after some trial and error. The working solution involved
referencing the classes with different stroke colors and applying the toggle function to the corresponding button with JavaScript, which allowed line highlights to toggle on and off with a button click. Issues arose, however, when attempting to code the second function.

A variety of strategies was attempted. They can be generalized into three categories, none of which were successful in toggling the image/content (Figure 23, Appendix K, p. 80). The first method involved referencing the image source in the HTML and changing the image link. The second method involved un-hiding layered divs specifically for the image and content. The last method involved creating a separate class with the background set to specific images, which could then be referenced by the JavaScript classList.toggle function.

Due to the time constraints and uncertainty of developing a usable product, the researcher and committee decided that the deliverable should be a finalized version of the Storyline prototype for testing purposes. This solution has the potential to be expanded into a more web-friendly format in order to increase accessibility for students.

2. Production

Initially, the researcher assumed that re-creating the organic event arrangement in Articulate Storyline would not be feasible due to the limited options for vector and curve manipulation within the program. After further experimentation, however, the researcher discovered a process of layering PNG images of highlights exported from Adobe Illustrator underneath buttons that could be hidden or shown on button selection, which enabled the original event arrangement to be utilized (Figure 25, Appendix K, p. 81). The PNG images of the highlights were stacked on the background layer under the buttons, as lines needed to be aligned with each other exactly to prevent slight misalignment during button press (Figure 27,
Appendix K, p. 82). The image and content visibility allowed for more freedom due to right-sided alignment and were placed in separate layers, which could be toggled on and off with a button press (Figure 26, Appendix K, p. 82).

Fourty-six different event buttons with different options were created. Some overlap existed in terms of structures highlighted, allowing some PNG highlights and images to be reused (Figure 27, Appendix K, p. 82). This redundancy was tracked with the button redundancy Table (see Table I), so that duplicates of PNGs with the same highlighting pattern weren’t created.

<table>
<thead>
<tr>
<th>Buttons</th>
<th>PNG name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ectoderm, Epidermis,</td>
<td>Ectoderm</td>
</tr>
<tr>
<td>2. Cardiogenic region, endocardial tube, heartloop</td>
<td>cardiogenic</td>
</tr>
<tr>
<td>3. Mesoderm, diaphragm</td>
<td>mesoderm</td>
</tr>
<tr>
<td>4. OBW, dermis</td>
<td>OBW</td>
</tr>
<tr>
<td>5. Pleruopericardial fold fusion, primitive pericardial foldsf</td>
<td>Pleuropericardialfolds</td>
</tr>
<tr>
<td>6. Pleuroperitoneal membrane, muscle</td>
<td>pleuroperitonealmembrane</td>
</tr>
<tr>
<td>7. Somite formation, muscular rim, muscle rim</td>
<td>somites</td>
</tr>
<tr>
<td>8. Intraembryonic coelom</td>
<td>Intraembryonic</td>
</tr>
<tr>
<td>9. Pericardioperitoneal cavity</td>
<td>Pericardioperitoneal canals</td>
</tr>
<tr>
<td>10. Pleural cavity</td>
<td>Pleuralcavity</td>
</tr>
<tr>
<td>11. Peritoneal cavity</td>
<td>Peritoneal cavity</td>
</tr>
<tr>
<td>12. Septumtransversum, central tendon</td>
<td>Septumtrans</td>
</tr>
<tr>
<td>13. Dorsal mesentery, crura</td>
<td>Dorsal mesentery</td>
</tr>
<tr>
<td>14. Respiratory diverticulum</td>
<td>respdiv</td>
</tr>
<tr>
<td>15. foregut</td>
<td>foregut</td>
</tr>
<tr>
<td>16. Midgut, gut herniation, intestinal loop</td>
<td>Midgut</td>
</tr>
<tr>
<td>17. endoderm</td>
<td>Endoderm</td>
</tr>
<tr>
<td>18. hindgut</td>
<td>hindgut</td>
</tr>
<tr>
<td>19. Primary bronchialbuds</td>
<td>Bronchialbud1</td>
</tr>
<tr>
<td>20. Secondary tertiary bronchialbuds</td>
<td>Bronchialbud2</td>
</tr>
<tr>
<td>21. IBW</td>
<td>IBW</td>
</tr>
</tbody>
</table>

Table I. Button list to organize redundant highlighted lines.
An image list was created with checkpoints for each of the 29 images to be shown on button click (Figure 32, Appendix K, p. 85). Some overlap existed between images, as multiple concepts or events could be shown with the same image. For each image, four checkpoints were planned: sketch, refined sketch, vector rendering in Adobe Illustrator, and revision. Due to time constraints, the timeline was tested with sketches only, which are listed in Appendix L, p. 88.

3. Post-Production

For testing purposes, a static resource containing only the content was created for comparison against the interactive resource. Both resources included an Introduction (Figure 28, Appendix K, p. 83) and an About section in the navigation bar that could be scrolled through with arrows, or clicked out of with the Exit button. The most apparent difference between the interactive and static resource was the visibility of the lines connecting related structures (Figure 29, Appendix K, p. 83). Other features of the interactive timeline included the ability to select weeks creating a section grouping around the events occurring in the specified timeframe. Week headers provided an overview of the major events occurring in the specific week. Only one button could be selected at a time within the timeline; on button selection, the associated PNG with line highlights would appear. An additional feature to be added could include related structure highlights to the button strokes themselves (Figure 29, Appendix K, p. 83).

A key difference between the interactive and static resource that became instrumental during testing was the “filters” tab in the navigation bar (Figure 30, Appendix K, p. 84). When clicked, a drop-down menu with the filter options “all”, “structures”, “spaces”, and “defects”
was provided. The defects tab showed hidden defect buttons at key time points, highlighted in green for visual salience. Without clicking this filter, defects were hidden by default.

The static resource only showed the images and content on click (Figure 31, Appendix K, p. 84). By default, any features that were hidden in the interactive resource were shown in the static resource, like the week highlights and defects. No filters tab exists in the static resource, and the navigation bar only allows users to explore the Introduction and About sections. No colored highlight appears when buttons are selected. Both interactive and static resources are publically available on Articulate Review and can be viewed with the links below:

Interactive Timeline:
https://360.articulate.com/review/content/e903d271-e974-4f99-9bad-3ff55a5b588d/review

Static Timeline:
https://360.articulate.com/review/content/d2ac589d-340c-4c5d-aabd-d3cb27623216/review

Any revisions to the timeline will appear as a course under the researcher’s articulate community profile:
https://community.articulate.com/users/natalieyoshioka

C. Evaluation plan

To gather both qualitative and quantitative data, subjects were asked to complete a series of tests in a crossover study design. All subjects took a pre-test to evaluate baseline level of embryology knowledge. They completed three tasks with the first resource (either static or interactive), which were timed to evaluate how much time was needed to discover embryonic relationships. After each task, the subjects were instructed to explain what steps they took to complete the task. This portion was audio recorded for future qualitative analysis. A post-test
was then distributed to evaluate knowledge gain. The remaining resource was then distributed, and the subjects were instructed to complete three different tasks, which were timed for comparison. After each task, responses were audio recorded. Finally, a survey was given to subjects to evaluate satisfaction with the interactive resource only.

1. **Study setting**

The testing sessions were performed in a quiet computer lab supplied by the school. The testing station had both the interactive timeline and static resource open in separate tabs so that the participant could easily switch between resources after finishing each phase of testing. The researcher was present in the room to observe how the subjects completed tasks, time the subject, listen and record walkthrough descriptions, and explain the testing process during the study. The estimated time period for the study was based on the data gathered from the initial review with committee members. Initially, a facilitator had been trained to moderate testing, so that at least two test subjects could be tested at once; however, all test subjects completed testing sessions within 45 minutes, as opposed to the estimated time of 1 hour and 30 minutes, so no test subjects had overlapping testing times, and the trained facilitator was not utilized.

Each subject was given a packet with the testing documents on a clipboard based on their group assignment. The first page was the data collection form (Appendix J, p. 74), which the Principal Investigator took to fill out. After the subjects completed testing with the first resource, they completed the second portion of testing with the remaining resource at the testing station.
2. Sample or population sampling methods

   a. Selection criteria

First and second year and dental students from the UIC College of Dentistry were to be recruited for the study as these students need to learn embryology material for their professional licensing exams. The timeline was designed to help students with a limited amount of time to discover and identify embryonic relationships more quickly. With a focus on clinical significance, the assessment is a strong indicator of resource usefulness when it is tested with participants who are required to apply this knowledge in their future careers as health care professionals. In addition, biomedical visualization students in their first and second year were recruited to participate in the study as well, since these students are either interested in medicine or have some embryology background. Testing with learners whose primary education is not medicine provided more data about whether the timeline could be useful for users of different backgrounds.

   b. Selection strategy

A recruitment email was sent by Dr. Alison Doubleday to the students in her dental classes. The Principal Investigator also sent the email through the BVIS listserv to recruit biomedical visualization students. A monetary reimbursement of $30 was offered as compensation for subjects’ time.

   c. Size

Twenty to forty subjects were recruited in order to garner a sample size large enough to reduce the margin of error for each group, ranging from seven to nine subjects. A total of 34 subjects participated in the study, with 11 dental students in their first or second year of study,
and 23 biomedical visualization graduate students in their first or second year of study.

d. Data collection

Subjects were assigned their testing group based on when they signed up for testing, in order to ensure equal numbers of subjects in each of the four testing groups. First, users completed the pre-test in their packet, which allowed the researcher to establish a base-line of embryology knowledge and examine knowledge gain when compared to the post-test. These tests were five questions in length and tested general knowledge of body cavity partitioning relationships. The pre-test questions were different from the post-test questions.

The subject then used the first resource, which was determined according to one of the four groups to which they were assigned. The subject was given two minutes to navigate the user interface of the resource to become familiar with the layout before starting the tasks. The subject was then instructed to start a timer when ready to start the task and was instructed to end the timer when they felt they had finished, indicating that they have completed the task. Three tasks were given to the users to complete with the first resource, and each of these tasks was timed so that a set of data about different tasks with different goals was gathered. After each task, a semi-structured interview of up to three minutes was initiated (Given, 2008). Each participant was asked to describe their thought process and briefly discuss the steps they took to complete the task. The responses were recorded with an audio recorder for future analysis.

After the three tasks using the first resource were completed, the subject took a short post-test with five questions that were of similar difficulty to those of the pre-test. No questions from the pre-test were repeated, as this would prime subjects about the post-test questions (Abbott & McKinney, 2013). The subject then moved to the tab with the remaining resource.
The subject then completed the same process of testing as performed with the first resource, but with three different tasks of similar learning objectives.

After all tasks and testing were completed, the subjects were then instructed to complete a short Likert-scale survey, which asked the subjects to evaluate the timelines on usability. This data contributed information about what specifically made the interactive successful in terms of design. The survey had five statements with a 5-point ordinal scale ranking system. Subjects were instructed to fill out the survey and flip over the form, so that the researcher would not be able to see the scores. The researcher explicitly stated that the subject should feel comfortable responding truthfully without worry of judgment. The data collection form for the tests is listed in Appendix J, p. 74.

**e. Method of analysis**

For the quantitative data, descriptive statistical analysis was performed to compare average time differences spent between completing a task with the interactive timeline versus the static resource to determine if there were any differences between the two. Only times taken from the first round of testing were calculated to help the researcher infer whether or not the interactive timeline was an effective tool for helping students uncover developmental relationships more quickly.

Scores on the pre-test and post-test were evaluated with descriptive statistical analysis to determine if knowledge of embryonic developmental relationships increased after using the resources. If the scores have increased in the group with the interactive timeline as compared to the static control resource, the researcher can conclude that the timeline was an effective resource for contributing to embryonic relationship learning. The pre-test and post-test
questions were developed so that a mix of embryonic material was tested, which correlates to information garnered in either task set 1, task set 2, or either task set.

Qualitative data was analyzed in several ways. Semi-structured interview audio recordings were transcribed with the transcription software Temi. Transcripts were then coded for repeating concepts to determine what these concepts had in common, which informed the development of themes and theme constructs (Auerbach & Silverstein, 2003; Bryman, 2008). This ultimately developed a theoretical narrative or summary of the key discoveries related to the hypothesis (Auerbach & Silverstein, 2003; Bryman, 2008; Chowdhury, 2015). The usability survey was analyzed with Likert scale analysis and descriptive statistics, with the averages of each of the survey questions calculated.
RESULTS

A. Quantitative Analysis:

1. Pre-Test/ Post-Test

Both interactive and static resources did increase knowledge gain. Scores increased by an average of 1.72 points (out of 5) in subjects given the interactive resource first, and 1.19 points in those given the static resource first. Both biomedical visualization and dental students performed similarly on testing, regardless of year of study or gender. Appendix N lists participant data.

2. Task times

Average task times for subjects were mixed, and times for each of the six tasks is listed in Table II. The data below describes the time that it took to complete each task for only the first encounter with a timeline, either static or interactive. Because the subject is unfamiliar with the resource, the researcher assumes that time taken to complete tasks using the first resource will be longer as compared to the second resource. To account for this discrepancy, only the average times for subjects’ first resource use are listed below:

<table>
<thead>
<tr>
<th>Task Set_Task number</th>
<th>1_1</th>
<th>1_2</th>
<th>1_3</th>
<th>2_1</th>
<th>2_2</th>
<th>2_3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactive Resource</td>
<td>190.44s</td>
<td>111.11s</td>
<td>213.44s</td>
<td>237.33s</td>
<td>49.22s</td>
<td>52.78s</td>
</tr>
<tr>
<td>Static Resource</td>
<td>151.11s</td>
<td>26</td>
<td>49.78s</td>
<td>227.42s</td>
<td>68</td>
<td>282.6s</td>
</tr>
</tbody>
</table>

Table II. Average times for task completion in seconds
For Task Set 1, average times for each task were lower for participants using the static resource vs. the interactive resource. For Task Set 2, subjects using the interactive resource were able to complete the tasks more quickly on average in comparison to those using the static resource.

An explanation for these differences in task times could be the result of the differences between the two task sets and resources. Both Task Set 1, task 1 and Task Set 2, task 1 asked subjects to find an embryonic defect, accessible only by filters. Based on coded responses from walk-through interviews and direct observation, subjects struggled to find the filters button in the interactive resource, which could account for the increased time taken to complete the task. Subjects using both the interactive and static resources, however, took longer to find the embryonic defects, noting lack of exact wording created difficulty.

3. Timeline Usability Scale

For the Timeline Usability Scale, five questions were given to subjects, regarding the interactive timeline only. Subjects rated the interactive timeline on how likely they were to use the timeline to study embryology, if they found the system unnecessarily complex/confusing, ease of use, clarity of illustrations and text, and clarity of organization out of a 5-point scale. Results were fairly consistent, regardless of area of study, year of study, or gender, and are listed in Table III.
<table>
<thead>
<tr>
<th>Timeline usability scale questions</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total AVG</td>
<td>4.67</td>
<td>1.85</td>
<td>3.94</td>
<td>4.05</td>
<td>4.44</td>
</tr>
<tr>
<td>DENT AVG</td>
<td>4.45</td>
<td>2.09</td>
<td>3.82</td>
<td>3.73</td>
<td>4.23</td>
</tr>
<tr>
<td>BVIS AVG</td>
<td>4.78</td>
<td>1.74</td>
<td>4</td>
<td>4.22</td>
<td>4.52</td>
</tr>
</tbody>
</table>

Table III. Survey question results. Survey questions can be found in Appendix I, and all participant data in appendix N.

Regarding the interactive resource, subjects felt that they would use the interactive to study embryology, felt that content was well organized, and did not find the system unnecessarily complex/confusing. Dental students rated the system slightly higher than neutral on ease of task completion and clarity of the text and illustrations (questions 3, 4). For future revisions, clearer and more refined illustrations are needed, as well as more simplified text/language.

B. Qualitative Analysis

Audio recordings of the semi-structured interviews were transcribed with the online transcription service “Temi.” The transcriptions were checked for major grammatical and spelling errors, then were carefully coded using a code guide developed by the researcher using major themes that emerged in the interviews, as seen in Table IV.
<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Filter difficulty</td>
<td>Subject had difficulty finding and using the filters</td>
</tr>
<tr>
<td>2. Button skim</td>
<td>Subject used the button headings to skim for information</td>
</tr>
<tr>
<td>3. Pics</td>
<td>Subject used the pictures provided to orient/determine the correct answer</td>
</tr>
<tr>
<td>4. Timeline headers</td>
<td>Subject used the timeline headers (either weeks number or short description) to narrow down where they should look</td>
</tr>
<tr>
<td>5. Systematic use</td>
<td>Subject worked through the timeline by clicking on each button in a section, or working left to right</td>
</tr>
<tr>
<td>6. Content</td>
<td>Subject used the content language/ event details to determine the correct answer, which could include keywords</td>
</tr>
<tr>
<td>7. Visual highlights</td>
<td>The highlights led the subject to the correct answer, or were used to help guide the user to an event</td>
</tr>
<tr>
<td>8. Surrounding context</td>
<td>The buttons surrounding the key event were helpful for determining where the subject should direct their attention</td>
</tr>
<tr>
<td>9. Adult structures</td>
<td>Subject used adult structures and worked backwards in the timeline to determine the embryonic structure.</td>
</tr>
<tr>
<td>10. Related words</td>
<td>From previous knowledge, subject related words that had the same or similar meanings to each other</td>
</tr>
<tr>
<td>11. Previous knowledge</td>
<td>Subject stated that previous knowledge helped them discover the event/ find the correct answer</td>
</tr>
<tr>
<td>12. Familiarity</td>
<td>Subject was able to go through the resource and find the answer more quickly due to increasing familiarity</td>
</tr>
</tbody>
</table>

Table IV. Code guide

Transcriptions are listed in Appendix O, with several sample analyses listed in Appendix P. Transcription analysis provided insight into subject thoughts as they worked through the tasks using the timelines, giving feedback for what they liked and disliked about the timeline. Subjects felt that the highlights were most helpful for finding relationships between adult structures like the diaphragm and its embryonic derivatives. Regarding the content, the pictures did help subjects complete the tasks and provide orientation, but subjects were primarily...
skimming text and button events to find the correct answers.

Subjects worked through content systematically, starting from left to right, and used this systematic method of exploration to find the answer if unsure about where to start. The timeline week buttons and headers were used more by subjects using the static resource as opposed to the interactive, and several noted that it was more clear that the information was structured temporally with the weeks initially divided. Subjects struggled to find the defects button with the interactive resource, which was essential for completing any task asking users to find an embryonic defect. Those using the static resource had less difficulty finding defects due to automatic display of defects on the home screen, which subjects felt were easier to find, and may explain the disparity in task times between resources. Surrounding context and buttons were commonly used to find the answers to the tasks, with participants noting that they were able to find body system sections after exploring the resource more thoroughly. Main suggestions included a more visible filters button, the ability to select by body system/adult structures, and improved illustrations.
DISCUSSION

A. Review of major points

Body cavity partitioning during human embryonic development is often difficult to understand because of the complexity of temporal relationships between developing organ systems within cavities. Existing educational material focuses on teaching material systemically, but does not provide students with an understanding of the larger developmental picture. An interactive timeline allows the user to explore the formation of the cardiac, respiratory, and gastrointestinal systems in relation to the development of pleural, pericardial, and peritoneal cavities during weeks three to seven of the embryonic period.

An easily accessible web-based interactive was an effective method for displaying large amounts of embryonic, time-based data. After the timeline was distributed, users were able to complete tasks in several minutes. Using an interactive timeline helped to improve student knowledge of both normal developmental relationships and congenital abnormalities that occur during the embryonic period.

