Understanding Student Success in Ultrasound Scanning:
A Grounded Theory Study

Sharlette D. Anderson
University of Missouri
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INTRODUCTION

Sonographers utilize sophisticated equipment to create images of anatomic structures for diagnostic evaluation. The images sonographers create, called sonograms, are usually 2-dimensional representations of the 3-dimensional anatomic structures that are being evaluated. While most modern ultrasound machines can be used to generate 3-dimensional images of some form, their use is currently limited and most diagnostic work is done utilizing 2-dimensional sonograms. Sonographers create these images by manipulating a hand-held probe or transducer against the patient’s body and evaluating the resulting images on a monitor. The professional role for sonographers is independent and requires a high level of clinical competence in part because the sonographer decides which images are “saved” and turned in for interpretation by the physician and which images are discarded. Sonographers are far more than just “picture takers”. Their professional role involves analysis as well as replication and application. Eraut describes application and replication as associated with technical professional knowledge, but describes interpretation and association as components of practical knowledge (Eraut, 1994).

According to the U.S. Bureau of Labor Statistics, the job outlook for sonographers is favorable with an expected growth of about 18% expected through 2018 (Statistics, 2010). The current economic stresses combined with increasing public knowledge about sonography as a career have resulted in increased numbers of applicants to sonography programs across the country. Sonography programs have limited enrollment due to the nature of clinical education, so there are generally more applicants than seats available. Therefore, it is in the best interest of everyone involved for sonography programs to have reliable methods of predicting which applicants are most likely to be successful upon admission. Furthermore, it is important for sonography educators to develop instructional techniques that enable students to be maximally
successful in achieving clinical competence because sonography students who do not achieve a satisfactory level of competence before entering the profession can have a great negative impact on patient care by failing to provide accurate diagnostic information to the interpreting physicians. In order to best achieve these goals, a thorough understanding of the process that sonography students go through when developing the knowledge and skills required to attain clinical competency is required.

There is very little literature available regarding how students become sonographers. From professional conferences to faculty break rooms, sonography educators have long discussed the observation that students who look quite promising on paper with very high GPA, ACT, and SAT scores don’t always excel in the sonography scanning lab. The students in a group who have the highest didactic scores don’t always have the best scanning performance, and, conversely, the students with the best scanning performance don’t always have the best didactic scores. This has led some educators to question the common method of using GPA and college entrance exam scores as the main admission criteria for entry to sonography education programs. Some experienced educators have expressed the idea that spatial ability testing might be a useful admission tool, but it has not been widely employed by sonography education programs at this time. A recent quantitative study demonstrated a possible connection between spatial ability and ultrasound scanning achievement, but it also raised more questions. The researchers administered a paper spatial ability test to a cohort of 17 sonography students and then monitored their scan test scores over two semesters. The initial scan test after 30 hours of instruction did not demonstrate a significant connection between spatial ability and scan test scores, but when the scan test scores over two semesters were evaluated, there was a statistically significant connection according to the researchers with students with higher spatial ability.
scores having higher scan test scores (Clem, 2010). According to the researchers, previous literature reported that dental and surgical students with higher spatial ability tended to perform better initially but their classmates with lower spatial ability scores would catch up over time and the gap in performance would decrease (Clem, 2010). So, what is different about sonography? What is the process that sonography students are going through that makes their spatial ability connection seem more significant later in the learning process?

Due to the paucity of literature relating directly to sonography, other clinical professions were explored in an attempt to gain insight into how clinical competency is gained by health profession students. A grounded-theory study from Norway about OB/GYN residents describes the process by which clinical education helps post-graduate medical students take their didactic or “codified” knowledge from medical school into the clinical workplace of the residency environment and, through observation, application, interpretation, and reflection, build a body of the “personal” or experiential knowledge that is needed for clinical competency (Teunissen, 2007). This description fits with Slotnick’s thoughts regarding medical training. He made the point that medical school and residency training do not give new doctors everything they need to become clinically competent because they need to also reflect on what they learned during these educational periods as they proceed through the daily requirements of clinical practice with their own patients (Slotnick, 2001). Both of these studies are specific to the experience of resident or newly licensed physicians. In current medical practice, physicians are certainly not the only clinical practitioners on the healthcare team. Nurses, pharmacists, therapists, and sonographers, as well as other members of the team, all need practical knowledge and clinical competency in order to enter their respective professions. Unfortunately, there is very little literature regarding the phenomenon of sonographers developing clinical competency. New sonographers need the
opportunity to reflect on their didactic learning and its application in the clinical setting as they transition from student to professional. Most sonography education programs are largely made up of didactic, or theory classes in the beginning and clinical hours are added as students progress through the curriculum so that by the end of the program students are spending many hours in the clinical setting. During the clinical rotations, sonography students apply codified knowledge from their didactic courses to real patients and also observe the actions of the more experienced sonographers who act as clinical preceptors and mentors. As they interact in the clinical setting with experienced sonographers, patients, interpreting physicians, and other members of the healthcare team, the sonography students begin to build the base of practical knowledge which is so important for clinical competency. Again, Eraut’s point regarding the premise that reflection is necessary for building personal knowledge or schemas which can be used for future reference in similar situations is brought to mind (Eraut, 1994). Social learning theories have also begun to be applied to clinical teaching. By putting health professions students in the clinical workplace in a setting where they can observe and emulate an expert in the field, they begin to find entry into the professional community they are aspiring to (Irby, 1997).

Spatial ability, specifically visual spatial ability, is a topic of much interest in professions that are highly visual such as radiology, dentistry, and surgery. Sonography is also a highly visual occupation. A 1984 study of radiology residents demonstrated a strong correlation between accuracy of radiograph interpretations and scores on a 3-dimensional visual spatial ability test. The purpose of this study was to examine a possible link between innate spatial ability as it relates to translation between 2-dimensional and 3-dimensional structures and to determine whether spatial ability testing could prove an accurate predictor of radiology resident
success (Smoker, 1984). Once again, the study focused on those who interpret the images rather than those who create them, but it seems that the process would be similar, so one would think it logical to expect similar findings for sonographers. Clem’s study (Clem, 2010) demonstrated a possible connection between visual spatial ability and sonography student achievement, but how does it really work?

**Purpose Statement**

This qualitative study was developed to dig deeper into the process and to understand more about how sonography students from a Midwestern university successfully learn to create and draw meaning from sonographic images and also more about the apparent link between visual spatial ability and the process of learning sonography. Success is defined as achieving passing scores on scanning competency tests in the scanning lab on campus and by the students themselves as they describe their own growth as they work toward clinical competency.

**Methodology**

**Research Questions**

A grounded theory methodology was followed for this study because the research involved developing understanding of a process. Grounded theory will aid in seeking an explanation of the learning process and the role that visual spatial ability plays (Cresswell, 2007), also providing more insight regarding the participants’ own viewpoints of their learning process to the information that has been obtained in the quantitative study mentioned before. In order to understand how students think as they go through a process, their voices must be heard. A qualitative approach is best suited to giving voice to the participants themselves.

The central research question for this study was, “How do sonography students successfully learn to create and draw meaning from diagnostic ultrasound images?” The related
sub-questions are as follows: (1) How do sonography students achieve ultrasound scanning success, (2) What factors do sonography students believe influence their success in ultrasound scanning, (3) How do sonography students perceive spatial ability in ultrasound scanning, and (4) Under what circumstances does visual spatial ability aid ultrasound scanning success for sonography students?

_Data Collection_

A purposeful sampling of first-year sonography students at a Midwestern university was done so that all participants were experiencing the process being studied at roughly the same stage. The study was approved by the university’s Institutional Review Board and written consent was obtained from all participants. All first-year students in the program were invited to participate in the study. Participation was strictly voluntary and the students had the option to remove themselves from the study at any time. All students were given an overview of the study aims and design and those who wished to participate arranged a mutually convenient time to meet with the researcher to sign the consent and to do an initial interview. Three participants were selected for this initial analysis, two females in their early 20’s and one male in his 40’s. Interviews were completed by the male and one of the females, and think-aloud exercises were completed by both females. In all, a total of 19 participants have agreed to participate in this research study; 14 females and 2 males. Their ages range from the early 20’s to mid 40’s.

The data obtained for this study were collected from individual face-to-face interviews and think-aloud exercises. Each student was interviewed once in the researcher’s office at the choice of the participants. Written consent was obtained from each participant prior to conducting the interviews and specific consent was obtained for audio-recording each time before the interviews or think-aloud exercises were conducted. The interviews were
approximately one hour in length and the think-aloud exercises ranged from 45 to 70 minutes.
At the conclusion of the interviews, participants were invited to contact the researcher if they had any questions or felt that they had any more information that would lend insight to the process being studied.

For the think-aloud exercises, the participants were asked to scan a young, healthy model and obtain images for the abdominal ultrasound protocol of their choice from the protocols they scanned during the semester. They were asked to verbally describe their actions as they manipulated the transducer, machine controls, and interacted with the scanning model.
Observations were made during the think-aloud exercises which were immediately noted to provide a rich description of the participants’ reactions and body language which contributed more detail about the feelings the participants were expressing non-verbally while scanning through the protocol.