B. Limitations

The most limitations were discovered during testing, which had not been accounted for during the study design. Subjects were tested while the researcher was present, and several subjects noted that this increased the pressure to perform well on tests. The majority of test subjects were fellow biomedical visualization graduate students, which introduced bias due to previous familiarity with the researcher and general research subject. The sample size of
students participating outside of the biomedical visualization field was small due to limited study enrollment. Because the resource was designed for students planning to become health care professionals, the previous experience of biomedical visualization students and their high visual ability may have potentially skewed results. A solution would be to focus recruitment efforts solely on subjects outside of the biomedical visualization graduate program.

The researcher noticed halfway through testing that some subjects decided to stop the timer before writing their responses to the tasks, as opposed to other subjects, who stopped the timer after writing their responses, which could skew results by several seconds. For future testing, developing a consistent method for subject task response would ensure more accurate data collection.

Testing proceeded with sketches of embryonic structures as opposed to finalized illustrations, which created some confusion in subjects, as they felt some of the tasks would be easier to complete using finalized illustrations. Several small bugs existed in the timeline, such as visible defect buttons, even though subjects had clicked out of the filters option. In the static timeline, the lateral plate mesoderm and paraxial mesoderm buttons were not always visible. Plans are currently in place to address these issues and incorporate feedback from subjects.

Superficial data analysis was performed with descriptive statistics, so no significant conclusions can be drawn from the data. This can be remedied by more thorough and robust statistical data analysis. Additionally, the researcher was the only individual coding the transcripts from semi-structured interview recordings. Having another primary coder analyze the data would solidify results and eliminate personal bias (Berends & Johnston, 2005).

The design of the timeline addressed multiple factors that influence user experience, as
outlined by Peter Morville’s usability honeycomb (2004). The timeline succeeded in usefulness, valuableness, and credibility due to the scientific accuracy and rigor of the information provided by the timeline events, organized by relationship and germ layer. However, regarding the remaining factors, improvements to the timeline could be made. The timeline was useable to an extent. Subjects did have difficulty using the timeline to complete tasks due to complexity of the layout and information. Regarding findability, subjects had difficulty finding essential features of the timeline, such as the defects button and week header highlights. Because the timeline was made with Articulate Storyline 360, the accessibility is extremely limited. This could be addressed by creating a web-based timeline with code, which would allow for customization and alt text to be added. Visuals could be improved to increase both the effectiveness and the aesthetics of the timeline, which would increase user motivation to explore and help users scan the resource for pertinent information. Future revisions for the interactive timeline that are planned include:

- Improved and finalized illustrations;
- Revised defects/filters button to make finding the filters easier. Defects should be accessible from the initial opening screen;
- Week and header buttons that will activate simultaneously to highlight a specific time period;
- Revised introduction section that will provide an overview of the different features or parts of the timeline, as well as a quick explanation of the color-coding system;
- Text revision to make skimming easier for users;
- Related buttons highlighted in addition to the initial button, which would make
related structures more clear; and

- Fix bugs with the filter button as some filters still remain visible when clicking on other filters, and the defect events disappear when clicking on other timeline events.

C. Implications for profession

This research adds to a limited amount of existing data on the effectiveness of interactive timelines in education, as well as providing evidence that this method is appropriate to help students learn embryonic relationships. The research also addresses the ongoing issue of lack of embryology education in the medical school curriculum and the lack of resources available for students learning embryology online.

D. Future applications

At the moment, the project is limited to the embryonic development of body systems during body cavity partitioning. The interactive only examines a small part of development and does not address simultaneous events in other body systems, so there is room for potential expansion to include more body systems. Little research has been done on the usability of interactive timelines and their effect on learning, so there is a lack of information in terms of what is most useful for data display in science education.

Because of the complexity of temporal data and abundance of developmental relationships, the timeline organizes large amounts of information spread over several body systems in an understandable way. It is designed to give users the ability to explore the resource based on their individual learning needs and preferences. Users should be able to complete tasks if the interactive is well-designed, but the amount of embryonic knowledge gained from the
experience could be dependent on previous knowledge of embryology and inclination or time to explore the interactive.

This research addresses the difficulties of conveying complex embryonic relationships in an organized system, and the success of this project sets the foundation for inclusion of more body systems with longer developmental periods to educate future health care professionals in their clinical practice. By expanding the limited amount of quality resources, this research provides a basic framework, which can be used to create additional interactive timelines for various aspects of embryology education.


The FASEB Journal, 29(1 Supplement). Retrieved from http://www.fasebj.org/content/29/1_Supplement/695.1.abstract


Federation of State Medical Boards of the United States and the National Board of Medical Examiners. 2017. USMLE Content Outline [Internet]. Retrieved from http://www.usmle.org/pdfs/usmlecontentoutline.pdf


https://doi.org/10.1177/1473871615605347


Appendix A: Recruitment Email

This email will be distributed to dental and biomedical visualization students enrolled in the University of Illinois at Chicago during the Spring Semester of 2018 through Dr. Alison Doubleday and the BVIS listserv respectively. During the week of testing, students will receive this email, explaining the research and what will be expected if they choose to participate. Students may choose to not participate in this research study. If they choose to participate, another email will be sent to potential subjects so that the PI can be sure the students meet the requirements, and to schedule a testing time. No identifying information will be kept past scheduling testing times.

Dear Student,

You are invited to participate in a research study that will evaluate the effectiveness of an interactive timeline which displays embryonic relationships and congenital defects. As a graduate student in Biomedical Visualization at the University of Illinois at Chicago, I recently created a freely accessible website that visually organizes and depicts body cavity partitioning relationships as part of my Master’ Thesis.

The data collected from the study will determine the efficiency, usability, and effectiveness of the timeline as a resource for displaying temporal embryonic relationships. Your participation is important for evaluating a potential addition to limited embryology learning material.

Attached to this email, please find the informed consent form. You will be compensated for your time and energy spent participating in this research in the amount of $30. You will be
asked to use a timeline on embryology to identify relationships of body cavity partitioning and will be asked to briefly discuss how you used the resource to complete the task. A pre-test, post-test, and short usability survey will also be administered. If you elect to participate in this research, please click the confidential doodle poll below to schedule a testing time. If none of the available times fit with your schedule, please email the principal investigator, Natalie Yoshioka, at nyoshi2@uic.edu to schedule a testing time. Please feel free to contact me with any questions.

[Doodle poll link]

Thank you in advance for your interest and participation,

Principal Investigator: Natalie Yoshioka

M.S. Candidate, Biomedical Visualization, Class of 2018

Email: nyoshi2@uic.edu

Cell: 410-967-2890
Appendix B: Intake Email

This email will be sent to individuals who expressed interest in participating in the study to confirm a time for testing after previously indicating their availability, and provide details about where testing will take place.

Dear Student,

Thank you for your interest in participating in the Master’s Thesis Research: Temporal Visualization of Body Cavity Partitioning: An Interactive Timeline. One hour and 30 minute blocks have apportioned for testing.

You have been scheduled for testing at [time] on [date]. Testing will occur at the Applied Health Sciences Building, Room 707, 1919 W. Taylor Ave. Please feel free to contact me with any questions.

Thank you for your interest and participation,

Principal Investigator: Natalie Yoshioka

M.S. Candidate, Biomedical Visualization, Class of 2018

Email: nyoshi2@uic.edu

Cell: 410-967-2890
Appendix C: Informed Consent Form

University of Illinois at Chicago
Research Information and Consent for Participation in Social Behavioral Research
Temporal Visualization of Body Cavity Partitioning: An Interactive Timeline

You are being asked to participate in a research study. Researchers are required to provide a consent form such as this one to tell you about the research, to explain that taking part is voluntary, to describe the risks and benefits of participation, and to help you to make an informed decision. You should feel free to ask the researchers any questions you may have.

Principal Investigator Name and Title: Natalie Yoshioka, BA; nyoshi2@uic.edu, 410-967-2890
Department and Institution: Department of Biomedical and Health Information Sciences
Address and Contact Information: 1919 W. Taylor St., Chicago, IL 60612, Fax: 312-996-8342
Sponsor: John Daugherty, MS; jdaug@uic.edu, 312-996-4975

Why am I being asked?

You are being asked to be a subject in a research study about the effectiveness of an interactive timeline displaying the relationships between developing embryonic structures.
You have been asked to participate in the research because your field of study is related to medicine and knowledge of human anatomy. As a medical, dental, Urban Health Program, Post-Baccalaureate or Biomedical Visualization student enrolled at the University of Illinois at Chicago, the understanding of adult anatomy is important. Being able to recognize the relationship between adult structures and human embryology may be critical in gaining greater understanding of structures and their relationships.

Your participation in this research is voluntary. Your decision whether or not to participate will not affect your current or future dealings with the University of Illinois at Chicago. If you decide to participate, you are free to withdraw at any time without affecting that
relationship.

Approximately 40 subjects may be involved in this research at UIC.

**What is the purpose of this research?**

This research is being done to better understand temporal data visualization and organization in the context of body cavity partitioning. Embryology is a difficult subject to teach because of the continuously changing structures. This research proposes to develop an online tool that can be used by students to discover relationships between organ systems in body cavity partitioning more quickly and efficiently. By organizing the information in a clean, well-designed, interactive format, users should be able to identify how different structures are related to each other during embryonic development. This will provide support for use of interactive timelines as an effective method for temporal data visualization and embryology education.

**What procedures are involved?**

This research will be performed at: The University of Illinois at Chicago Applied Health Sciences Building 1919 W. Taylor St. Chicago, IL 606012.

You will need to come to the study site one time over the next week.

There is a single round of testing conducted, and testing will be completed during the date and time as scheduled with the doodle poll. Testing will be completed within the scheduled day.

This visit will take about 1 hour to 1 hour and 30 minutes.

The study procedures are:
- Pre-test: 5 questions to evaluate basic embryology concepts
- Complete 3 tasks using either the interactive timeline, or content only timeline: this section will be timed to evaluate if the timeline organization is effective
- 3 minute walkthroughs: After each task, explain what you did to complete the tasks. This section will be audio recorded.
- Post-test: 5 questions to evaluate knowledge gain after timeline use.
- Complete 3 tasks using the remaining resource: this section will be timed for comparison to the first resource
- 3 minute walkthroughs: After each task, explain what you did to complete the tasks. This section will also be recorded.
- Usability Survey: 5 questions to evaluate how easy the interactive timeline was to navigate and use.

**What are the potential risks and discomforts?**

The likely risks and discomforts expected in this study are:

- Cognitive stress or discomfort may result from sitting down to complete a pre-test, a series of timed tasks, and a post-test for a period of time.
- Being recorded when responding to questions regarding the process followed to complete tasks may place some minimal pressure to provide socially desirable answers to questions.

**Will I be told about new information that may affect my decision to participate?**

During the course of the study, you will be informed of any significant new research information (either good or bad), such as changes in the risks or benefits resulting from participation in the research or new alternatives to participation, that might cause you to change your mind about continuing in the research. If new information is provided to you, your
consent to continue participating in this research may be re-obtained.

**Are there benefits to taking part in the research?**

You may not directly benefit from participation in the research.

**What other options are there?**

You have the option to not participate in this study.

**What about privacy and confidentiality?**

The people who will know that you are a research subject are members of the research team. Otherwise information about you will only be disclosed to others with your written permission, or if necessary to protect your rights or welfare (for example, if you are injured and need emergency care or when the UIC Office for the Protection of Research Subjects monitors the research or consent process) or if required by law.

- Study information which identifies you and the consent form signed by you will be looked at and/or copied for checking up on the research by: UIC Office for the Protection of Research Subjects, State of Illinois Auditors

A possible risk of the research is that your participation in the research or information about you and your health might become known to individuals outside the research.

- You will be given an ID number that will correspond to your audiotaped responses. The ID numbers and audio recordings will be stored on a password-protected hard drive and kept in a locked locker in a swipe-access only room.
• Audio recordings and ID numbers will be kept only throughout the duration of the study, and will be deleted following data analysis. No indirectly-identifying information will be kept past the completion of the study. When the results of the research are published or discussed in conferences, no information will be included that would reveal your identity.
• You have the right to review your recordings at the completion of testing if you wish to do so.
• The research team are the only individuals who will have access to the audiotapes and ID numbers.

**What are the costs for participating in this research?**

There are no costs to you for participating in this research.

**Will I be reimbursed for any of my expenses or paid for my participation in this research?**

You will receive $30 in cash for your participation in the study. You will receive your payment immediately at the end of the visit in person by the Principal Investigator, Natalie Yoshioka.

**Can I withdraw or be removed from the study?**

You have the right to leave the study at any time without penalty. The researchers also have the right to stop your participation in this study without your consent if they believe it is necessary. For example, your participation in the research may be stopped if the researchers believe it is in your best interests or in the best interest of the research. In the event you withdraw or are asked to leave the study, you will still be compensated as described above.

**Who should I contact if I have questions?**
Contact the researchers Natalie Yoshioka (Principal Investigator) at 410-967-2890 or nyoshi2@uic.edu or John Daugherty (Faculty Sponsor) at 312-996-4975 or jdaug@uic.edu:

- if you have any questions about this study or your part in it
- if you have questions, concerns or complaints about the research.

**What are my rights as a research subject?**

If you feel you have not been treated according to the descriptions in this form, or if you have any questions about your rights as a research subject, including questions, concerns, complaints, or to offer input, you may call the Office for the Protection of Research Subjects (OPRS) at 312-996-1711 or 1-866-789-6215 (toll-free) or e-mail OPRS at uicirb@uic.edu.

**What if I am a UIC student?**

You may choose not to participate or to stop your participation in this research at any time. This will not affect your class standing or grades at UIC. The investigator may also end your participation in the research. If this happens, your class standing or grades will not be affected. You will not be offered or receive any special consideration if you participate in this research.

**Remember:**

Your participation in this research is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University. If you decide to participate, you are free to withdraw at any time without affecting that relationship.

**Signature of Subject**

I have read (or someone has read to me) the above information. I have been given an opportunity to ask questions and my questions have been answered to my satisfaction. I agree
to participate in this research. I will be given a copy of this signed and dated form.

__________________________   ____________
Signature                   Date

__________________________
Printed Name

__________________________   ____________
Signature of Person Obtaining Consent Date (must be same as subject’s)

__________________________
Printed Name of Person Obtaining Consent
Appendix D: Pre-Test Questions:

Italicized type will be for research purposes only, and are not disclosed to the student.

1. The diaphragm is typically completely formed by:
   a. Week 3
   b. Between week 4-5
   c. Week 7
   d. Week 11
   e. After birth

   Answer: C, testing knowledge of timing in embryology, task set 1 or 2

2. What does the septum transversum give rise to in the fully developed diaphragm?
   a. Central tendon
   b. Muscular portion
   c. Right crus
   d. Left crus
   e. None of these answers are correct

   Answer: A, testing knowledge of embryonic derivatives of the diaphragm, task set 2

3. Which of these embryonic defects results from failure of the ventral body wall to form properly during lateral folding?
   a. Parasternal herniation
   b. Gastrochisis
   c. Esophageal atresia
   d. Spina bifida
   e. Diaphragmatic herniation

   Answer: B, testing knowledge of embryonic defects, task set 1 or 2

4. Which of these embryonic structures helps to anchor the diaphragm to the lateral body walls?
   a. Pleuroperitoneal folds
   b. Dorsal mesentery
   c. Pleuropericardial folds
   d. Muscular rim
   e. None of these answers are correct

   Answer: D, testing knowledge of embryonic derivatives of the diaphragm, task set 1

5. What embryonic process forms the intraembryonic coelom?
   a. Cardiac looping
   b. Lateral folding
   c. Intestinal herniation
   d. Atrial septation
   e. None of the above

   Answer: B, testing knowledge of body folding, task set 1 or 2
Appendix E: Post-test Questions

1. During which week does lateral folding occur?
   a. Week 2
   b. Week 4
   c. Week 7
   d. Week 8
   e. Fetal period
   Answer: B, testing knowledge of timing in embryology, task set 1 or 2

2. Which developing structures contribute to an adult diaphragm?
   a. Somites C3-C5
   b. Septum transversum
   c. Pleuropericardial folds
   d. Liver bud
   e. Allantois
   Answer: B, testing knowledge of embryonic derivatives of the diaphragm, task set 2

3. Which embryonic defect describes a blind-ended gut tube?
   a. Tracheo-esophageal fistula
   b. Esophageal atresia
   c. Ectopia cordis
   d. Pulmonary hypoplasia
   e. Patent ductus arteriosus
   Answer: D, testing knowledge of embryonic defects, task set 2

4. The diaphragm is formed mainly from which of the following embryonic tissues:
   a. mesoderm
   b. endoderm
   c. ectoderm
   d. Two of the above
   e. None of the above
   Answer: A, testing knowledge of embryonic derivatives of the diaphragm, task set 1 or 2

5. In body cavity partitioning, which is true about lateral folding?
   a. lateral folding causes the endocardial tubes to merge with the dorsal aorta
   b. lateral folding causes the endocardial tubes to form the primitive heart tube
   c. lateral folding translocates the cardiogenic region to the area below the septum transversum
   d. lateral folding does not contribute to the formation of the diaphragm
   e. None of the above
   Answer: B, testing knowledge of body folding, task set 1 or 2
Appendix F: Tasks - Set 1

Task 1:

Please complete the following task, taking as much time as you need. Hit the timer when you feel you are ready to start and you may immediately begin your task. When you have finished the task, hit the timer to indicate that you have finished the task. The task is:

“Use the resource to find the name of the embryonic defect that would result from abnormal partitioning of the pleural and peritoneal cavities.”

The name of the embryonic defect that would result from abnormal partitioning of the pleural and peritoneal cavities is:

________________________________________________________________________

Answers accepted: Diaphragmatic herniation, parasternal herniation

Task 2:

Please complete the following task, taking as much time as you need. Hit the timer when you feel you are ready to start and you may immediately begin your task. When you have finished the task, hit the timer to indicate that you have finished the task. The task is:

“Use the resource to find the name of the structure that forms the most lateral part of the diaphragm, anchoring it to the lateral body wall.”

The name of the structure that forms the most lateral part of the diaphragm, anchoring it to the lateral body wall is:

________________________________________________________________________

Answers accepted: Mesoderm of the body wall, rim of the body wall mesoderm
Task 3:

Please complete the following task, taking as much time as you need. Hit the timer when you feel you are ready to start and you may immediately begin your task. When you have finished the task, hit the timer to indicate that you have finished the task. The task is:

“Use the resource to find the name of the embryonic structure that separates the cardiovascular system from the respiratory system in the chest cavity.”

The name of the embryonic structure that separates the cardiovascular system from the respiratory system in the chest cavity is:

________________________________________________________________________

Answers accepted: Pleuropericardial folds, pleuropericardial membranes
Appendix G: Tasks-Set 2

Task 1:
Please complete the following task, taking as much time as you need. Hit the timer when you feel you are ready to start and you may immediately begin your task. When you have finished the task, hit the timer to indicate that you have finished the task. The task is:

“Use the resource to find the name of the embryonic defect that would result from abnormal separation of the respiratory and gastrointestinal systems.”

The name of the embryonic defect resulting from abnormal separation of the respiratory and gastrointestinal systems is:
________________________________________________________________________

Answers Accepted: Tracheo-esophageal fistula, Esophageal Atresia

Task 2:
Please complete the following task, taking as much time as you need. Hit the timer when you feel you are ready to start and you may immediately begin your task. When you have finished the task, hit the timer to indicate that you have finished the task. The task is:

“Use the resource to find the name of the embryonic structure that gives rise to the central tendon of the diaphragm.”

The name of the embryonic structure that gives rise to the central tendon of the diaphragm is:
________________________________________________________________________

Answers accepted: Septum Transversum
Task 3:

Please complete the following task, taking as much time as you need. Hit the timer when you feel you are ready to start and you may immediately begin your task. When you have finished the task, hit the timer to indicate that you have finished the task. The task is:

“Use the resource to find the name of the embryonic structure that forms the most dorsal part of the diaphragm, anchoring it to the posterior body wall.”

The name of the embryonic structure that forms the dorsal part of the diaphragm, anchoring it to the posterior body wall is:

________________________________________________________________________

Answers accepted: dorsal mesentery, esophageal mesentery
Appendix H: Walkthrough Script

After each task, the facilitator will say:

Facilitator: You will now have three minutes to discuss the steps you took to complete the task.

Please explain what you did briefly from start to finish, for example, what you clicked on or what you did to find the information.
Appendix I: Timeline Usability Scale

Regards the interactive timeline only.

1. I would use this interactive to study embryology.

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2. I found the system unnecessarily complex and confusing.

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3. I found it easy to complete the tasks given to me and find information about body cavity partitioning.

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4. I felt that the illustrations and text were clear.

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5. I felt that the content was well organized.

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Appendix J: Data Collection Form

(front)

Date:
Moderator:
Participant:

ID:
Gender (circle one): male female prefer not to disclose
Discipline/Field of Study:
Year of Study:

Resource used (circle one): interactive static
Task set used (circle one): task set 1 task set 2

Pre-test score: ________/ 5 points

Time for task 1: ______________ min __________sec
Time for task 2: ______________ min __________sec
Time for task 3: ______________ min __________sec

Post-test score: ________/ 5 points

Flip to the back before the subject moves to the next station so that neither the participant or second moderator can see the scores and times.
Data Collection Form

(back)
Date:
Moderator:
Participant
ID:
Gender (circle one): male female prefer not to disclose
Discipline/Field of Study:
Year of Study:

Resource used (circle one): interactive static
Task set used (circle one): task set 1 task set 2

Time for task 1: ______________ min __________sec
Time for task 2: ______________ min __________sec
Time for task 3: ______________ min __________sec

Survey:
Question 1 score: __________/ 5 points
Question 2 score: __________/ 5 points
Question 3 score: __________/ 5 points
Question 4 score: __________/ 5 points
Question 5 score: __________/ 5 points
Appendix K: Workflow for Interactive Timeline Development

Figure 10. Body cavity partitioning concept map made with CMapTools Online

Figure 11. Color-coded concept map made with Adobe Illustrator to detail connections between structures in the time periods which they occur.
Figure 12. Composition thumbnails for possible event arrangements

Figure 13. Option 1 for potential look and feel of the timeline
Figure 14. Option 2 for potential look and feel of the timeline.

Figure 15. Simple site-map, showing page organization of the website.
Figure 16. Initial wireframe sketch

Figure 17. Finalized wireframe sketch
Figure 18: Wireframe in Adobe Photoshop CC

Figure 19. Initial nine color compositions
Figure 20. Two revised color compositions

Figure 21. Vector wireframe in Adobe Illustrator, with each vector labeled
Figure 22. Initial Prototype of the timeline in storyline

Figure 23. JavaScript code options that did not work
Figure 24. Simple website skeleton without functionality

Figure 25. Initial version of the timeline in Articulate Storyline 360 with PNGs from Adobe Illustrator
Figure 26. Storyline layers created for selectable content

Figure 27. Articulate Storyline buttons with specific triggers
Figure 28. Interactive timeline- introduction walk-through describing body cavity partitioning

Figure 29. Features of the timeline include ability to select pathways and distinguish weeks with highlighted bars
Figure 30. Defects highlighted with the filters defect tab selected

Figure 31. Static Resource- comparison view
Figure 32: Image list with checkpoints

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Introduction plan:

Illustration size: 1000 x 1659
Appendix L: Illustration Sketches
Appendix M: Timeline Button Content

1. **Ectoderm**: One of the three primary germ layers, the ectoderm is located on the dorsal aspect of the embryo, and will become the skin and nervous system. The ectoderm undergoes neurulation, the formation of the brain and spinal cord, which will not be addressed.

2. **Mesoderm**: The mesoderm is the middle germ layer of the embryonic disc, and has distinct subcomponents, three of which will be discussed here: paraxial, intermediate, and lateral plate mesoderm. Mesoderm generally forms muscles, bone, and other connective tissues.
   a. **Paraxial**: most medial portion of mesoderm, which become the somites.
   b. **Intermediate**: The portion between the paraxial and lateral plate mesoderm, which form most of the urogenital system. This will not be addressed in the timeline.
   c. **Lateral plate**: The lateral plates are the most lateral portion of the mesoderm, which split at the periphery to surround the viscera (joining with the endoderm to form the splanchnopleure) and the body wall (joining with the ectoderm to form the somatopleure). The space between these two layers is called the intraembryonic coelom.

3. **Endoderm**: The endoderm is the ventral layer of the embryonic disc, and will form the lining of the gastrointestinal system and respiratory tract.

4. **Gastrulation**: Differentiation of cells into a trilaminar germ disc composed of three primary germ layers: ectoderm, mesoderm, and endoderm. These three layers differentiate into specific body structures:
   a. Ectoderm- skin and nervous system
   b. Mesoderm- muscle, bone, and other connective tissues
   c. Endoderm- lining of respiratory and GI tract

5. **Lateral/Cranio- caudal folding**: At the end of the third week, the embryo is a flat, trilaminar disc. As it expands, it folds ventrally at the cranial, caudal, and lateral margins, which creates the tube within a tube body plan.

6. **Inner Body Wall**: Before embryonic folding (lateral and craniocaudal folding), the lateral plate splits, the outer plate lining the ectoderm, and the inner plate covering the endoderm. During lateral and craniocaudal folding, these folds from either side of the embryonic disc will meet to become the outer and inner body wall respectively.

7. **Outer Body Wall**: Before embryonic folding (lateral and craniocaudal folding), the lateral plate splits, the outer plate (somatic mesoderm) lining the ectoderm, and the inner plate (splanchnic mesoderm) covering the endoderm. During lateral and craniocaudal
folding, these folds from either side of the embryonic disc will meet to become the outer and inner body wall respectively.

8. **Epidermis**: The ectoderm will contribute the outer covering of the embryonic body walls, which becomes the epidermis of the skin.

9. **Dermis**: The portion of the paraxial mesoderm just deep to the ectodermal covering, which will form the dermis of the skin.

10. **Cardiogenic region**: A mesodermal proliferation of cells that form cranial to the developing mouth in a horseshoe-shaped arrangement, which will eventually become the heart tube.

11. **Endocardial tube fusion**: Lateral folding causes the endocardial tubes to fuse in the midline, creating one primitive heart tube.

12. **Heart looping**: The heart tube undergoes a series of looping to position the developing atria and ventricles appropriately within the primitive pericardial cavity.

13. **Somite formation**: The paraxial mesoderm forms somites adjacent to the neural tube. These eventually differentiate into sclerotome (axial skeleton), dermatome (dermis), and myotome (muscle). The nerves associated with somites C3-C5 innervate and migrate with the future central tendon of the diaphragm, which originally forms above the head, but translocates below the heart during embryonic folding.

14. **Septum Transversum**: Forms during week three as a thickened mesodermal bar, cranial to the cardiogenic region, which is translocated below the heart into the future thoracic cavity during craniocaudal folding. The septum transversum becomes the central tendon of the diaphragm and is innervated by nerves that develop in conjunction with somites C3-C5.

15. **Pleuropericardial fold fusion**: Pleuropericardial folds grow coronally and medially from the body wall. An extension of the body wall, these folds prevent the growing lungs from encroaching on the developing heart, and eventually form the pericardial sac, to separate the cardiovascular and respiratory systems in the chest cavity. These folds carry the phrenic nerves medially.

16. **Pleuroperitoneal membrane**: These membranes completely separate the pleural and peritoneal cavities by closing off the pericardioperitoneal canals, as they grow transversely from the posterior body wall.

17. **Dorsal Mesentery**: The dorsal mesentery forms the most dorsal portion of the diaphragm and becomes the crura, which anchor the diaphragm posteriorly to the bodies of the lumbar vertebrae.

18. **Pericardial cavity**: A bi-layered serous cavity which surrounds the heart. It is composed of an outer fibrous membrane, and a two-layered inner serous membrane, which secretes fluid to prevent friction during heart movement.
19. **Pleural cavities**: Two separate serous cavities lateral to the pericardial cavity, which house the right and left lungs.

20. **Peritoneal cavity**: The serous cavity inferior to the diaphragm, which houses the gastrointestinal system.

21. **Intraembryonic coelom**: As the lateral plate mesoderm splits and the embryo undergoes folding, an intraembryonic body cavity (coelom) is created. This space is continuous with the outside amniotic environment at the yolk sac. The cranial end of the space is the primitive pericardial cavity, whereas the spaces lateral to the gut tube are the pericardioperitoneal canals.

22. **Primitive pericardial cavity**: Cranial end of the intraembryonic coelom in which the heart will undergo development.

23. **Pericardioperitoneal canals**: The portion of intraembryonic coelom lateral to the gut tube and posterior to the septum transversum, into which the bronchial buds will grow. The developing pleural and peritoneal cavities communicate through these canals.

24. **Myoblasts**: Myoblasts from the mesoderm of the outer body wall proliferate along the outer edge of the diaphragm, anchoring the diaphragm to the body wall.

25. **Muscle rim**: A rim of muscle that surrounds the inferior aperture of the rib cage.

26. **Muscle**: Muscular portion of the diaphragm.

27. **Central tendon**: Tendinous, middle portion of the diaphragm, through which the inferior vena cava passes. The central tendon is formed from the septum transversum.

28. **Crura**: Two connective tissue extensions, formed from dorsal mesentery, which anchor the posterior diaphragm to the bodies of lumbar vertebrae. The right crus extends from L1-L3, while the left crus extends from L1-L2.

29. **Diaphragm**: Muscle separating the thoracic and abdominal cavities, which closes the inferior thoracic aperture and creates an atmospheric pressure difference between the cavities, essential for breathing.

30. **Foregut**: Cranial region of the gut tube which forms the pharynx, esophagus, stomach, and superior half of the duodenum. Additionally, the lungs, liver, and pancreas are formed by budding off of the foregut.

31. **Midgut**: Mid-region of the gut tube which forms the portion of the GI tract from the distal half of the duodenum, including most of the small intestine, to the proximal 2/3rds of the transverse colon. This portion undergoes gut herniation to form an intestinal loop.

32. **Hindgut**: The most distal portion of the gut tube, which will form the last 1/3rd of the transverse colon to the rectum.

33. **Gut herniation**: The rapidly developing midgut will herniate into the yolk sac, where the midgut will rotate around the superior mesenteric artery. Closure of the diaphragm
likely facilitates this normal herniation by preventing the midgut from moving superiorly.

34. **Intestinal looping:** As the gastrointestinal tract herniates out of the abdominal cavity, it will undergo a series of rotations, which forms the intestinal loops of the small intestine.

35. **Respiratory Diverticulum:** Forms as a ventral evagination off the thoracic foregut, which will eventually bifurcate to become the lungs and bronchial tree.

36. **Primary bronchial buds** The respiratory diverticulum branches into two primary bronchial buds, which will become the right and left primary bronchi.

37. **Secondary bronchial buds** The right primary bronchus branches into three secondary bronchial buds, while the left primary bronchus branches into two secondary bronchial buds. The secondary bronchial buds become the secondary bronchi leading towards each lung lobes.

38. **Tertiary bronchial buds** The secondary bronchial buds each branch into tertiary bronchial buds, which will ultimately form the tertiary bronchi that supply each bronchopulmonary segment.

39. **Pericardial cavity forms** The pericardial cavity is formed when the pleuropericardial folds, carrying the phrenic nerves with them, meet in the midline and create the pericardial sac.

40. **Pleural and peritoneal cavities separate:** The diaphragm completely separates the pleural and peritoneal cavities, with the transverse growth of the pleuroperitoneal folds and the fusion of the folds with the septum transversum and dorsal mesentery. Fusion of these structures closes off the pericardioperitoneal canals connecting the pleural and peritoneal cavities.

41. **Diaphragm closes:** Pleuroperitoneal folds fuse with the septum transversum and dorsal mesentery to close off the diaphragm completely before midgut herniation begins, preventing intestinal herniation into the thoracic cavity.

42. **Defect: Gastroschisis:** A birth defect in which the gastrointestinal tract develops outside of the abdominal cavity because of incomplete fusion of the anterior body walls. This defect can be distinguished from omphalocele by the lack of amnion covering the intestinal herniation.

43. **Defect: Ectopia cordis:** A ventral wall defect in the region of the thoracic cavity, which results in heart formation external to the chest because the anterior body walls fail to fuse.

44. **Defect: Diaphragmatic hernia:** A birth defect formed by intestinal migration into the pleural cavities, due to improper closure of the pericardioperitoneal canals by the pleuroperitoneal folds. This obstructs lung growth, resulting in pulmonary hypoplasia.
45. **Defect: Tracheoesophageal fistula / esophageal atresia:** Improper separation of the trachea and esophagus by the tracheoesophageal septum, which usually results in a combination of tracheoesophageal fistulas/ esophageal atresias.
   a. **Tracheoesophageal fistula:** abnormal connection between the trachea and esophagus
   b. **Esophageal atresia:** a blind-ended gut tube

**Defect: Omphalocele:** A birth defect in which the midgut does not return to the abdominal cavity after herniation into the umbilicus. This defect can be distinguished from gastroschisis, as the intestines will be covered by a thin layer of amnion.
Appendix N: Quantitative Data

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Figure 33. Task times and pre-test/post-test scores
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Figure 34. Survey question scores
Appendix O: Audio Transcriptions

Participant 7ECNR- Group A

PI: Ok, this is resource 1 task 1.

Speaker 1: So essentially the first task was to use a resource to find the name of the embryonic defect that result in abnormal partitioning of the plural and peritoneal cavities. So in order to do that, I entered the, the website by going straight to enter, bypassing the introduction, going to filters, understanding from filters, I could go to defects and then exploring the, um, the last stages of the defects. So I went through a few of the defects because I had prior knowledge of gastoschisis, which I'm probably pronouncing incorrectly. Um, read the description of that one, looked at the illustration, um, and then, because I knew I had to find something about the peritoneal and pleural cavities, I went back farther into the diagrams and searched for something that read similar to that, so pleural and peritoneal. So I was able to scan for the pleuroperitoneal membrane. And once I found the plural peritoneal membrane, I was able to follow it directly to the diaphragmatic, which I said that wrong. Hernia. Um, and from there, reading the description to inform my decision that that is the partitioning, um, abnormal partitioning peritoneal cavities.

PI: resource 1 task 2.

Speaker 2: All right, so for this one, I needed to use the resource to find the name of the structure that forms the most lateral part of the diaphragm, anchoring it to the lateral body wall. So I entered the application, I clicked directly out of the introductions, I went into the filters and from there I went straight to structures. From structures, I know I'm looking for diaphragm, so I went directly to the diaphragm. And then looking back on the other options on the body wall mesoderm was the next step because I know I want to talk about the body wall. Um, from there I used the illustration in order to inform "Am I in the right place?" because the lateral part of the body wall, because I know it's a lateral part because my prior education, um, I was able to say, OK, it's purple. Read the description "lateral body wall" is right there. Scan it. That's what you want. Body will mesoderm done.

PI: resource 1, task 3.

Speaker 2: OK, so for this one, it was use the resource to find the name of the embryonic structure that separates the cardiovascular system and the respiratory system of the chest cavity. This one I had a hard time with. So I went into the application, I clicked out of the introduction when straight to filters. From filters, I went into structures because I wanted a structure, um, this highlighted all the structures
for me. And then the next thing I needed to scan for was something related to the cardiovascular system and the respiratory system in the chest cavity. So I know these are the pericardial cavities. Um, so that was the first thing I saw when it really clicked and through there. Um, and then I followed the highlighted arrows as I clicked on different structures that had names like pleural cavity, pericardial cavity, and then their major linkers, the primitive pericardial cavity.

And um, the pericardioperitoneal canals and all those guys. And I even went into the interembryonic coelom probably said that wrong. And then I went and I read the descriptions for the majority of those hunting and scanning for something that says separating the cardio from the respiratory. So there's a lot of that. Anyway. Um, I ended up hitting on the primitive pericardial cavity as the answer because I couldn't find anything that matches the wording of separated the cardiovascular system. Um, I picked it because I know that it ultimately leads to the pericardial cavity, which I know you've got to have one cavity to separate from the other cavity. It wasn't really sound logic. I'm, I did, however, when I went and clicked on their primitive pericardial cavity, noticed that from the mesoderm, there was a linker that went all the way up through the dermis.

So I looked at those. I don't know what the somatoplure is. Um, and I didn't really scan this guy do too much, read the description, didn't get anything that said what I wanted. And I'm kind of left it as that. I looked at the pleural pericardial fold fusion, which ultimately I found out was the answer. But that took me almost six minutes to find. And I was fairly frustrated at this point, um, because again, I was just scanning for a lot of this information. Anyway. Got to the pleuropericardial fold, was convinced that wasn't the answer because I didn't scan when I should have and read the description and then I saw the description and then that was the answer. And then I was slightly frustrated that I didn't read the description. Could've helped just by having like a highlighted structure within the illustration because then I would have just looked because when I was in the pericardial cavity, the, it makes a structure that clearly separates them. Had the pleuraopercardial fusion had that, maybe that would've helped.

**PI:** resource 2, task 1

**Speaker 2:** "Use the resource to find the name of the embryotic defect that would resolve from abnormal separation of the respiratory and gastrointestinal systems." I struggled with this one. I, um, entered the application, bypassed the introduction and that essentially my first thing is to look for were, um, something that talked about respiratory and the gastrointestinal system and then separation. So I went to the, um, essentially everything that spoke to me as an embryonic defect, clicked on all of those options, read their descriptions, didn't really get anything that hit a hot spot for me to say, "Oh, this is the answer." Then I went into the pleural and peritoneal cavity separation part that separated by the week six. Um,
went through all of those buttons, clicked scans, scanned for days, looking for something that matched the, um, the description that I'm looking for. And then ended up having to read a bunch of them. Ultimately, I never found the answer and was left guessing. Um, mostly because I was searching for specific wording and not wording that could mean what was being asked.

**PI:** resource 2 task 2

**Speaker 2:** "Use the resource to find the name of the embryonic structure that gives rise to the central tendon at the diaphragm. So essentially I went into the application, bypass the introduction, went straight to looking at the diaphragm closes part portion. So from the diaphragm closures portion I went and looked up to see all these different doodads. The crura shout out at me because I remember clicking on that prior and read the description, but essentially what I ended up doing was clicking on the central tendon, reading the description and understanding that it's, um, tendinous middle portion that is formed from the septum transversum, which led me to my answer.

**PI:** resource 2 task 3

**Speaker 2:** Use a resource to find the name of the embryonic structure that forms most dorsal part of the diaphragm, anchoring into the post to your body wall. So I entered the application bypassed the introduction, went straight to um, the diaphragm area that I had been playing in earlier. Um, I saw the crura earlier went to that. I read that it anchors posterior to the diaphragm, assumed that the crura was the answer. Assume that incorrectly at 22 seconds wrote the answer down, went back in to answer it, only to realize formed from the dorsal mesentery was the embryonic structure that we were actually looking for. And that's how I answered the question.