Data Analysis

Open, axial, and selective coding were employed in the data analysis consistent with grounded theory methodology. The interviews and think-aloud exercises were transcribed verbatim and analyzed sentence by sentence. Open coding was performed and then keywords were combined into categories during axial coding. The interviews and think-aloud exercises were treated separately during open and axial coding due to the difference in the type of data collection. The axial codes were then combined for selective coding of the emerging themes. Selective coding was then utilized to identify themes that described the emerging theoretical construct. Analysis was an ongoing process throughout the study and coding was repeated multiple times as more data was gathered.
Open coding identified approximately 60 codes which were consolidated to 27 axial codes and finally through selective coding into seven themes that described the core process that the participants described. Throughout the analysis, the question was constantly asked, “What are the participants saying about the process of learning to create and draw meaning from sonographic images?” The role of visual spatial ability became a sub-question to the central question of the overall process of learning ultrasound scanning.

Validation of this study was sought through triangulation, peer review, and immersion in the field. Data were sought from multiple sources by utilizing interviews and think-aloud exercises. Peer review was sought from another ultrasound educator in the program, and the data was discussed with the participants themselves in order to ensure that the voice of the participants was not obscured by the bias of the researcher. The primary researcher has been a sonographer for more than 20 years and has been a full-time ultrasound educator for over seven years. A desire for understanding in order to improve teaching practice was the driving force for the researcher. This researcher was also a co-investigator in the quantitative study that raised some of the research questions for this study, so care was taken to separate the quantitative stance of the previous study from the current qualitative study and to ensure that the interpretations of the researcher were not biased in such a way as to distort what the participants intended to say.

**Findings**

The central theory derived from this study is called *striving for clinical competence*. It describes the process that the sonography students in one university based ultrasound program undergo as they learn how to create and draw meaning from diagnostic ultrasound images. This process includes a central goal of attaining clinical competence and a central distracter of high
cognitive load. Between the goal and the distracter are five additional themes that describe the skills that the sonography students must master in order to complete the component of clinical competence that revolves around the ability to create and analyze sonographic images. These five additional themes include: (1) generating a mental three dimensional anatomic map; (2) manipulating the transducer; (3) optimizing images; (4) analyzing images; and (5) meeting high expectations of themselves and of others. The theory is depicted in Figure 1 in the appendices.

The study participants represented a range of the demographics seen within their classmates. Participant 1 was a white female in her early 20’s. She was from a small town and was on her first career path. Participant 2 was a white male in his 40’s. He was from an urban area and had enjoyed a previous career as a photojournalist before deciding to embark on a career in sonography. Participant 3 was a white female in her early 20’s. She was from a very large town and was also on her first career path. All three participants were in their second semester of the ultrasound program and in the first semester that included scanning competency tests in the curriculum.

*Generating a Mental Three Dimensional Anatomic Map*

Both participants in the study emphasized the importance of being able to look at a sonographic image and place it within a mental map of the overall anatomy of the abdomen. The necessity of intimate knowledge of anatomy was the most recurrent topic throughout the interviews and the think-aloud exercises. Both participants expressed a sense of pride and accomplishment in the amount of anatomic knowledge they were attaining and in their ability to apply it to ultrasound scanning. Participant 2 said:

“…so, when I say really knowing your anatomy, I mean having this …building your own little virtual 3D picture in your head of the abdomen and if you really
have that 3D picture accurate and complete, then it’s so much easier to associate the image on the screen with your picture in your head if you just if you really know…um…you know, what percentage of the abdomen the liver is taking up, you know, it just….that’s kind of how I thought about it is….think about all the major players, the liver, the pancreas. Think about how big they are….what portion of this abdomen are they filling up? And then how do they relate to each other? The pancreas is not up top of the liver, no, ok let’s move it down in your picture, let’s kind of push it behind, you know…if you just kind of have that 3D picture in your head, then umm…you’re looking, then when you’re scanning, you’re sitting there in front of the person to the side of them and then so you just first of all just throw that 3D picture like kind of overlay it over their body…ok, and then you’ve got the transducer, so you know, I’m gonna look at little slices of my picture in my head and I’m kind of testing the accuracy of my picture in my head…”

It seems that sonography students can easily get disoriented when looking at sonographic images if they do not have the mental “roadmap” to use as a guide. They need a global reference in which to place the sectional images they create in order to draw meaning from them.