**Participant 6PUN8- Group C**

**PI:** resource 1 task 1

**Speaker 1:** so when you let me like, explore for two minutes, I saw the filters tab and then when I click filters there are defects and it highlighted in green all the defects that are possible. And so I just started clicking through them and like reading what it did and then I clicked the tracheoesophageal Fistula, which said the improper separation of trachea and esophagus. And I was like, OK. I really wish I had this!

**PI:** Hahaha great! So in terms of like finding the answer, it was you saw the filters and then it was a systematic way that you just worked through each one?

**Speaker 1:** Yeah.
PI: Okay, gotcha.

PI: resource 1 task 2

Speaker 1: It said that gives rise to the central tendon and like the first section in week three, like it's boxed off and it's like, it's like where everything gave rise to it. So I just wanted to go through that first to see if that gave rise to anything. That was a central tendon.

PI: So you saw the beginning part first..?

Speaker 1: Because when you click the week it highlights everything.

PI: resource 1, task 3.

Speaker 1: OK, this one I might have been lucky, cuz I just clicked that one, but it's like the same process as the second task where, things are giving rise to each other. And I just followed the thing.

PI: resource 2 task 1

Speaker 1: This one was harder because there was no filter, but um, uh, did the key words like the peritoneal cavities, pleuroperitoneal membrane and then um, it was like it separates the Pleural and peritoneal cavities, so like, and you had to be something with that. And then there is no like disease or bad sounding name here. So I went to the next one and so this was lit and then I thought that that made sense.

PI: in terms of like finding diaphragmatic hernia it was more proximity or...?

Speaker 1: Yeah, it was just like, the setup of this one is in order sequential order. So this was messed up. Then it had to be something after it. So then that was like the first thing that I saw.

PI: resource 2 task 2.

Speaker 1: I was kind of all over the place and clicked the mesoderm and all of a sudden like three different things popped up.

PI: Oh, that's a bug.

Speaker 1: about this lot and I was like, uh, OK. And I thought it was a lateral plate afterwards, but it wasn't. And then after that I got kind of lost, but then you told me that it was the diaphragm. So I had to go later into the week, but I knew the process had to be before diaphragm closes as it was developing. So then the first thing I clicked was body wall mesoderm.

PI: resource 2 task 3.
Speaker 1: This one I had less of an idea like where to start the task, like I was just clicking around and I was like clicking through all the respiratory ones and then the anything that had cardio on it, but I guess I missed this one pleural pericardial fusion. But I feel like that would’ve just made sense if I actually read the story. A lot of people have been saying that, um, the wording like. Yeah. Yeah. Because it asks for the structure are OK. OK, excellent.

Participant 4VDW4- Group A

PI: resource 1 task 1.

Speaker 1: OK. Um, to start off, I noticed that I needed to look for the pleural and peritoneal cavities. And so when I looked onto the interactive computer again, um, I noticed that it said pleuropericardial fold fusion and pleuroperitoneal membrane. And so I was clicking on those to try and figure out, um, what defect would arise from that was what the question asked. I was really confused because all I could see it was really, um, which it only showed what it was going to and like you could highlight what was happening in each week. It took me awhile to understand. I initially went introduction and then about, and none of those help me. So I was ignoring the filters tab. Um, but then when I clicked on filters and it showed defects, I was able to kind of figure it out. It took me a second to figure out, like clicking on just up peritoneal membrane would take me out of the filter versus clicking on the actual defect that the aide would say.

PI: So how did you narrow it down to diaphragmatic hernia once you found the filters?

Speaker 1: Um, oh. Because it branched off of the pleuroperitoneal membrane, which I read about before would separate the cavities.

PI: resource 1, task 2.

Speaker 1: OK. Um, so I’d already explored it and I knew, uh, that clicking on each of the, words would tell me like what it’s function was. And so I just started clicking. I saw diaphragm and I knew each of those parts listed that were part of the diaphragm. And so I started to work my way backwards from those when I didn’t find the answer I was looking for. I was mainly focusing on anchoring the diaphragm to the lateral body wall. The question. Um, and so after I found all those parts and just started going backwards and I saw a body mesoderm was said specifically, it anchors the diaphragm to the lateral body wall. I was a little confused because I didn’t know if it was asking me the body wall mesoderm or what its derivative was, which would be the muscle rim. But anyway body wall mesoderm would still be correct.

PI: So did you start from muscle rim or did you start from crura and work up or work down?

Speaker 1: I started at crura, I didn’t think to look at the central tendon or the muscular portion because, um, when I was, when I was clicking on those, those descriptions just didn’t make sense. But I saw that the crura was like the posterior body wall. And so that one, it didn’t seem correct, but I went back to the dorsal mesentery and that confirmed that it
wasn't going to be the right one. And then I went up to the muscle rim just because muscle rim kind of sounds like it'd be the correct answer.

PI: resource 1 task 3.

New Speaker: The question asked me to identify the cardiovascular system, what separates the cardiovascular system from the respiratory system, uh, because I had done the question earlier and had explored it and I knew what the pleuropertitoneal membrane did and I had already looked at what the pleuropericardial folds were, when I was just like getting introduced to it, I knew kind of what those would function as. So I started there. Um, I initially clicked on the peritoneal membrane and that highlighted that routes to the muscular portion of the diaphragm, which I kind of knew that wasn't right, but I clicked on it anyway. And then, it also went back to somatopleure. Since pleuropericardial folds and the pleuropertitoneal membrane both branched off of those, I decided to click on somatopleure first. And then I decided once the somatopleure was incorrect to click on the pleuropericardial fold fusion. And that's specifically set. It separates the cardiovascular and respiratory system.

PI: resource 2 task 1.

Speaker 1: I just happened to look over at the screen and saw tracheoesophageal fistula, and I knew that fistula meant opening and so I clicked on that one and that was the one I saw. I read it through, it made sense, but at the same time it didn't say any key words like the questionnaire. So I did look around to find out to see if I found any more. So I looked at gastroschisis and ectopia cordis, but none of that even made sense. Um, and so I went back to that one because it made the most sense because I know the trachea as part of the respiratory system and the, uh, esophagus is part of the gastrointestinal system.

PI: resource 2 task 2.

Speaker 1: I initially clicked on central tendon, but I really skimmed it and I didn't see that it said the answer. So, I was looking around to see if I saw anything that said what central tendon arise from or anything like that, which was really hard because there's no connections to it. Um, but then I clicked on it again to see if something else from the description cued me into another thing to click on. And then I read it all the way, saw that it's at the answer.

PI: resource 2 task 3.

Speaker 1: OK. Um, so I remember from the last interactive session that uh, the crura anchored the diaphragm to posterior body wall. And so I read that, but it didn't say any of those key words. And so I was thinking that maybe it was crura, but then I also wanted to look back at the dorsal mesentery, which it mentioned that it arose from. And when I clicked on dorsal mesentery, it says it anchors it to the posterior body wall, this one is correct because I'm looking for the embryonic structure.
Speaker 1: I started with keywords which was abnormal separation of respiratory and
gastrointestinal systems. So from first looking at it, I remembered that there was the
pericardial forming, um, and that later on was the just subsystem. So I started with
those key words of like respiratory and pericardial stuff just cause that's what I
remembered from first looking at it and I would click what I remembered, um, of the
keywords, read what it was recognized, whether it was what I was looking for or not.
Um, a lot of the stuff I first looked at, it wasn't quite what I was looking for. Um, slash
was a little overwhelming I guess because there were a lot of options. I'm at a certain
point I was just clicking until I found the key words I was looking for, but I knew I kept
coming back to a certain point that, that was related to what I was looking for.

Speaker 1: So this one took me a lot faster and mostly because I clicked on all a bunch on the first
task. I remembered clicking on it and remembered where it was and I remembered it
from the pre-test, but I had to click on it and look through it to make sure that whatever
remembered wasn't just association was actually that it was the right thing. Perfect. OK.

Speaker 1: So this one was also quicker, like task 2, because I had clicked through a bunch. The first
task, i Knew about where to look. I didn't really remember what it was called. Also, the
fact that it said Dorsal, it was kind of clued me just to check it out and see if it was right
or not.

Speaker 1: Initially it was easier with the lines and organization, so I knew what system was related
to what embryonically. That was really helpful. Um, I knew I was looking for a defect, so
at first I was looking in that the like plural and peritoneal subjects, but then nothing I
was looking for was a defect. It was anatomical structures. So at a certain point I was
wondering if it was even there and then I, then I looked up and I realized that in the last
one there's only introduction, about, and this one had filters and then it had um,
diseases or whatever it was. And then the fact that it was different color was really nice
and they changed. They weren't there before, which it is nice because it would be
overwhelming. But it was kind of confusing.

Speaker 1: Currently off the, the lines, the colored lines, because this was up on the top, was the
pleural section and then down here was when it got to, um, it was a pleural cavity of, at.
I followed the lines. I can't really rationalize how, but that got me there and the fact that
they were colored in terms of the defects and I knew that that was what I was looking
for. That was most related to compared to the other ones. I've done some other ones
and then once I read about it seemed like the right one.

PI: resource 2 task 2.

Speaker 1: OK. So for this one I knew I was looking for a structure so I wanted to see what kind of filters they had and structures was an option. So I clicked structures and then the colors changed which was nice and then certain things were eliminated and I started looking for um, mesoderm. Cause I knew that that had to do the diaphragm, but like the majority of this is the mesoderm. So at that point I was kind of just clicking for things that seemed relevant and I started on the right half with the very specific ones because I was thinking it would be a more specific answer. And then it turned out it was kind of a more general answer that had that listed specifically lateral body wall.

PI: So you worked from a specific structure and followed back to a more general?

Speaker 1: Yeah. So I. Yes and no. I visually started in Mesoderm, but I knew it would be more specific. So then I went all the way more specific because I thought the answer would be probably the most specific and then none of them had the information relevant to the question and then I went back.

PI: resource 2 task 3

Speaker 1: for this one. I picked up in the keywords cardiovascular and respiratory system and I knew those were middle tabish. Um, so I started with clicking on intraembryonic coelom and primitive pericardial cavity, cuz those were close. But they didn't have the information I wanted. Um, so I went, I didn't click on them, but I was looking forward at pericardial cavity, pleural cavity, peritoneal cavity. And those were never separations. Those, the things themselves. Um, so I went back to mesoderm and up and that got me to pleuropericardial fold fusion.

Participant 50ZE2- Group C

PI: resource 1, task 1.

Speaker 1: OK. OK, so the way I start to find the answers that I already know that question is asking for a defect and I’d already explored the website. There is under a filter category. I can find, I can click on the defects so that were highlighted, those defects. So I can just check out the defect because there are a lot information on the website, but when they filter out, there’s not a lot of things. those defects are highlighted in green. So I click on those defects and I read the description. Then I find out the answer.

PI: So what led you to diaphragmatic hernia first?

Speaker 1: Because, uh, the diaphragm is like this separation of the abdominal cavity and the pleural cavities. So it's kind of, I was thinking that is the separation between the two
systems, but it's not actually what the question is exactly asking.

**PI:** resource 1. Task 2.

**Speaker 1:** OK, OK. For this question, the keywords I'm trying to find are the diaphragm and the central tendon. So I first I, I find the diaphragm, but it's pretty obvious on the right. And also being more familiar with the word diaphragm. I find that if I click on this and I read the description, but I try to find the central tendon. I was reading the description. I was not finding that central tendon is actually just under the diaphragm in the map. So I found that. Then I traced it back following the red line. So I found this thing that give rise to the Septum transversum.

**PI:** resource 1, task 3,

**Speaker 1:** OK, for this question, I also start with the diaphragm. And uh, when I click on the diaphragm, there are red lines so I can find the structure that are only to diaphram. Then I found the dorsal mesentery which is close to what they ask the dorsal part of the diaphragm. So I click on that. It's says exactly. Look at descriptions, exactly what the question asks.

**PI:** resource 2 task 1,

**Speaker 1:** Okay, so I just find the pleural cavity, the peritoneal cavity on the, on the map. Then I noticed that in the middle there is a diaphragmatic hernia. So I read that description and believe that is the answer.

**PI:** resource 2 task 2 OK,

**Speaker 1:** I click on the diaphragm trying to look for clues, but then I didn't find a lot of things, but they're not thinking that is answer. They're asking for the lateral part and I believe the ectoderm, is was more to the outside so I looked a bit up to the upper portion of the maps and I found this body wall mesoderm because related to the lateral body wall. So I read the description that I found out.

**PI:** So in the process of looking up towards ectoderm, you found body wall mesoderm?

**Speaker 1:** Yeah.

**PI:** resource 2 task 3.

**Speaker 1:** OK, first I read the question. Now I locate the pericardial cavity on the map. So I looking for something that around it might be the answer. So I click on something, but the first I think it asks for a structure? So I look at the. The, the pericardial fold fusion. I thought it was a process, not the structure that I did not really read that closely. I skipped on that one. I look at the pleuroperitoneal membrane and there's a structure I'm thinking might be the closest to the answer, so I put that down at first, but then I rethink about and look at the future again and the description that the. It's the answer.
PI: resource 1 task 1.
Speaker 1: Um, well I kind of, when I was going through in the beginning, kind of found the disorders and defects are at listed on the bottom. So then, um, I think I first clicked tracheo- I think that was the first one I clicked actually. Yeah. Um, but like, yeah, I think I went through that one, got herniation and then it just, it was just listed there.

PI: resource, 1 task 2
Speaker 1: I think one of the pre-test questions involve the Septum transversum. So, um, when I was just going through it in the beginning, I'm like, I found that it was the central tendon and I was just skimming through it. So, um, yeah, that's why I knew the answer to that one.

PI: resource 1, task 3.
Speaker 1: So I first went through the things on the right side, diaphragm muscle or muscular portion and um, I wasn't sure if the answers and then I went back and then, um, I clicked on Dorsal mesentery and then it was there that the Dorsal mesentery forums and most dorsal portion.

PI: So in terms of finding dorsal mesentery, after looking through everything on the right side, was there anything that drew your eye?
Speaker 1: Um, I mean, I think I, I clicked on Septum transversum actually first after reading about this cause the septum transversum is related to diaphragm and then so was the Dorsal mesentery, like it was mentioned in the other headings. So then that's why I went back to that. Um, but yeah, I think that's one. I had a little bit of a harder time. So I think, yeah, I went through everything on the right side.

PI: resource 2 task 1.
Speaker 1: Um, so this one is a little bit harder, but um, yeah, I went through all of these pleural cavities, peritoneal cavities, tried to trace it back to see if I missed anything. And then I finally, after going through all of that, I clicked on filters and then saw that there was the option for choosing defects. And then I went to diaphragmatic hernia, I, once I saw that these came up.

PI: So after, after you clicked on defects, uh, how did you find diaphragmatic hernia?
Speaker 1: Because it was located right between the pleural and peritoneal cavities.
PI: So what do you think would help the filters button stand out a little bit more?

Speaker 1: Um, I guess I just wasn't really paying attention there. Maybe if there was like a little thing on once you clicked on these descriptions that said, oh, to see if there's further information or anything like that. Um, check out the filters tab.

PI: resource 2 task 2.

Speaker 1: So I clicked on, I'm like diaphragm first, and then I went through the muscle rim, muscular portion, central tendon, crura. And then I, once I didn't find anything there, then I traced, um, because it highlights all of the, like things leading up to it. So I went through those. So then I went to the Dorsal mesentery and then that was for like the posterior and then I went to the body wall, mesoderm. And that was the lateral part.

PI: resource 2 task 3.

Speaker 1: So, um, I kind of went through like the pericardial region, so like once I clicked, like first, first I went to the cardiogenic region, couldn't really find anything there and then I went through like the primitive pericardial cavity. And then, um, so I went through like the highlighted portion, so pericardial cavity didn't give me information about that. So then I went back to somatopleure and then to, um, to pleuropericardial fold fusion.

Participant CE2QM- Group B

PI: Resource 1, task 1.

Speaker 1: So I read the question and then I there were some key words in here and pleural and peritoneal cavities and so I saw a couple of words that said pleural cavity and peritoneal cavity and then I, there's a button in the middle and so then I clicked on that and then I read the description and that seem to describe what I thought was what the question was asking for. And then just to be sure I clicked on a couple other things that I thought were close, but then I went back to the first one that I looked at.

PI: resource 1 task 2.

Speaker 1: So basically I did the same thing that I did in question one. I looked at, um, keywords and then I realized that that wasn't what I needed. I didn't need to look for the word lateral since it wasn't as important. And so then I tried to look at words that would be describing a, I don't know, structures that turned into other structures. And so then I found I was like, OK, well pleural cavity and diaphragmatic- and then I looked at the diaphragmatic hernia button and then I looked at the buttons surrounding it and then I found what I wanted.
So in terms of finding body wall mesoderm of both sort of drew you to that, besides - Or was it just proximity?

Proximity. Because it, the keywords didn't help me and then I was like, well I need to learn about the diaphragm. And then body wall mesoderm was near that button.

So I knew that it had to be somewhere near the beginning because there's like a linear progression of the thing, so then I went to the beginning and then I knew it was probably in the middle of things and then it was pretty easy to find.

That's interesting, actually a lot of people start from diaphragm section and they find central tendon first and they work their way back to septum transversum. So that's sort of interesting, that's a response I haven't heard before.

Yeah, I mean I guess I would make more sense.

Septum transversum is also like a bigger button, so maybe it's easier to see?

Yes, I think that it could be it, since it's all surrounded by words and that's alone.

So I looked at the key words again and I was just looking for the two words. I'm the respiratory system, cardiovascular system and the names of those cavities. And so then I clicked on, um, pericardial cavity and read the description and it wasn't exactly what I wanted. And then I clicked on, I think two other buttons and one of them was the right answer. But I found it pretty quickly. So it was, um, a lot to do with proximity in keywords.

So this one, I got it wrong the first time and actually I was looking, since this question was similar to one of the other questions, I thought it was a separation between the heart and the respiratory system again, and then it's always clicking on things that weren't going leading me to what I wanted and I re-read the question and then, um, I misunderstood again and I thought it was cavity separation and then I finally got to the right. Correct answer.

So, OK, so what led you to diaphragmatic hernia in the first place? Or, oh, it was just the fact that it was similar to a previous question.

Yeah, it was similar to a previous question and um, that's pretty much it.

So then finding the correct answer what led your eye?
Speaker 1: So, yeah, so when I was, I’m checking out the site, I realized, uh, I was trying to find patterns between the, the coloration of the lines, and then I realized that I could filter out abnormalities. And so then that was really useful. So it was basically between of grouping of keywords and also colors, and then a filter. The filter was really useful knowing that I could just look at just abnormalities.

PI: resourced 2 task 3.

Speaker 1: Um, basically I tried to work my way back from the diaphragm button and then I saw the body wall button. So basically it was keywords again. And then, uh, I tried to keyword for mesne-. What did, I don’t know. Somehow I found it and then I read the description and that was what I wanted to do.

PI: Do you think the key word dorsal led you?

Speaker 1: Oh yeah, yeah, definitely.

MAC67- Resource B

PI: resource 1 task 1.

Participant: So I knew when I was looking at the module before I was given the question that I had seen a couple defect pieces. So the first thing I did was look at the defect pieces and I thought based on the layout that the defect pieces were all on the far right. So then I ended up looking on the far right and I picked ectopic, cordis because it seemed like a plural defect. Um, and I kind of missed the peritoneal part. So then, um, I was trying to decide between ectopia cordis and and gastroschisis because I thought they were in the right region so then I picked ectopia cordis because I thought it was closer. So then after that I realized that the Patterning, the spatial arrangement of the words wasn’t what I thought it was as far as like a system.

Participant: Like I thought they would be on the far right because I thought all the defects would be at the end of development. So then once I, um, got the, we got it wrong the first time I went back and started looking earlier in the timeline for different defects and then I finally noticed the bottom parts and I was like, oh, plural and peritoneal or at the bottom. So then once I figured out that it was the pleural and peritoneal category I had to be in, then I just had to click on the different words and see which ones were defects. And then the diaphragmatic hernia was the defect and I figured it out.

PI: resource 1 task 2

Participant: OK. So for this task, I spent more time thinking about the question before I used the tool and I drew a drawing before I started to try and figure out what was lateral as in what is lateral mean and what does the opposite of lateral, which I think is medial, but I’m not sure. And um, so I made myself a drawing of medial
and lateral and where I thought lateral will be on the diaphragm. And then I remembered to look at the bottom part first and I saw that there was a diaphragm section. So then in the diaphragm section I clicked through the diaphragm drawings until I saw the one that I thought was most lateral, but I also had to draw the diaphragm drawing too because I didn't really, I found it confusing. Um, so then once I drew the diaphragm drawing and I clicked through all the options, a couple times I decided on muscle rim.

PI: Gotcha, okay so in terms of orientation, is it difficult to orient between anterior and posterior for a diagram like this?

Participant: Um, well at first I wasn't sure because when I think about anatomy I think about an adult who's standing in anatomical position, but then embryology, I think of an infant curled up in the fetal position so that I'm not quite sure anymore because that's what I drew here. I was like, wait, so then would this be medial and lateral if it was an infant? And then it was like, no, that's not right. Um, so there was that. I had trouble figuring out because I don't know, I guess because I'm embryology feels different. And then from this view it said it used the word, um, it said aperture, the inferior aperture of the rib cage. And I, I knew this was, this was looking from the top. I didn't quite under, like this one was looking up from the patient's feet. I didn't really understand quite which one this one was?

PI: It's cuz it's flipped, and you're looking from the top and I can definitely see how that could be confusing.

Participant: And I was questioning what aperture was, so I guess I just hadn't heard it before. I was like, what the heck is the inferior aperture?

PI: Yeah, inferior aperture of the rib cage is just like the bottom opening, so the cervical portion would be the superior aperture.

New Speaker: Okay, cause when I have all three colors on like I know the muscles and it fit well. And then when this one was isolated I was a little bit unsure. Yeah. I just wasn't sure.

PI: resource 1, task 3.

Participant: I read the question and I drew a drawing that I remembered what cardiovascular and pleural sections were in a dark in the lines to remember. I needed a boundary. I even tried to draw it from the side too, and then I looked at the guides and I saw week five was pericardial and then I picked the first one and I was lucky and the first one said in that it separated cardiovascular and respiratory.
PI: So I'm moving through this one, systematically, you saw pericardial cavity and worked your way down?

Participant: Yeah, so if it hadn't been at the top, it would have given me a minute, but it was at the top. So I found it first.

PI: resource 2 task 1.

Participant: Yeah. Um, I skimmed it and I thought it sounded like the other question. So then I didn't draw anything. I just want to the tool and I saw the filters at the top. I was clicking around and I wasn't and I was like, but there's not any defects on here. So then I asked if I could use the filters and I was told that I could, so I use the filters and there was a filter for defects and I was like, oh, OK, great. So then I went back down to the week division and I picked week six for the pleural and the pericardial cavity separation. Um, because it said an abnormal separation. So I thought separation. So then the only one in that was a diaphragmatic hernia and I thought it seemed right because it was the intestines being in the pleural cavity.

Um, so I picked that and then I was told it was wrong. Um, no, it was explained. It was explained that it was about that the organ systems. Um, oh, another thing I did was I, um, before, when I was doing it as I like, IS read respiratory as plural and gastrointestinal is peritoneal, which is, I think the opposite of what it was before. Um, so then I was like thinking in embryo mode, but um, so then she said it was close, but it was about organs and not systems. So then I think I went back and figured out that I started clicking on other things that weren't defects, but then I realized if I hovered it, the color would tell me if it was a defect or not. And um, I think I must have just moved a little bit earlier in the timeline. I that's how I found it.

PI: resource 2 task two.

Participant: I drew what I was looking for, so I drew the central tendon of the diaphragm and at first I drew it the way I would draw it and then I tried to draw it the way it looked last time and from memory and then I went to the filters and try to see if there wasn't a filter for what I was looking for and there was one for structure so I sort of clicked around the filters because I wasn't totally sure. And then I settled on structures and clicked on central tendon and the pink line went to the Septum transversum. So I picked that one.

PI: resource 2 task 3,
Participant: I drew pictures of where ventral and dorsal were, just in general on a fish and then I did because that's how I remember it is because of the dorsal fins and then I did a ventral and dorsal aspect, the person with the diaphragm and I drew the crus because I was pretty sure that was it and then I went to the application and I went to the filters again and I went to structures and then I clicked on the crura and it had dorsal mesentery and mid gut and then I clicked the other ones just to double check and for a second. I wasn't sure if it was muscle rim, but I ended up deciding it was crura and I picked Dorsal mesentery because I think it seemed more specific to the crura than the mid gut does. So I thought more specific was better.

Participant UO4MA - Group A

PI: resource 1 task 1.

Speaker 1: Um, so because I'm extremely tired, I basically started clicking around, I started in the big topics first and then I thought I would work my way down to try to like filter towards the answer, but then I remembered that you already had filters preset in and that there was a specific filter for defects. So then once I found that it was simpler just to like conquer and divide between the ones that were highlighted as defects. And then I was not trying, ideally not even to read the full text. Um, I was just scanning for keywords that would give me the answer. Like actually I probably could've gotten to the answer faster if I had looked at the picture instead of reading. Um, but for some reason the pictures weren't really grabbing my attention, so I went straight to the words.

Speaker 1: I don't know if that's because they're not like fully rendered or or, or they're black and white? Um, but like I'm a little slow tonight. So like I even had, I even had to read the task more than once, but I was just like, OK, plural and peritoneal cavities. And if I had looked at this picture, I would have known immediately that that's what it was. But I had to read this a couple times for my brain to be like, is this what I want? So the pictures I know would have been helpful, but for some reason my eyes weren't directing me there. To use that as like a valid way to find the answer.

PI: resource 1 task 2

Speaker 1: um, so same, same thing again. Basically I started clicking through everything; I put on the filter faster this time, but the way this filter appeared is very different from how the defect filter appeared. So it took me a little longer to like interpret what exactly I was looking at because it doesn't kind of like super obviously highlight, um, or at least to me, the structures, it highlights more like the paths. Um, so then I was just scanning for words relative relative to what I needed, like following the paths that were highlighted. Then I finally found diaphragm and then I remember being, having a moment's hesitation between this because diaphragm, um, looks like even though it's above muscle rim, muscular portion, central tendon and crura, it looks like it's at the same level of importance even though the diaphragm is the larger structure in all of those are portions of that structure. It looks like these are all separate pieces. Um, so I was like muscle rim, oh part of the diaphragm. And then I started to click through these, started reading them, and then remembered, no, just look at the picture and the picture and
that got me to the answer a lot quicker again. Um, especially cause you highlighted with color. Um, and then I just totally neglected reading the descriptions and base my answer off the picture.

**PI:**  
**resource 1, task 3.**

**Speaker 1:**  
Um, same thing. Basically I'm finding that in, using the interface, it's weirdly like I feel like every time I'm getting to the right answer, obviously it's directing me in some form, but it's almost subconscious. It's not really like I'm consciously like, oh, this makes sense because I'm following- it's like I'm clicking on filters and I'm tagging stuff. And like through that process of like, you know, clicking stuff and going through things like it pushes me in the right direction eventually.

**Speaker 1:**  
But it's like when I look at this overview it's like chaotic and, and, but like embryology is chaotic. So like I don't really know how, you know, like there's no way to fix that. Um, so it's almost like it's working on a subconscious level rather than like me being able to look at this and be like, oh yeah, like immediately I know what I'm looking at. It takes like a little bit of thought, but it's almost like in the back of my mind and then it's pushing me to what the ultimate answer that I need.

**PI:**  
I have never gotten that response before, that's interesting.

**Speaker 1:**  
Like I wouldn't say that if I was studying, because like often when I'm taking tests, like if I was taking a test on this subject, I'll remember the textbook page that I was studying and I'll be like OK that figure that it was in the top left corner, what did it look like?

**Speaker 1:**  
And I'll remember things that way literally by like visual memorization. I don't think visual memorization would help me later here. Like with this overview at all, but like the way the filters are set up and the way that the colors and the flow like pushes you in certain directions. Like subconsciously it'll push you to the right answer. But overall it's not going to help me. Like I would never memorize this diagrammatic scheme, you know, or like looking at this diagrammatic scheme I don't think would necessarily- unless you put like a lot of hours of studying and like clicking through and memorizing like- would help me like get the overall, you know, unless you spend a lot of hours with it.

**PI:**  
So I'm anticipating that this would be more of a reference.

**Speaker 1:**  
Yeah, this is is not a primary reaching tool.

**PI:**  
Yeah. Not at. Not at all. Um, so in this case to find pleural pericardial effusion, do you think it was more of like the push and the flow that got you to the answer?

**Speaker 1:**  
Yeah. Yeah.

**Speaker 1:**  
**resource 2 task 1.**

**New Speaker:**  
Um, I missed the filters immediately. I was looking for the filters. The look like the
overall view of this one actually was more apparent and it wasn't until I was looking at this one that I realized that the other one, it wasn't totally apparent that it was distributed by time, like relative because you have the columns here that like directly line up with the weeks. The other one there are no columns and in the other one because you have the flow lines, you're, it's more like my mind is more associating like what is coming from what not necessarily just that they're coming from each other but not necessarily that you're moving relative to each other in time. Yeah. So this one I was actually like, oh, like if I. The time makes sense. Yeah. That's why I think like if your click tracking this. So then like I went through each of the weeks first, which actually gave me a better overview of when each of the major major things happen. And I didn't do that in the last one.

Speaker 1: But yeah, without the lines connecting things, it was kind of like more of a free for all in my brain, like where I should be clicking next.

PI: So what drew you to diaphragmatic hernia?

Speaker 1: Um, first I was just looking for words that looked like they were defects. Um, so like I was just like visually scanning for like root word differences between what I knew would be like a defect or just a structure or like a phase of time. Um, I think I missed tracheoesophageal fistula because it's so small and diaphragmatic hernia is pretty large, like just text wise, like their boxes aren't significantly bigger than one another, but the text is like more compact and triggers off a deal. So it's just harder to like read. So my eyes didn't pick up on it as soon. And then when I picked diaphragmatic Hernia, my eyes scanned the drawing and I saw lungs and gut and I was like, this one. Yeah, thanks.

PI: resource 2 task 2

Speaker 1: Um, same deal. I went straight to the diaphragm hierarchy earlier, so I knew that central tendon was a portion in here. Um, and then once I found it, I read like the body of text and the Septum transversum was included. Um, I mean there's the potential that that might not have been what you were asking for if like you were asking for like ectoderm, mesoderm, endoderm than it wouldn't have been in there and you would've had to follow it back. But that one was pretty clear.

PI: resource 2 task 3.

Speaker 1: Um, same deal. I went straight to the diaphragm hierarchy and just started clicking through and started looking at the pictures first to see if it was in the kind of posterior dorsal position that I wanted. And then scanning the text boxes for the phrase formed from, because that tends to be what you lead with all the ones where you're asking for embryonic structures. So then once I actually started at the bottom of this text box, because that's where you had formed for in the last embryonic structure question. So my eye went straight to the end of the text box and when I didn't find it, I jumped back up to the front of the textbox and found it there.
Participant X6OJG

Speaker 1: resource one, task one. OK. OK.

New Speaker: Um, so first I started out at the big headings the week five and week six, which is the transition between pericardial cavity formation and enough spaces formation. So from there I found one of the abnormalities is the diaphragmatic hernia, but then it was not the correct answer. So the only other choice was to check yourself in jail. But then I kept going back and forth and because the wording. But definitely the wording here is very specific versus on a task. It's more I would say obstruct. So I was, I had difficulty between just like committing to a decision. So I kept going back and forth and clicking on different buttons, although I knew there only two abnormalities. So that's great.

Speaker 1: resource one task 2

New Speaker: um, so I just looked for the central tendon and clicked on that, which gave me the answer to the task button and then read the prompts. Yes.

Speaker 1: resource one task three

New Speaker: for this task. Um, I looked at the diagrams mostly because the prompts or look at the posterior most dorsal part of the diaphragm. So from there I was looking at the definitions and clicking and seeing where they would point on a diet, that diagram. And then from there, um, I guess toward the end, I just didn't really read the question carefully, but the answer's in the description after I found the posterior portion yourself or did you have trouble recognizing which is posterior to anterior? No, no. If you click right from the beginning, you're like, it kind of guides you through like from the anterior to posterior. So I thought like if you follow that then you can keep track of it. Perfect.

Speaker 1: resource 2 task one. OK.

Speaker 2: And so I had a lot of trouble completing this task just because although I saw the connections or how I re-read through the definitions and how they separate, I didn't fully explore the, I guess the animation and didn't notice that where is the filter function where you could have helped me find the disease directly. I knew the region or like approximately where that defect, which should have been found, but I just didn't see the function of finding that defect. But um, now now that I know where it is, it's would've made it probably 10 times faster to find the answer.

Speaker 1: OK. So what do you think would help make that filters stand out or whether you think I could do to put it in a different place or something?
Speaker 1: resource 2 task 2 OK.

New Speaker: Um, so would this, would this task? I think it's associated with a diagram. So I clicked on the diagram and saw where the connections were, the connections linked to I guess from there. And then from there I kind of started clicking one by one and then just reading the description of each and see if the link's match up to what the task is asking me to find.

Speaker 2: Um, I think like right now it's color-coded. Honestly. I feel like maybe you should've had the filter, like instead of having it on there because I don't go through these functions at all. So maybe having, um, like putting it in that corner on the outside so you could see it clearly right away or just color-coding things maybe or maybe having the functions that says defects right on the outside. So when you click on defense, the highlights, the defects and under structures, but have the filters will be on the outside so you can see your options right away. And sort of clicking on the filters because I didn't even think of pressing perfect.

Speaker 1: resource 2 task three. OK.

New Speaker: Um, so what, this one, I guess it took a lot of careful reading. I feel like the question, the second and third tasks are not that hard. You just have to read more carefully. But I feel like for the main, um, like if the word is like the main, I guess the answers, if they could have been the bolded or color-coded that would've made like they would have made it stand out a lot more easier. Especially if also if there were colored on, like for example, on this diagram it's not colored, but if it was colored on there and ended award was also bolded or maybe if it wasn't bolded or cut color and if you click on the water it would show up on a diagram. I think that would also help to. That'd be nice in terms of finding the answer was there are things that you click on. Um, well I knew it had to be some sort of a separation. So I was thinking it could be maybe I'm like it's a membrane or, or some sort of a space. But I went on filters maybe this time, maybe be like a function that would separate those two, but then, um, there weren't, there wasn't a function, so I just kind of going from knowing that it's some sort of like a separation barrier. I clicked on like one of the two membranes. Um, and yeah, from there I just didn't read it carefully enough.

Speaker 1: resource one, task three

New Speaker: for this task. Um, I looked at the diagrams mostly because the prompts or look at the posterior most dorsal part of the diaphragm. So from there I was looking at the definitions and clicking and seeing where they would point on a diet, that diagram. And then from there, um, I guess toward the end, I just didn't really read the question carefully, but the answer's in the description after I found the posterior portion yourself or did you have trouble recognizing which is posterior to anterior? No, no. If you click right from the beginning, you're like, it kind of guides you through like from the anterior to posterior. So I thought like if you follow that then you can keep track of it. Perfect.
**Participant HEA5Y**

Speaker 1: resource one Task One. OK.

New Speaker: So I started with the words that I knew that I was looking for, which is plural, and peritoneal pleural had to do something with lung. So I started with the um, how the lungs broke off the bottom. I just went through all those steps but I didn't see anything about the defects there. So then I went, I found the filters and I changed it to defects and then I was still confused because I couldn't find anything that came from the lungs. So then I looked to see if there's anything that had to do with peritoneal it couldn't see the wood peritoneal in the flow charts. So then I just started clicking around a little bit more and then I looked kind of circling through the actual defects are highlighted. And then once I clicked on the diaphragmatic hernia and I read it, I realized it had the same words and thoughts and processes that the question was asking. Yeah. Because I kind of was looking for the specific words as suppose to me. Like I didn't know what to connect it to basically. Yeah.

Speaker 1: resource one task 2

New Speaker: OK. So I immediately switched my filters to structures and knew I was looking for a structure and then primarily is focused on the complete structures, the ones that were at the end of the week seven because I assumed it was a not like a in-between structure was like an structure. Um, and so I found the one that sounded right and had the anchoring it in my mind kind of made sense and then it must have realized it was wrong. I like through it again and then just got the kind of orientations corrector my mind. Um, well the, so the image actually helped cause I was, I was more um, I wasn't thinking like side to side as much originally, but when I saw [inaudible] I just from like the description of muscle room originally. Um, I didn't say anything about like attachments, it just said ribs. Um, so I thought it was something that was as close to the ribs and not necessarily like attaching to it. But then when I saw the picture and knew what I was looking for was more of like a lateral thing. I made sense.

Speaker 1: resource one, task three,

Speaker 2: So I got confused because I was looking for things that had to do with the heart and things that had to do with the lungs. So I focused on those areas and I looked through each one of them and I couldn't find anything about separating, just basically structures, so I kind of guess things that may have to do with things that are between them and I got very, very annoyed with the fact that these are just floating in a. they're not connected to anything. I don't know what they mean or where they're coming from, from like the but they're not but empty space in looking at the path of what it actually is. I got as far as the cardiogenic region, which didn't go higher up because I just saw ectoderm and that was just skin. So it didn't look down to being there.
Speaker 1: With this one are or what do you think would make it easier to find it?

Speaker 2: There probably isn't a better place to put it. Just like it's hard because we're trying to orient based on what we know about anatomy and not the way things are kind of form basically. So you kind of thinking about the end product and making associations backwards and it's not set up that way. So it's easy to get lost.

Speaker 1: I do think it would be helpful if there was like an end product here, which would be the pericardial sac. Sac.

Speaker 2: Yeah. I think more. I mean the colors are helpful, but I think there’s potentially an opportunity for small icons because you tend to look for the words that you know, but you might know the visuals as well, but you don't know the word, so. Yeah, that makes sense. It's easier to scan them for pictures in discounters and um, yeah, I see the words, but I miss them because it's kind of gets lost in the sea of three words. Those words are long, so I agree. It does make an artsy. Awesome. Cool.

Speaker 1: resource 2 task one

New Speaker: So I first alert for the filter and I really, it wasn't, it lives gone. So then I just kind of looked for where had I already remembered their, um, the defects existed, so refer promote primarily. I remember them being more towards the [inaudible] and so I looked at those first. Um, and then I saw the diaphragmatic hernia in week six and that kind of, let's close. It made sense that it would be kind of between, um, you know, gi and respiratory. But then after you explained it a little further and I found the other one which was on point for the question.

Speaker 1: resource 2 task 2 OK,

New Speaker: this one was quicker because it's during the first set of past with the other interactive. I spent a lot of time looking through the parts of the diaphragm and where that came from. And I spend a lot of time looking, you know, following that flow. So, and both. When you actually click central tendon, um, it says Septum transversum in the description and I’m going to go to Septum transversum, which I remember where that was from the previous one. It confirmed the question.

Speaker 1: resource 2 task 3 OK.