**Manipulating the Transducer**

Sonographers create their images by manipulating a hand-held transducer over the patient’s body. It involved an element of eye-hand coordination similar to that of playing the piano or typing without looking at the keys. With experience they develop the ability to manipulate the transducer almost subconsciously in response to the image they see on the
monitor in order to get images of the area of interest. However, the participants in this study indicated that it is not an easy skill to develop. Participant 1 said:

“I think, knowing what you’re looking at and figuring out how that’s laid …and…how that organ or structure is laid in the body to where you can move the transducer and see it or …like knowing how the beam …That’s one of the things that I had the hardest time in the summer was learning how the beam goes through the structures that you’re looking at….because when you’re putting the beam on top, you’re not looking at it like flat, you’re like taking a slice through it, and I think that was hard for me to realize, but I finally got it.”

**Optimizing Images**

Ultrasound equipment is very complex with many controls that sonographers can use to manipulate the sound beam and the images generated. Additionally, minute manipulations of the transducer can dramatically change the image. The study participants described image optimization as one of the hardest things to learn about creating useful diagnostic ultrasound images. Participant 2 said:

“…what’s hardest is to feel like you just got a “A” picture, a gold star picture, like this is the textbook…that is technically and anatomically an awesome picture of the pancreas, because, I’m feeling like, dang, that gas is there, or I just can’t quite…it if I do this, I lose that…you know…there’s so many…ways you can change the picture…and then lose something you might want.”

**Analyzing Images**

Sonographers do much more than just create sonographic images. They are constantly editing the images they create, deciding what to send to the interpreting physician and what to discard as well as deciding what can or should be done to make the image better. First year
sonography students begin this process by analyzing anatomic landmarks on the image to determine whether they are in the area of interest. By comparing the image on the monitor to their mental anatomic roadmap, sonography students evaluate the landmarks seen and determine how to manipulate the transducer to center on the area of interest. During the think-aloud exercise, Participant 1 chose to do a sonogram of the abdominal aorta. This was the first scanning protocol that the sonography students learned. She said:

“And so, we move on to where you have the celiac and the SMA…in the picture and that’s the mid.”

The fact that the celiac and superior mesenteric arterial branches of the aorta were present on the image helped the participant decide that she was in the desired area of the aorta for this part of the protocol.

When Participant 3 did her think-aloud exercise, she also chose the aorta protocol. She struggled to work around bowel gas which distorts the sonographic image as she looked for her landmarks. She said:

“…that’s the SMA….but I just can’t tell because it’s not like really a distinct break, and I can’t adjust it…”

“I started back at the top (mumbles) I’m trying to get a better picture, but I can’t (sigh). So I need to change my (indistinguishable). Hmmm, gotcha!”

“…I can finally see the SMA coming off, so ….and that’s like the …one of the major landmarks…and I’m pretty sure that’s the body of the pancreas (points on the screen).”

Meeting High Expectations
Due to the current nature of admissions screening in most university based sonography education programs, sonography students are typically high-achievers who are accustomed to academic success. They set high expectations for themselves. Additionally, these students perceive others to have high performance expectations from them. The general education and science prerequisites for sonography educational programs tend to be traditional lecture based didactic courses that involve information being dispensed by the instructor with the student being an almost passive recipient. Courses of this nature tend to revolve around codified knowledge with little if any practical application required (Eraut, 1994). The ultrasound scanning lab is a much more constructivist atmosphere where the instructor demonstrates the scanning protocol and provides initial guidance while the students practice, but the students must figure out much of the technique for themselves because it becomes more real for them than if they are led by the hand throughout the entire scanning practice. Most first-year sonography students are not used to this type of atmosphere. They are used to being given a list of things to accomplish and knowing that if they accomplish the things on the list they will get the grade they desire for the course. Participant 1 said:

“Ummm...Kind of...I thought maybe there would be like more direction when it comes to scanning, but you kind of just put us in there and are like...just start scanning and...figure it out and get used to it. So that was kind of hard. ... I think it’s helpful because you have to figure it out and you learn by figuring it out yourself. So...I don’t’ know. I think it’s good and bad at the same time.”

She was uncomfortable with the constructivist atmosphere in the scanning lab but could also see the advantages it provided as well as the challenges.
Participant 2 also commented on the difference between the type of instruction and learning involved in the ultrasound scanning lab as compared to traditional courses as well as his own expectations for himself:

“I just haven’t had as much positive feedback and confidence from what I’m trying to do and what I’m getting done with scanning, whereas, my other tests and the other challenges of the program, the feedback’s more concrete, and for better or for worse, you know how you’re doing and it just seems like with scanning, it’s more vague and more nebulous how I’m really doing.”