New Speaker: Um, it was in quicker because I already had spent time looking through all the parts of the diaphragm and what they were because of the previous question with the muscular rim. Um, so, but I, I almost put the crura itself because the question isn't state crura it states than it is to structure within an still embryonic structure. So I was like, that's probably not it. So then I had to kind of try to remember kind of backstop straight back and then found dorsal mesentery and saw that his description matched.
Participant 19TJB

Speaker 1: resourced one task one.

Speaker 2: So for this task I try and simplify the defect was mentioning in task one. Initially I was clicking around like the timeline with three, four, five, six and different like boxes in the, um, concept map and I did a fly in the future and then later I was able to find a future feature which helps a lot to separate out the defects and also highlight all the defects in the consumer. And then I can click on each one and read the description. That helps a lot.

Speaker 1: OK, so what drew you to diaphragmatic hernia as the answer?

Speaker 2: I'm also, there were like boxes in front of it leading to the hernia. Like it talks about the pleural pericardial effusion in the Pearl peritoneal membrane. So I thought it's probably related to dividing the pro and peritoneal cavity, which was mentioning the question.

Speaker 1: resource, one task 2

New Speaker: um, for this one I thought it was very useful to look at the actual diagram that came with the term because he was asking which one in to the lateral body wall. So I feel like the diagram which has the structure highlight it in the diagram helps a lot for me to like maybe imagining where it doesn't even structure structure go. And where does those structure connected to.

Speaker 1: resource one, task three,

New Speaker: um, same as task one. Different boxes in the concept map or like the concept map as a whole helped me lead into the answer because I can look up like how is connecting to like the different parts, like other parts like pour it and pericardial cavity somehow. It's like highlighted when I Click on this too. And then, uh, yeah, I also found that description to be helpful at Finding my answer.

Speaker 1: resource 2 task one.

Speaker 1: I feel like it a bit less helpful because I have less guidance like futures or like lines conducting from one place to another, but I guess one thing that helped me is that the description has a defect in the front. So there are several box with the defect labeled like as part of the district descriptions. So that Kinda helped me [inaudible] the answer you to diaphragmatic hernia. I thought it was also surprising like the respiratory, like cavity and the other. I'm like gastrointestinal cavity or like peritoneal cavity. Um, and then I couldn't really. I didn't really think of other answers so I just put that one down.
New Speaker: So for this one I think it was mentioning a pre survey. Yeah. So I kind of remember that was like the central tendon was being tested. So when I was, when I had the two minutes to explore, I kind of clicked. I'm like a few structures of the diaphragm, so I kind of remember this one and also set from the description that is formed from September transfer some. So I don't know, I just took like A. Yeah, this one was kind of fast for me and easier for me to find.

New Speaker: So I feel like it's like tasks to like earlier I had the chance to like explore, um, the, um, the program and also like in the earlier activity I was also able to, like when I was doing a bunch of tasks I was able to click around and see like already kind of learned like the different structures of a diaphragm. So I feel like this one was a also easier to find because I already kind of, yeah. Learned about it. So for this one, did you find the answer by reading the description about the cra or did you find that answer by clicking on the Dorsal mesentery button on my phone? The question by click on the crew and the. Yeah. Read the description and fund that is formed from the Dorsal mesentery.

Participant AZ9HG

New Speaker: So I'm not sure what these are. So I kind of go through this for the terms here first and then same, those two terms. Can I have, you know, which is the term on the paper awhile to realize this part and then I click on it and it seems this is how the normal development is, but it doesn't really tell me what's the disease name. So then I just go up to look for which one might be that one to scroll, kind of go through each column. So that's how I thought that might be the one, but I'm not quite sure. So that's how I got answer.

New Speaker: looking for the words in this one. I looking for lateral, so that's why I came. I found this one and it was trying to find my answer there and then I was kind of looking through all of them, but I'm not quite sure what's in the aisle looking for bothering wall. I saw this one and I click on it and then I found this answer. I'm looking for.

New Speaker: OK. So for this one I'm not quite sure of the keyword to look for. So that took longer and also I felt like I saw an answer before I was looking for and couldn't find it. So I kinda had to go through a lot of them and click on them to connect, go through each column to find those things. Yeah, yeah, yeah. A lot. Yeah. Reading the details information here as
well. So to figure out which one is

Speaker 1: resource 2 task one.

New Speaker: OK, so I thought got tricked by this work, so it hasn't because yeah, I was looking for that word and I'm getting different answers for, but I think I got this one module at times, but I wasn't sure exactly the same words, so that's something took me quite a while to figure it out and I think this filling or apart, this thing is really helpful to know. If you just click on this and you can look for defects, which has A. Yeah, it makes it much faster to find what you want.

Speaker 1: resource 2 task 2

New Speaker: I think this one either than previous ones, so cause I was looking for central attendant and I know it's a structure, a structure, so I go to theaters and go to structures and then from there you can see the name is right over there and it links back to the trans. The trans person has a structural kind of. It has formed the embryonic structure it has formed from.

Speaker 1: resource 2 task three.

New Speaker: OK, so for this one I went to the structure directly and then I was looking for dorsal part of the diaphragm and then I saw the dorsal. I'm sitting right here and then when I click on it and give me the right answer immediately. So was there anything or you saw Dorsal mesentery first? I saw this dorsal thing first. OK. Yeah. And also because there's a diaphragm here, so yeah, I just click on those first to check in or just call the answer. Yeah.

Participant X3MUH

Speaker 1: resource one, task one,

New Speaker: since it was talking about the plural and peritoneal cavities, I looked for those words and what was nice is that I saw both of them surrounding another box that says diaphragmatic hernia. And so I clicked on the two about the plural and perennial cavity is real quick to make sure, OK, I remember what those are and then click dive or medic hernia. And it seemed right. I hesitated a bit because a lot often with these kinds of questions and kind of been conditioned to look for exact wording and I didn't need an exact wording, but uh, mostly based on my previous knowledge I was thinking like, oh, that makes sense because the diaphragm is what divides those two spaces as per what the question said. So then I was like, oh, well yeah, that is what the, it does make sense.
So I think I was helped by previous knowledge, but I did like that there was a clear sign, like visual connection between the two in this, for the specific question.

Speaker 1: resource one, task to

New Speaker: this one was a little harder because I was focusing mostly on diaphragm and then there’s the diaphragm sector to the very end that has the separate parts, which I suppose is referring to most of what it’s got once it’s more fully developed. And so I clicked those a bit. None of them were fitting the lateral aspect of it. Um, and then so I was clicking around on other things and I’ve, my. I came to the body wall mesoderm, which caught my eye because it mentioned body wall in the question. So body wall in that. And then once I saw that picture it felt pretty clear that it specifically said lateral body wall. So I felt that one was a little bit. There was some connecting things, but that was a little close to luck because I did not connect that to the diaphragm because they’re kind of separate. And um, yeah.

Speaker 1: resource one, task three.

New Speaker: OK. This was another one where I think I knew some aspect of the previous thing, those talking about the cardiovascular system and I was thinking, oh that’s the, the Pleura is going to be something to do with the Pleura. So I clicked on anything that looked like it had to do with that. Um, so involved a little bit of clicking around to various things. Um,

Speaker 1: This was like previous knowledge and key words.

New Speaker: Yeah. mostly. That definitely was how it went faster. I think I was looking more for a couple of things, like if the Septum transversum because I was a word like, yeah, like oh that’s a separating thing. But then it wasn’t about that. So I quickly went to other things. So I guess I got to this one eventually because it seemed the pleuropericardial. So that involves both van heart and then I read it and it matched the wording. And so.

Speaker 1: Resource to task one.

New Speaker: Um, so the main issue with this one was I did not immediately realize that the MD facs had a separate filter, so I will say wants to filter was on. That definitely was an easier way to find it. But I suppose I don’t know if that’s just me not thinking too. It might be, I will say it's probably, I will say from, I was focusing on what was similar to the previous one, which was almost all in here and didn’t really think to start clicking on a bunch of other things that there’s clearly are, um, maybe because I was thinking too much of testing. So I was like, I’m going to try to learn things instead of like exploring the functionality. So, um, but at once I clicked on the defect, it was easy to connect the, the, the, the, the, the two systems that I was asking for, the respiratory and gastro, gastro intestinal.
New Speaker: So that it's a good system. I just couldn't find it. I don't know if that was me or thesis to allow OK filters somehow at any having just an introduction of some sort of introduction that says, here's how to use this, here's this section, so look here and click on things. Look here because we love even something super detailed just to draw it into do this as things you can click on this and as click on and then I think people will click on them and figured out like how I figured out, oh, the weeks having separation was actually had been thinking. I was like, I wish there was some way that they differentiated where the weeks where there was. I just hadn't clicked on anything, which I guess I'm a bad computer generated because I didn't immediately, but I think that would help us if there was just a very brief introduction that was saying things are here to click things here to click. Here's helps believers in about socialism.

Speaker 1: resource to task to

New Speaker: and this one I felt was much easier because it had been in preachers in the pretests and so I'd already been kind of thinking about the things, the things that we're doing, the pre-test for things I was thinking about a lot. So that was a lot of diaphragm things. And so since I was actually a question I had already looked at it. So I. and so in my exploring I had noticed that very clear connection, which is very useful in absolve us of the resource I think clearly shows this goes to that. I think I did it very quickly because I had remembered that the central tendon comes from something and I kind of even remember what the name was. I just really quickly clicked on it and then knew it. So that was where that came from.

Speaker 1: resource 2 task three.

New Speaker: This one was also easy because I had again had been looking a lot at the diaphragm. Questions in the a static resource, so I had kind of of since I've noticed several questions on the diaphragm, so I thought, oh, I shouldn't look at diagram questions and that's why I had been focusing on that and so it helped me too, you know, kind of which one to click on very quickly. However, again, it was still very helpful in that I could look at diaphragm kind of thing. I couldn't remember the exact thing, so I kind of went by the pictures and saw the crura specifically. We're in the back and I also quickly read through and say, talk about posterior stuff. I was like, ah, so I get to go back found dorsal mesentery to collect on that. Double check to that was matching the question wording and that's how I got the answer.

Participant G2NUW

Speaker 1: resource one, task one. OK. And then just give me an overview of what you did, what you clicked on, what you've found confusing.

Speaker 2: Based on the question. I knew that I would want to look at the plural and peritoneal cavities, but once I got there there didn't seem to be anything at all about a defects. And then I looked through and realize that I couldn't really find defects anywhere on there. So after a little while I think I was confused and if I didn't know it was possible, I think I might have given up on it. Um, but then I found the filters so I kind of wished that the
filters were a little more obvious or that there was a way to get to the filters without going up here or that like if you clicked on these guys here or like these guys, like if you wanted to learn more about them then there was an option to get to the defects that they were related to.

Speaker 1: That's perfect because a lot of people have had trouble finding the filters is a very common issue. And Yeah, I definitely wanted to get your opinion on what you think would be most helpful in terms of making the filters stand out more.

Speaker 2: Well, um, I mean part of it is that like it's like a testing environment, so I'm a little more nervous and not reading through things as carefully as I could have done otherwise. I don't know if the filters were in the tutorial, but. OK. So if the filters were in the tutorial and if it showed me the different options for them because just looking, I think it's not intuitive. If you're looking for defects to immediately go to filters.

Speaker 1: resource one task to,

New Speaker: um, that one was definitely easier than the last one. So I started with diaphragm because I knew I wanted the structure that forms the most lateral part of the diaphragm, the diaphragm. And then from there I see body wall, mesoderm, and I see that even the diaphragm doesn't have a line that goes to anything I'm body wall. Mesoderm is highlighted in, well, it's got a line through it that's highlighted in red and so does diaphragm. Um, so that's actually the closest to diaphragm. So that's the one I looked at first, which is part of why I got it so fast. Um, and then I looked at body wall mesoderm and saw anchoring the diaphragm to the lateral body wall. So because that wording was the same as the question, I definitely knew right away that that was. I would be surprised if that wasn't the answer. Although I think if I were studying in an unstructured way, it might have been harder to get through and scan for that kind of information, but it was easy. Based on this question.

Speaker 1: resource one, task three.

New Speaker: So, um, this one was kind of similar instruction to the last one, so I was looking at the embryonic structure that separates the cardiovascular system from the respiratory system and um, so I think I started at cardiogenic region and then went to a heart looping. Um, but then from there, um, was like, that's kind of a dead end even though it's his heart related. And then I was like, wait, pleural pericardial over here, right over here. Actually, they're like pretty approximal to each other. Um, so pleural pericardial that might have something to do with the lungs and heart. And then I looked at pleural pericardial fold and uh, yeah, that's the one player compared cardio fold fusion. And then I saw the phrase separated the cardiovascular and respiratory systems in the chest cavity. I think so, even though there wasn't a direct red line from heart looping to, um, pleural pericardial effusion.
New Speaker: So this one I found a little tricky because this time I did have the names of the defects up here, but um, Yeah, there wasn't as much connection obviously between them than there was with the version with the lines and also, I don't know for awhile I was just kind of like fluttering through and trying to figure out where it might be in clicking on names of things that I knew were defects to see what they were. But then I decided to get really systematic about it and then I was like, OK, I could use the term ectoderm. Endoderm seems to have all the gut stuff in it. And then I found from their, um, tracheoesophageal Fistula, which has tricked you in a soft gel in it. So probably the one I'm looking for and then I found it and it was right. Excellent.

New Speaker: Well, I knew what I was looking for the central tendon of the diaphragm, so I clicked on central tendon and then found that it was formed from the Septum. Transversum central. You find it easy to find central tendon. Um, I think I had seen it a couple of times and also I, you know, I was just kind of scanning around. I don't think I systematically looked for central tendon. Um, but I probably did see the big word diaphragm at the bottom of week seven. And then I saw the word diaphragm over here at the top of this cluster of things over here.

New Speaker: I found this one a little bit harder because I was looking for the most dorsal part of the diaphragm, anchoring it to the posterior body wall. So I looked at diaphragm and I was like, it's gotta be somewhere here in diaphragm. The illustrations helped in the fact that they were color-coded helped, but it wasn't, I mean unfamiliar with what a diaphragm looks like at different angles, but like not so familiar that I look at it right off the bat and I'm like, that's where that is. So it took a little bit of orienting to figure out which part was kind of the most posterior. Um, and then I was like, well, this is really the most posterior because it kind of looks like it's about as opposed as the most posterior part of the multiple muscular portion. And then I was like, well, let's figure it out. Anyway. Um, and I clicked through. It was the last option down here. Um, and I actually went through the other three first and figured I'd gotten all of them I think. So I went to Korea and then I was like, OK, [inaudible], and then I was like, dorsal mesentery. Um, that seems like a structure, but I was like, what if there's something else that the Dorsal mesentery comes from? What if that's the structure I need? And then I looked and I actually didn't see Dorsal Mesentery, but now I'm finding that it's like right here. Um, and then I was like, well, that's probably the structure.

New Speaker: Um, yeah, yeah. The, the images helps me orient a little bit. I, I wish there had been like an interior poster kind of thing on them or maybe a little bit more context or like
something like that. Honestly, just like I'd posted area would've worked because if I was a little less familiar with how this all went through, I'd be pretty confused. I think.

**Participant N6EN1**

**Speaker 1:** resource, one task one.

**Speaker 2:** Um, so I initially started looking at all the different body systems that were related to either the respiratory tract or gastrointestinal systems. Um, so the first answer I put was intestinal herniation because I saw that, um, I can't find it now, but uh, I put that as a first answer that was not right. And then, um, my second answer, I look actually found out about the filters tab which greatly narrowed my answers to only the effects of the program. Um, so that helped me a lot and I kind of clicked through those and found um, a disruption between the diaphragm and then testaments. I chose that as my second answer. That was incorrect because they were looking for, from our answers through the systems. And that's when I started looking again through the defects. And the only answer that made sense with the different organs was the tracheoesophageal Fistula. And that was my final answer.

**Speaker 1:** So in terms of finding the final answer, it was more of a systematic process where once you've found the defect, so you just sort of went through all of them. Did the color help you?

**Speaker 2:** The green coloring? Yes I'm depicting the different, um, defects in where they come, came from. Um, helped a lot to kind of make me think of the different steps that were required in creating this defects. Also helped to, um, with kind of showing the different organ systems.

**Speaker 1:** resource, one task to

**New Speaker:** piggybacking on my last first task, um, I use the filters, oil filters. I saw that there was individual, Oregon's I'm listed on the far right side of the program and I kind of went through there and found a central tenant which was what they were asking. And I clicked on the picture and then gave me a nice little blurb about what it was and what does form from and also a nice picture to go along with that.

**Speaker 1:** resource, one, task three

**New Speaker:** I was looking for the question was asking and was asking an embryo and structure that forms more, most also part of the diaphragm. So I backtrack did from what I knew made it the diaphragm. And um, I just look back and find the key word of the Dorsal mesentery, um, because the question was asked in the Dorsal and I clicked on that and he came in and I splurged and explained that it was a dorsal portion of the diaphragm.
New Speaker: I first looked at all the different weeks and found what the question was asking for, which was a separate and I looked through there and it was a little more difficult in the last one because it didn't give me exactly what defects to where. Um, at first I thought got herniation was the defect, but after reading the blurb it was not considered defect. And I looked at the next, what I thought was the defect was the Diet fragment hernia and that it was actually labeled dire fragment was actually labeled defect when, when I clicked on it. And that's how I found the answer.

Speaker 2: first looked into the diaphragm closes, which is week seven a to figure out the most lateral body wall. The diaphragm and I first started clicking through all the different parts. Is he the pictures because nothing was labelled as lateral. Um, then I came upon the muscular rim, which at first initially thought was the right answer, um, but I tried the muscular portion and the colored pictures gave me a better depiction of what the answer, what the question was looking for. And I clicked the muscular room because the picture was highlighted in green or purple. And to show the most outer, most wall was the most of their rent. But there was no specific, um, description in the blurb to say that it was the most lateral.

New Speaker: I clicked on the bottom and found the tab which was pericardial cavity forms in week five, and I had a little more trouble pinpointing what they were looking for. Click through all the different most of the boxes of this category, and I finally found the right answer was pleural pericardial fusion. And I didn't find the answer from the actual box in like the chart. I found it actually in the blurb and I kind of mentioned in there.

Participant BYBQ3

New Speaker: OK, so I saw um, plural and peritoneal cavities separating, so I saw these keywords and it made me think that it would be located in here in week six. Um, and so I was looking through all of these and didn't see exactly what I was looking for. Um, so I started clicking on, um, I figured it happened, would happen earlier on, so I was clicking on the words that I'm indicated a disorder. Um, and then I was going down the list for week four and clicked on the, um, clicked on a few of these and then, um, went down to this very bottom. It's really small, so it was kind of like innocent the bottom. So it was like the last thing I clicked on, um, so it was lateral and cranial-caudal folding, which didn't
really don't know. It didn't give me as much indication, I guess that this is what the information in there would be good.

Speaker 1: resource one task to

New Speaker: um, so I first was looking for, um, the word central tendon or diaphragm. Um, I, I'm not exactly sure why, but I was leaning more towards this side of week three or four. Um, uh, I didn't see exactly that, those, either those two words, I guess I'm seeing diaphragms hernia now, but, um, I answered this on the pretest, I think as the central tendon, I believe. So that was my educated guess. And so I clicked on that to see if I was right from their pre-test and that's what I chose prior knowledge about the central tendon. I'm not of how it's developed, not the embryology version of it. Yeah.

Speaker 1: resource one, task three.

New Speaker: Um, so from the last question, the Septum Transversum, uh, it's related in task three, so I figured regionally they would be pretty close to each other. Um, and I saw the word dorsal. Um, so I clicked on that before I clicked the item that was, um, just below the Septum transversum just to test out to see if that was maybe related to what I was looking for. But I figured it would be like a sub topic if it was talking about a piece, not an actual, like germ layer

Speaker 1: resource to task one.

New Speaker: So I initially gravitated towards the two tabs of pleural cavity, peritoneal cavity, and trace those back to their commonality, which was the Perry cardio peritoneal canals. Um, so, um, that didn't look like the radiance or it looked like it was just a structure in a disorder. So I was kind of looking in this area for the answers. So, um, uh, I also tried tracing back if there are any lineages and set up to the Somato player player and that wasn't really there. So, um, I guess perio, cardio, cardio peritoneal canals and that wasn't right. So when I stopped, um, you let me know that I was missing a key item. So then, um, that made me think of obviously this toolbar appears. So I clicked through these and then once I had the filters, um, it populated things that weren't there before, so diaphragmatic hernia wasn't listed without clicking filters. So, um, that was integral integral to finding the answers so that I found tie for acrobatic hernia. So, yeah. What do you think would make filters stand out more so that it's easier? The fines, um, is anything green before you hit filters? So maybe I think, um, if you indicated that that's a possibility, um, maybe that lineage is possible with that color because that's how you're associating all these other lineages with a specific color. I have to do something to me.

Speaker 1: resource to task 2.

New Speaker: All right. Um, so I knew that I was looking for something in relation to the diaphragm.
Um, so I clicked on the, um, subtopic of diaphragm and then, um, I understood these to be subtopics about the diaphragm, so that was clicking through these. Um, and I was thinking maybe that this would have the answer in one of these. I obviously didn't find what I was looking for, so I went over to the left some for the areas that had lineage from each of these sections and kind of click through those. Um, uh, I was assuming that it was, um, I was thinking maybe it was like a muscular portion because this looks in the image that like it's attaching latterly. Um, so was I clicked on the plural peritoneal membrane and the pleural pericardial fold Fascia thinking that those would be possibly have the answer in it. And then when I went back to the muscle rim, I realize that that's actually attached to the body wall. And so I clicked on body wall mesoderm.

Speaker 1: resource to task three.

New Speaker: So I knew that the, um, two things that were involved that were looking for where the pleural cavity and the pericardial cavity. So when I follow these two lines in, I was thinking about my answer would be within these three. Um, so, um, I don't know why I didn't notice this before, but when you click well, OK, so to click on the right answer was where I'd associated the pericardial cavity, but it didn't highlight the pleural cavity. So I think when I clicked on this a while ago, um, I wasn't making the connection that these two things were associated with the plural paradigm pericardial fold fusion, which I guess seems silly, but, um, but yeah, so, and that got me a little bit lost because I was expecting the answer to be in here. Um, but, um, I guess like, this isn't the name, so maybe I should have clicked on them. So that's how I eventually got to it.

Participant JW3BY

Speaker 1: resource one, task one.

Participant: Um, so I started clicking through the different structures of the embryo. I didn't know about that because I did think normally like any normal person would. So it took me awhile to find the filters so that I can actually get to the actual defects and once I found that it was much easier to find.

Speaker 1: Yeah. So once you've found the filters, how were you working through to find the correct, the correct answer?

Participant: Um, I actually just kind of read the names and. OK. Like what I, what I was trying to look for, what I was reading I wanted to see like I would click on it if it was something that I thought was related to what I was trying to answer.

Speaker 1: What do you think would have helped you find the filters faster?

Participant: Maybe, maybe if in the introduction it showed you like, oh you can do this and this. Maybe I read it wrong. I don't know if you had something. So if it had something like go through those to filter out based on what you want to find, maybe that would've been easier.
Speaker 1: Some people have suggested doing something like color code or like make them filters, stands out or put it in a different place because a lot of people have had trouble finding. You're not the only one. You're not the only one. And it's hard because that's the first. That's the first task too. So it's like the first time you're acquainted with the resource. Right. Well, so you're like unfamiliar with it at all. Exactly. So that makes it tricky.

New Speaker: So for this task I directly went to filters and I clicked on structures because I was looking for what gives rise to the central tendon, so then I found the central tons on there and just traced it back to the structure. Excellent color help you with that? Yeah, it was just made it easier to follow.

Speaker 1: resource one task to,

New Speaker: So for this task I kind of did the same thing as task to where, again, use the filters to filter out structures since I was looking for what makes up the post anchors, the diaphragm to the posterior body wall. And then I just clicked through all the different parts of the diaphragm to find which one said this anchors. Seriously, that band, was it clear that the diaphragm when you clicked on the diaphragm, all of these were related at first when I clicked on it and nothing really happened, that kind of threw me off, but then I realized like, oh, there's nothing that's stemming from it. So that must mean that it, like all those things that are under it are a part of the diaphragm.

Speaker 1: And then what drew you to body wall mesoderm first?

New Speaker: The picture. OK. Yeah, I looked at the picture and it was a lot of it, like the thickest part was posterior. So I was like, maybe it's that.

New Speaker: So in this case, the words are what clued you in.

New Speaker: Yeah, I had to like literally go through every year.

Speaker 2: I don't even know where to begin with this desk. Um, it was really hard to find the answer just because like I can kind of see the connection between the different boxes, but it's chaotic to me. So, um, it took me a while to zone in on the answer and I just kind of found it just by like reading all the labels and being like, OK, this is just the structure or this is an area actual defect.

New Speaker: So in this case, the words are what clued you in.

New Speaker: Yeah, I had to like literally go through every year.

Speaker 1: Did you start from the or did you start from the left and work towards the right?

New Speaker: I started from the rights just because that I don't know why. That just seems better to me. A perfectly acceptable answer.
Speaker 1: resource to task to

New Speaker: So I again, started from the right side this time looking for structures and just reading their description and then I eventually moved left and came across body wall music, Durban. Then I read the description and use the answer.

Speaker 1: Do you think using the previous resource helped you find the answer?

New Speaker: Definitely. I think I would've been like a fish out of water.

Speaker 1: resource to task three.

New Speaker: So I again looked for structures like labels that had names of structures. I kinda just zoned in on the middle because I kind of knew that was around the area where it talked about the lungs and the heart and then I just kind of clicked through them until I found more of a systematic way of finding the answer and had to go for reach one.

Participant UM6LU

Speaker 1: resource one, task one.

New Speaker: Um, so, um, I tried to find were like plural and peritoneal or, um, and so kind of between those was a, the diaphragmatic hernia. So then I clicked on that and then like read the, um, the description and uh, I got a little confused I guess with um, the pericardial peritoneal canals part. Um, so then I looked through gut herniation too and like realized it wasn't that.

Speaker 1: resource one task 2

New Speaker: So, uh, I think I had a similar question to this past semester, so, and I think that, I hope the answer was correct but um, so that's Kinda why I just kind of jump to that one cause it does anchor just posted early. Um, and then the muscular room and the muscular portion, I was just getting confused on, um, but then after I realized that the muscular portion wasn't right, then I looked at the pictures and the room was kind of on the lateral side, so more lateral to the muscle and the, just how it was grouped with the diaphragm and they all had like similar pictures, just like kind of highlighting a different part of the same picture.

Speaker 1: resource one, task three.

New Speaker: So, um, I was looking for something with like cardio and I'm like Pleura in it, um, which is kind of why I was like drawn to the, like week four, I'm kind of column in the middle with
pericardial cavity and pericardial peritoneal canals. And then, um, so I looked through all those which took awhile and then none of those really made sense and then I kind of move to the next week, which makes sense now looking at the paragraph pericardial cavity forms. So, um, and then I read through the pleural pericardial effusion and um, even though I was looking for like the fall itself, it was, I took like an extra second to look at that too.

Speaker 1: resource 2 task one.

New Speaker: Um, so I use the filter to look for, um, the defects, um, and then I just kind of went through them in order. Um, so then, uh, I was just look for the esophageal one because gastrointestinal system. And then, um, the wording is like pretty close to the question too, so it's pretty easy to see.

Speaker 1: resource 2 task 2

New Speaker: um, so I just look for central tendon and then clicking on that, it just brought me back to the Septum transversum. So it was, and it says it too also in the description for central tendon.

Participant UOXKM

Speaker 1: resource one, task one, so just sort of explain what you did and how you got your answer.

New Speaker: The first thing I did was look for the words were on the peritoneal cavity and I found those and then use the filters to find the defect and then I read the defect for diaphragmatic hernia. Then read the other defects to check my answer.

Speaker 1: resource 1 task 2

New Speaker: uh, so the first thing I did was look at the diaphragm structure and use the color coded color coordination to figure out what was most lateral played with some of the filters to see structures and then traced it back to the message, which I thought was the first. And then I figured out it's a body long term to volleyball mesoderm, the color coordinated filter, color-coordinated filter. Wonderful.

Speaker 1: resource one, task three.

New Speaker: The first thing I did was click lateral cranial caudal folding for me before I actually not sure why, um, and then I clicked, splanchnopleure and Hind Gut and read those and then looked up and found cardiac region and read quickly those endocardial to fusion and heart looping. And then, those filters showed up and saw pericardial cavity, which I also had read those and the intraembryonic coelome and pericardial cavity. And then I
guess those filters led me to play a part or cardio cold fusion. And then I read that and saw that the answer was correct in there.

Speaker 1: There was a highlight that shows up from pleuropericardial fold fusion.

New Speaker: Yeah, it did it.

Speaker 1: resource 2 task 1

New Speaker: So the first thing I did was try and go through and click all the things that I thought were defects by their names and read them all and I tried to trace back from the diaphragm, um, that, that was hard. So we clicked around things that I knew were respiratory and gastrointestinal to try and trace it in my mind how things formed and where things could go wrong and then I clicked it plural. And peritoneal cavities separating, which made me think it was what I put out. Diaphragmatic hernia. And then for a really long time I also thought it was gut herniation and then

Speaker 1: It was interesting. I looked at the heart a little bit because I had noticed that you stopped on tracheoesophageal fistula and esophageal Atresia for a little bit.

New Speaker: Yeah. In the beginning I wasn't really sure because respiratory diverticulum was there. So I thought of a divide and it's also on a dividing line. I think I just forgot that that's often goes in front of it. Um, yeah, no, good to know.

Speaker 1: resource 2 task 2.

New Speaker: I'm like diaphragm. Then I went down and click central tendon, which I had remembered where that was from before, and then I read the description. It said it's formed from the Septum transversum.

Speaker 1: resource 2 task three.

New Speaker: Diaphragm again with the color coordinated structures and then click through muscle rim, muscular portion, central tendon and crura and read through those and identified what was dorsal and then went back to the left to find the embryonic structure and check his dorsal mesentery and then read the description to know what it was.

Participant SPOBD

Speaker 1: resource one, task one. OK. So just describe what you did, the steps that you took to complete the task.

New Speaker: First I read a classroom but I have a little bit confused now. What they exactly they're talking about. Uh, I think at first time I didn't understand the question very clearly design I looking for that and then I recognize the fact, the fact, right? So then I know
what, what should I be looking for? And uh, I'm a little bit confused about this part because they are all the how to say the same color button. So I cannot find the, all the defect to immediately place. So I just find as a system like respit the respiratory tree and the guts and the Xa, I follow that back to find the right answer.

Speaker 1: resource one task 2.

New Speaker: OK, so after the first test, now I have that more familiar about this thing so I know where I should look for, so I just find you. Whereas they're separate and I find that that thing.

Speaker 1: 00:00 resource one. Task Three.

New Speaker: 00:08 OK, so yeah, because I did last the test and this test is a connect with so I just looking around nearby and I choose that button. The dorsal mesentery. So I found that that's the right answer. So yeah, that's why I founded the right. Is that right?

Speaker 1: resource 2 task one.

New Speaker: OK. So, uh, when I explore this, interacted with sources, I've found that there's a filter and it has the defect leader defects. So I know this question is asking about the defects and I just look for that and they show up and I found the complete overall oral cavity and between this they have this defect. Yeah. Awesome. So you were able to find it based on. It's between the parents in the oral cavity? Yes.

Speaker 1: resource 2 task 2

New Speaker: So for this I was looking for the structure first. Uh, but I, yeah, I, I, I'm a little bit confused. I don't know where I shouldn't look at so then I just find does the dire frame the spot and I just follow the lines and a look around and there's a button like father wore mentioned and I read that there is inflammation there. So yeah, I basically, I follow the line to go back to for, to find that part. And you worked for the diaphragm? Yes.

Speaker 1: resource 2 task three.

New Speaker: OK. So this is why, uh, why make it wrong? I don't know. I think yeah, I think basically I got the basic idea wrong. So it's between the cardio system and the rest of the array system. So I find it the wrong place at first time. Then I know it's about like the I always know is around this part because the cavities part but, I can not find it. So at first I looking for the cavity of space but I found these in the wrong way. And the second time I know I need to look around at this here, but for this there's no line here so I just, I don't know. Ah, so then I found the weight when I clicked this. If this last show off. So maybe here. So I find this for a long time. Yeah, that's fine. That's totally fine.

**Participant G2LP1**
New Speaker: complete the task and if you ran into any issues and went through it. So at first I went to the filter tab and I immediately started looking for the different um, uh, the formations that can happen that have effects that can happen. And um, I kind of wanted at first I click just on the different defects on. I wanted to tell me my answer and it didn't give me my answer and then I got a little bit stuck because there was nothing that said a system or b system. But I think after, I kinda was guessing around for the first three minutes, it finally clicked to me just exactly how the logic works for this. Um, so I was able to then be like, OK, well I'm looking at the, uh, the respiratory system and the gastrointestinal system, so that is from the endoderm. And then I went and looked to see where they are branching from and that is in week four, lateral and craniocaudal affording. And that was how I was able to finally arrive at the answer. So I think it just took me a little bit more than two minutes at the beginning to orient myself to how this is working.

New Speaker: OK, so I was looking to a, a structure that gives rise to the diaphragm. So immediately I went to the filter section and looked for structures and I was able to kind of just map out the different structures that exist. If I first saw diaphragm on the top and I guess that's a heading and not necessarily a the thing itself. So I almost wish that was called out a little bit differently because it looked like it was a structured just like everything else. But then I read under it and I'm like, oh, there's the central tendency to trace a little line back to the Septum transversum and get my answer.

New Speaker: OK, so for that one I'd already kind of looked at the diaphragm before, so I immediately went to those structures. I didn't actually know which structure was the dorsal part of the diaphragm, like I didn't know what his actual name. So I had to click through each one to figure out that it was the era and from that it was easy to trace it back and read that it was the Dorsal mesentery that did it.

New Speaker: Alright, so I immediately missed my little filters and colors and I started to just scan for like anything like the plural or peritoneal cavities. I, I did find them eventually and luckily the thing I wanted to find was partitioning the two cavities. I'm talking about the abnormal partition. So I figured the diaphragmatic hernia was the answer and it was true.

New Speaker: well I misread the question a little bit and I thought it was just looking for the structure that is the lateral part of the body wall with the diaphragm. So I was looking under the diaphragm, found the muscle portion. It looked like it was on the lateral part, so I assume that was the answer, but if I was looking for the embryonic structure, I'm not
entirely sure. I would've known to go back there immediately. I probably would've started like looking for things in the vicinity of it and maybe would've arrived on like peritoneal cavity or something instead.

Speaker 1: resource 2 task 3.

New Speaker: OK. So for this one I was immediately looking for anything about the cardiovascular, better cardiovascular or respiratory system. Um, I found the respiratory system, but for some reason I wanted the, a cardiovascular system to be like close to it and like I didn't realize that they kind of, they split setter is so much higher up on the thing. So I was looking around kind of just clicking a lot of buttons and I eventually was just ran out of buttons to click. So I like kind of moved up and found oh here's our things relating to the heart. And then from there I was able to kind of like track my way to the point where the pro very cardial full fusion happens. Backtracked to pericardial hold. Yeah. The fold. Like the word fusion to me made it sound like it was an event and not a structure. So since I was looking for a structure, like I guess that was, that was my thought process was like I'm looking for an object.

Participant XSRFS

Speaker 1: resource one, task one,

New Speaker: uh, to find the answer to task one. I first a scan through the images to find any name that showed a dis function, so something like a gastro ss or top ECTOPIA quarters. And then I realized later that actually you should look at what the plural or preneurial cavity when the paranoia per plural and peritoneal cavity separate. There's that week six. And then I realized, oh, then you can just focus down and find the defect within that time period. And then you can find the answer.

Speaker 1: resource one task 2,

New Speaker: uh, to find the answer of finding where the attachment of the body lateral wall was. I first initially thought it would be in week seven were the when the diaphragm closes because that's when I expect that the time for it to attach was. But I was kind of wrong. So I had to, I was looking back to find out when the cavity's separate as just like, it must be within that time period. So I just went through the buttons within that time period and found that one of the descriptions matched. So I realized that's the answer.

Speaker 1: resource one, task three,

New Speaker: uh, so I knew that I need to look for a time when the fold between the heart and the lung occurs. So I knew it was the pericardial cavity formation week five. So selecting through the cat. The options there. I initially thought it would be just the membrane because it did say that the heart and the lung separated there and I didn't read carefully enough not realizing that it didn't actually say separate. It was more of a, just a general explanation of a membrane there. A actual answer was pericardial fold fusion where the
f full that's actually made when the separation happens. So that was the, it's actually, um, so the thorough peritoneal membrane is separating the, um, respiratory system. So I'm pleural cavity from the peritoneal cavity, the respiratory and GI system. So the one that I was looking for was respiratory and heart. Yeah. That's this guy, if that makes sense. Yeah. I was just like, oh, this is. I don't know what I read it as.

Speaker 1: resource 2 task one.

New Speaker: Uh, so initially I was confused on how to find to defects because I didn't realize they weren't actually visible and I didn't realize that there's different filters and I never turned on the filter. So after I realized that I should be able to turn out the filters, I turned it on and then I was able to find the defects and then I approached the wrong defect which separated the different cavities instead of the actual structures. So afterwards I pr, I realized that if it's the structures, there was only one other answer, tracheoesophageal fistula. I'm actually, because I already knew about soft g off South Australia, Patricia were like, um, they, the two, the two esophageal and the tracheal tubes don't separate properly. So I knew, oh, she must be actually talking. The question was actually we be talking about that and then if it's talking about structure. So that's probably what the answer was.

Speaker 1: resource 2 task 2

New Speaker: um, so for the next question, I just realized since I knew about the filter function, now I just use the filter function to figure out which structures lead to what structure. And then I saw which align lead to central tendon. So it was color-coded, went back to the Septum transversum and was able to find the answer.

Speaker 1: Resource 2 task three

New Speaker: So I was kinda confused for this question. Even though the answers should was dorsal mesentery? I approached it more like what should, what is attached to the rim area of the diaphragm, which I assumed would be the closest. Forgetting that the room is like lateral, lateral. So I first picked body-worn mesoderm and then I kind of went backwards from there and then afterwards I thought, Oh, I must be picking the wrong. Like since I picked the wrong one, I thought I'll go backwards from central tendon. So it kind of worked my way down the list that was given from the dive underneath the textbox diaphragm, assuming that somehow it would be like from the most dorsal down to the most media because of the order of the children to endoderm. And then later when I actually looked at the word dorsal mesentery, I was like, oh damn, that's very. Obviously that's the Dorsal area. And I totally got confused. But yes, definitely helped a lot.

Participant 0G4U0

Speaker 1: resource one task one.

Speaker 2: So in order to, um, find the embryonic defect that would result from abnormal
partitioning of the plural partition, Pereira peritoneal cavities, I just split it up into first finding the defects. So I went to the filter because I'm trying to find a defect at first. Went to the filters, went to defects in the defects tab, separated. I'm into specific defects in sections a and at different points in time. So I saw that at week six, um, there was a separation between plural and peritoneal cavities. So I just click that and it kind of gave me a understanding of where, at what point in time this would happen. So I clicked the diaphragmatic hernia, which was one of the options in the defects filter. So I click that and um, the information about what it was. And so I, I'm pretty sure that's what the, um, the defect is, that's what it shows.

Speaker 1: resource one task 2

New Speaker: I was get confused. I'm trying to find the name of the structure that was on the outer part of the body wall because, um, I was looking when I hit structures, kind of all of these seem to light up as structures. Um, and I'm just going towards the diaphragm. And so when I click the body will return and it told me that this is myoblasts from the user to remove the outer body while [inaudible] only the outer edge of the diaphragm, anchoring it to the lateral body wall. And then I thought that the structure that would be creating that would be the sole nights. So that's why I picked. So my initially and then afterwards I picked body wall.

Speaker 1: resource one, task three,

New Speaker: a little bit of time. I was looking for an embryonic structures separating the cardiovascular system from a separate system. So I was looking for like some sort of system filter to the like, oh yeah, there's a system filter and then separate those two. Um, so, but because there wasn't that, I just looked for structures, and I found like pericardial cavity and pleural cavity initially. Um, and that seemed like respiratory and cardiovascular. So then I thought that that was the primitive pericardial cavity, but that's not a structure. So that was where I went wrong initially. So then I went to structures and uh, initially went towards the pleura peritoneal membrane. Um, and I chose that over the pleuropericardial fold fusion because it had the word membrane in it. And that membrane sounds like more infrastructure than fusion even though it's still in the structures tabs. So these are all structures. So that was an error on my part, not necessarily the air on the interface.

Speaker 1: resource 2 task 2

New Speaker: this one was a little smoother. Um, I've found central tendon and just click that box. And within that the information gave me the Septum transversum, which is where it's formed from. Um, I really, because of the interactive, I wanted to have a line that connected to. Is that in here? Oh, it's not. OK. So Yep. The actually maybe helped out with this one a little bit because then it forced me to just read it instead of trying to connect the dots somewhere actually. But that's just different leader. OK, that's it.

Speaker 1: resource 2 task three.
New Speaker: For this task I'm supposed to find the dorsal part of the diaphragm. And created the poster boy. Well, um, initially went for body warm as a derm because it anchors the diaphragm to the lateral wall and a bed ladder body wall and forgot that it was posted. And then the second, my second tri, I went to her home peritoneal membrane, which is not, it doesn't incur the, um, the different at all, but I saw a post to your body wall and I was tired of trying to find it and I was looking for key words and I've just chose that one. So after I got that one wrong, I was you know, I was ready to actually read now because I felt that so. So I found the one that was the post, the Dorsal mesentery, which is the correct answer. So I actually read their stuff. OK? Yeah. After realizing that that wasn't the right answer.

Participant SPDB5

Speaker 1: resource one, task one,

New Speaker: um, read the question. Drew a lung and a stomach to be like respiratory and gastrointestinal. So I knew I was looking for a, didn't read anything, really went through the pictures. First of all, if I could see anything bank related to lungs and stomach and then figure it out. There were certain cards that actually described a defect, so forgot about all the other ones and looked for the defect ones and then tried to see which one fit. And then this one kind of fair because it had to do with the gut and a stomach. So I was like that one, but then it was wrong. So I had to look for the other ones and did that again. And that's it.

Speaker 1: resource one task 2

New Speaker: read the question, circled structure and diaphragm because those were the important parts and also underlying central tendon. Looked at timeline and found the word diaphragm looked at diaphragm, looked at the things underneath the diaphragm. The same picture, but different colors. Found the word central tendon didn't read it. Looked around some more. Went back to central tenant. Oh, the answer was at the end. I should have read it. That's it.

Speaker 1: resource one, task three,

New Speaker: circle structured, dorsal part, diaphragm, and post to your body was underlined, went back to diaphragms, checked each one, forgot how to interpret those images, figuring out which part was Dorsal, which part was ventral? Crura looked OK, and then I was like, Huh, lumbar, that's Dorsal, right? And then I wrote the answer.

Speaker 1: resource 2 task one.

New Speaker: Well, there were no baby pictures and I was looking for the baby pictures because I knew the baby pictures, showed the defects really confused and tried to click everywhere. Uh, figured out I could click on things other than the time I'm found the defects. But then I had found the defect.
Speaker 1: resource 2 task 2

New Speaker: filter, restructure. It looked, look at the pictures, didn't read the stuff. The pictures showed the muscle to be the one that was most lateral. The other ones were not really lateral. Picked it.

Speaker 1: resource 2 task three

New Speaker: I had to find a structure, filtered for structure, looked for words that men hurt or lungs, found a pleural pericardial, which sounds like heart and lungs or read the thing. Trying to figure out which word was the actual structure that I had to put down as the answer and put just very baroque, period. Pleural pericardial. The end.

Participant VEYJ1

Speaker 1: resource, one, task one,

Speaker 2: uh, the first thing I did was I went to the filters and then the defects because the question is talking about defects, uh, I clicked through them all but the answer wasn't like really clear, so re oriented better. I went back to the introduction and through that again, and then at the bottom and I've found where there was some cavities separated at week six, the plural peritoneal, so are hooked on that. And then I read through that. Um, then I went back to the defects, and went from there and then I got to the diaphragmatic hernia and because there was in the image there was um, like a intestine is going kind of into the lungs. I thought that's what he was talking about. Um, but that's more of a hernia then, like the system actually like failing a separate. So I went back and then I got to the trickiest.

Speaker 1: resource one, task two.

Speaker 2: Um, let's see. I think the first thing I did was go back to the intro so you can check out like the partitioning and how it worked and everything so I can get the colors oriented right. Um, then I realized it was, had to do with the Mesoderm, so I went from there and then I kind of checked out the three extensions, the lateral plate for axial and then the other lateral play kind of thing where they went to, um, checked out, just kind of like some extensions from those as well. Um, and then I realized I was talking about a structure, so I went to the filters and then pick structures. Um, that led me to the central tendon, which I probably should've seen a while before. I didn't realize I had its own little box, but yeah.

Speaker 1: resource, one task three.

Speaker 2: On the previous question, I knew that there was all the structures on this corner on the uh, right side, so I just started reading those one by one. I got through the muscle room, which the sketch look like it came from, you know, the post your body wall and then I kind of backed up and read more about that. But then I went to a master portion and that of was dragged from the euro peritoneal membranes. So I clicked on the, on the
plural flouro peritoneal membrane and it said that they grow transversely from the posterior body wall. So I chose that and was wrong. And then judging by, um, the sketches, I either knew it was the muscle in just because it looked like it had attachments, but it also said it just attached to the rib cage. I was unsure about that. And then I said the cra also attached to a, some of the Vertebra, but I wasn't sure if that really counted as the posterior body wall. So I went with the muscle rim and what's wrong? And then you have to be the cross.

Speaker 1: resource 2 task one.

Speaker 2: All right, so I went to the timeline because I had already noticed that there was a spot for plural on peritoneal cavity is separating. Um, and then from there I just sort of read through a couple of the blocks in the air. So I got herniation first and I knew that that was a defect and that didn't sound right. And then so I looked for the other defects and found diaphragmatic hernia and yeah, read that and chose that one.

Speaker 1: resource 2 task two.

Speaker 2: I. Because the question was asking about parts of the diaphragm. I knew that there was a bunch of diaphragm structures on the right side, so I read through them. Um, I remember from going through the other resource that there was, I remember like reading that there was like some kind of like lateral. I'm like anchoring to the lateral body wall and something and it turns out that was the body while mesoderm. But because this was, it didn't have any of those connections, I couldn't find. It just took me longer to answer. And then I just kind of took an educated guess at the muscle written.

Speaker 1: resource 2 task three.

Speaker 2: Um, so let's see. I would ask about separating the cardiovascular respiratory systems. So during week five at the bottom, I hear the pericardial cavity form, so I figured that was important. Uh, I clicked on the box about the pericardial cavity. Um, and then just talk to that at separating. Umm, so I knew it was somewhere around there and then there were the two boxes about it, which were the peritoneal membrane and the flora pericardial fusion. So obviously I went to the pleural pericardial fusion a square because you know that cardio and the names and read through that and realized it was the right answer.

Participant Q9144

Speaker 1: resource one, task one.

Speaker 2: OK, so first, uh, after getting familiar with the system, uh, I kind of looked at how it's broken up in terms of weeks because the question asks about a embryonic defects that would result from abnormal partitioning of these cavities. So I tried looking for keywords such as the plural and peritoneal cavities and that seems to be around week five, week six, so I kind of focused my efforts on here and then we're looking for an
embryonic defect. So these all seem like normal regulatory steps except for the few that say like diaphragmatic hernia, that's definitely a defect. And then you have gut herniation, that's another defect. So I focused on these two first and then I clicked on those to kind of see what the little info was about them and then they have to make sure I don't exclude anything outside of that. I looked at week three, four, and seven, didn't really see anything that matched. So I ended up going with diaphragmatic hernia on the end.

Speaker 1: resource one, task two.

Speaker 2: OK, so the kind of approach, the question the same way as they did the first one that I tried looking for key words in the question. Um, so we're looking at anchoring the lateral body wall from, of the diaphragm and the most lateral part and we're looking for the name of this structure that forms that. So, uh, I tried looking at a few weeks back because it wouldn't be at week seven because that's when everything's already closed. So if we were looking for something that forms, that would probably be weeks three to five, I, I was guessing. Um, and so that's where I was trying to look for things that kind of led to lateral as looking for keywords like lateral. It wouldn't probably be any membranes or cavities. Uh, I tried going back to like Dorsal mesentery because that's where I know things kind stemmed from. Um, I think I landed on what I learned on, yeah, Dorsal Mesentery, uh, because it, it had a few words of lateral, but it didn't feel very right. I think I was struggling on trying to like find the thing that was exactly right. Ended up being in week six, body wall mesoderm. So yeah.

Speaker 1: resource one task three.

Speaker 2: OK. So, um, for this guy, I kind of focused on the keyword separating the cardiovascular from the respiratory system in the chest cavity. So I'm looking at kind of how the weeks are broken up a week, six to plural and peritoneal cavity separate. So it, we were looking for something that does separate that. It would probably be week five or week four maybe. Um, from what I know background wise, cardio would probably be the m perry. And then for respiratory be plural. So pleural pericardial folds is usually what I was looking for. So pericardial cavity. I tried looking around there and then I found a pleural pericardial effusion. Read a little bit about that and then they kind of broke it down word for word.

Speaker 1: resource 2 task one

New Speaker: differently because I know it's interactive and it's set up with the filters which I went straight to the defects because of the question asked for embryonic defect and so that kind of gave me a lot less options to choose from and narrowed it down. From there we're looking for respiratory and GI system, so gastro and then we're trying to look for, so like trachea, esophagus, anything like that. And then I just kinda read through all the little bios of each single one. Um, I was debating between diaphragmatic hernias versus triggers off a geophysics July or a treacherous for awhile. But then I've read about Triquillo Joseph Geo Fistula one last time and it kind of pretty much word for word what they were asking for. So.
Speaker 1: resource 2 task three.

New Speaker: So for this question, um, they’re looking again for embryonic structure, except there were more specific most dorsal part of the diaphragm and grant to the poster body wall. So, uh, and I remember reading about this in the previous, uh, experiment as well. So again, go to filters. I went to structures and then, uh, I've found crura which was, um, fit the description of most stores part and anchors to the posting body wall and then it back into the Dorsal mesentery. And that's what I got as an answer.
Appendix P: Sample Analysis- Audio Transcripts

Participant E56JS- Group B

PI: resource 1, task 1.

Speaker 1: OK. So basically, um, the words that stood out from the task where pleural and peritoneal cavities and partitioning. So I looked at the timeline and immediately saw that week six with pleural and peritoneal cavities, that jumped out. Um, so I clicked on that and the heading that said, week six: pleural and peritoneal, but I didn’t find anything there. So then I started like moving through the different headings above. Um, but nothing. I didn’t see anything right away. I guess I was expecting the baby picture, because I remember it from the beginning task, but didn’t see it. So I was just like going through the other weeks to see if I had missed the baby anywhere. But then, Um, I went back to week six because I thought it had to be there and I finally found that diaphragmatic hernia. So.

PI: resource 1 task 2.

New Speaker: OK. So the pop-up that popped out were diaphragm. So I went to week 7 because it’s titled “Diaphragm Closes” and I had some idea from classes that I’ve taken before. So, um, basically I went through a diaphragm: muscle rim, muscle portion, central tendon, and crura and then um, the pictures gave it away, but then since crura said “anchored”, I kinda just like went towards that one because end of the scripture that says anchors, but realistically just anchors to the back. So I didn’t pay attention to the lateral body wall, which the picture obviously shows it, even though the description doesn’t say it.

PI: resource 1, task 3.

Speaker 1: OK, so I was looking for the cardiovascular system information, so I knew week five was pericardial cavity forming. So I just started from the top to the PR pleuropericardial fold fusion. And then um, from there I was able to read the description of pleuropericardial fold fusion that, um, this fold is the one that separates the cardiovascular and respiratory system.

PI: resource 2 task 1.

Speaker 1: OK. So, um, at first I didn’t see the filter for um, the defects, but once um, that was clicked and the defects were highlighted, um, it was very obvious and then I just mistakenly thought, well, I went towards what separates the respiratory and gastrointestinal cavities, or the pleural and abdominal cavities versus the respiratory and gastrointestinal systems. So I, I chose the wrong answer at first.
PI: So what drew your eye to diaphragmatic hernia?

Speaker 1: Just because that, I mean, I guess that it was more obvious. Once you really think of a respiratory and gastrointestinal system. Of course I've had like the classes previously which have revealed those defects, so I kind of already know. OK. So the next defect would be the tracheoesophageal fistula because nothing else would really connect the two. But I was thinking cavities and the answer was the most obvious. OK, perfect.

PI: resource 2 task 2.

Speaker 1: OK, so this one was very intuitive. So I knew I was looking for an end organ and what it was derived from. So I went to week seven, clicked on central tendon and then followed the colors which are very nice. Um, and followed it to its origin.

PI: resource 2 task 3.

Speaker 1: Um, here, I did the same thing, so I knew, um, from a previous question and this activity that I had messed up, I put crura as being like anchoring to the lateral wall, but it really connects it, um, anterior to the back. So I already knew, OK, so crura connects it to the back. So I clicked on crura pretty fast and then I saw that it's actually was the dorsal mesentry. Threw me a little bit off that like there were two before dorsal mesentery two lines, but then I quickly figured out, OK, so it just means that from mesoderm, two things are giving rise. So that was fine.
Participant TUBS6- Group C

Speaker 1: OK. So the prompt said to talk about abnormal separations. So I knew it was some kind of defect related to respiratory and the GI tract. So I looked for a, the area where it talked about the respiratory diverticulum and the gut. And for a long time I couldn’t figure out what it was because I didn’t see a section for defects. But then when I went over to filters and it’s pretty self-explanatory where the answer was.

PI: So, um, in terms of making the filters stand out more, what do you think would help?

Speaker 1: Um, I think it, um, I think I didn’t press on filters because I didn’t think it would lead to something that would add on to this map. I thought it was more like something that um, the colors are sort of filters. Filters imply the highlights themselves.

PI: resource 1 task 2.

Speaker 1: OK. So the word that popped out were diaphragm. So I went to week 7 because it’s titled “Diaphragm Closes” and I had some idea from classes that I’ve taken before. So, um, basically I went through a diaphragm; muscle rim, muscle portion, central tendon, and crura and then um, the pictures gave it away, but then since crura said “anchored”, kinda just like went towards that one because end of the scripture that says anchors, but realistically just anchors to the back. So I didn’t pay attention to the lateral body wall, which the picture obviously shows it, even though the description doesn’t say it.

resource 1, task 3.

Speaker 1: OK, so this one, it said the dorsal part of the diaphragm. So I look to the diaphragm to see, um, any other features that popped out to me. And once I clicked diaphragm, this whole thing lit up. So within that I look for the word “dorsal”, which was in dorsal mesentery. And you know, the explanation lead me to the right place.

PI: resource 2 task 1.

Speaker 1: OK, so it’s uh, something about abnormal partitioning of the pleural and peritoneal cavities. So I look for cavities, and there were pericardial, pleural, and I thought I read pericardial, but it was peritoneal. So I went back between these two and these two and then look for defects surrounding it, which got me to ectopia cordis, which was wrong. So once I read it again, I realize was peritoneal. So I look between these two. And in between was type format hernia.
Speaker 1: OK, so I knew it was about the diaphragm, so I looked in that section where there were about four different components of the diaphragm, and I went through each one looking for which one was the most lateral, which turned out to be the muscle.

PI: resource 2 task 3

Speaker 1: OK. So it says separating the cardiovascular system and the respiratory system. So I looked at words like cardio and you know, a plural. And then I found there’s the pleur pericardial folds fusing together to form the pericardial sac, which separates the two, um, respiratory and cardiovascular system.
Appendix Q: IRB Approval Report

Exemption Granted

February 2, 2018

Natalie Yoshioka, BA
Biomedical and Health Information Sciences
809 S. Damen Ave.
SSR Room 604B
Chicago, IL 60612
Phone: (410) 967-2890

RE: Research Protocol # 2018-0050
“Temporal Visualization of Body Cavity Partitioning: An Interactive Timeline”

Sponsors: None

Dear Natalie Yoshioka:

Your Claim of Exemption was reviewed on February 2, 2018 and it was determined that your research meets the criteria for exemption. You may now begin your research.

Exemption Period: February 2, 2018 – February 2, 2021
Performance Site: UIC
Subject Population: Adult (18+ years) subjects only
Number of Subjects: 40

The specific exemption category under 45 CFR 46.101(b) is:
(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

Please note the Review History of this submission:

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You are reminded that investigators whose research involving human subjects is determined to be exempt from the federal regulations for the protection of human subjects still have
responsibilities for the ethical conduct of the research under state law and UIC policy. Please be aware of the following UIC policies and responsibilities for investigators:

1. **Amendments** You are responsible for reporting any amendments to your research protocol that may affect the determination of the exemption and may result in your research no longer being eligible for the exemption that has been granted.

2. **Record Keeping** You are responsible for maintaining a copy all research related records in a secure location in the event future verification is necessary, at a minimum these documents include: the research protocol, the claim of exemption application, all questionnaires, survey instruments, interview questions and/or data collection instruments associated with this research protocol, recruiting or advertising materials, any consent forms or information sheets given to subjects, or any other pertinent documents.

3. **Final Report** When you have completed work on your research protocol, you should submit a final report to the Office for Protection of Research Subjects (OPRS).

4. **Information for Human Subjects** UIC Policy requires investigators to provide information about the research to subjects and to obtain their permission prior to their participating in the research. The information about the research should be presented to subjects as detailed in the research protocol, application and supporting documents.

Please be sure to use your research protocol number (2018-0050) on any documents or correspondence with the IRB concerning your research protocol.

We wish you the best as you conduct your research. If you have any questions or need further help, please contact the OPRS office at (312) 996-1711 or me at (312) 355-2908.

Sincerely,

Charles W. Hoehne, B.S., C.I.P.
Assistant Director, IRB #7
Office for the Protection of Research Subjects

cc:  Anthony Faiola, Biomedical and Health Information Sciences, M/C 530
     John Daugherty, Biomedical and Health Information Sciences, M/C 530