**Dealing with High Cognitive Load**

The many new tasks, the amount of prerequisite knowledge, and the unfamiliar instructional setting combine to create a very high cognitive load for the students. Both of the interview participants described feeling sometimes a little overwhelmed and emphasized that time management was a key ingredient for success in the program. Participant 1 said:

“Ummm…I think remembering all your classes…remembering everything you have to do in each of your classes every week and studying for every test and…sometimes your tests on the same day…and just I think time management. Because I’ll get home and my roommates have been home for 6 hours already and I’m just getting there and I have homework to do, so…I don’t…It’s just time consuming, but you have to do it, so…I don’t know what else to say.”

The students’ own expectations for themselves also contribute to the high cognitive load. Participant 2 said:
“...my feeling when I finished competencies so far has been that I just wish that I was better at it. I just wish I could have done better. I wish it had been easier, you know, I wish I could have done it with more ease.”

**Attaining Clinical Competence**

As the students gained experience operating the ultrasound machines and scanning healthy models, they began to reduce their cognitive load to some extent. Their mental anatomic roadmap became more concrete and fully developed. They developed muscle memory that allowed some manipulation of the transducer to become more automatic. Image optimization was not as big a struggle as it was in the beginning. Analysis of the images to localize the area of interest and determine whether or not the image is of diagnostic quality also became more familiar. The participants expressed a common concern about being competent when they began to interact with real patients in the clinical setting. Participant 2 said:

“I’m just here to try to you know, umm, not do any clinical harm when I get out there. Not mess anything up too bad and uh, most importantly just not look like a total horse’s ass too much of the time, you know… Look like a little ass a little of the time is going to happen…you know, like people who…who I encounter that think “He’s trying hard and he’s doing really well for you know, for where he’s at. He’s not a 5 year experienced person, but, but, you know, he seems to know more than he should or we might expect him to know”. I’d like to be a little ahead. That’s kind of my goal.”

**DISCUSSION**

**Summary of Findings**
The central theory generated from this study, striving for clinical competence, defines factors that sonography students deal with when learning how to create and draw meaning from sonographic images. One of the most important factors that influences their success is the generation of a mental three dimensional anatomic representation of the area that is to be scanned which is used as a guide when analyzing the sonographic images that are created. All of the participants stressed in the interviews how important anatomic knowledge is when learning to do ultrasound scans, and the importance of this roadmap was also brought out in the think aloud exercises as evidenced by the participants’ frustration when they could not see the landmarks they expected to see. This seems to be the theme where visual spatial ability is most relevant. The ability to look at a two dimensional image and visualize the three dimensional structure it is representing is a core element of the generation of this mental anatomic guide, and previous literature has demonstrated a relationship between visual spatial ability and success at interpreting diagnostic images (Smoker, 1984). This is not to say that sonography students are doomed to fail if they do not have high visual spatial ability, but to suggest that those whose visual spatial skills are less developed may have to work harder to create their mental anatomic roadmap.

As the sonography students develop their mental anatomic model, they also learn to navigate this mental anatomic map by mentally placing the images they create in the appropriate locations within the mental representation in order to localize the area they are focused on examining and also to compare the images they create with what they have learned to think of as “normal”. As they manipulate the transducer and scan through the body, the sonographic images they create need to correspond to their mental map in order to make sense. Early on, sonographers recognize variations from what they expect to see as defects in their mental map or
ineptitude at manipulation of the transducer. As they become more confident and their mental representation is more fully developed, they begin to recognize variations as “not normal”. Eventually, with even more experience, they begin to recognize patterns that deviate from “normal” as consistent with particular types of pathology. This is all part of the journey from codified knowledge to practical knowledge (Teunissen, 2007). The participants in this study were still in the beginning stages of the process; still filling in the holes in their mental anatomic representations and learning to recognize what they saw on the sonographic images as either “normal” or “not normal.”

Concurrently with generation of the mental anatomic representation and manipulation of the transducer, sonography students also learn to manipulate the controls on the ultrasound equipment to optimize the images they create. Everything from formation of the sound beam to degree of echo amplification to the number of shades of gray displayed in the image can be manipulated to make the image more acceptable to the sonographer and in turn the interpreting physician. Sonography students learn early on that fluid filled structures should be black, solid organs should be various shades of gray, and highly reflective structures like calcifications should be white. However, that is a tremendous understatement of the detailed analysis that is involved in deciding when the image is as good as you can make it for that particular structure on that particular patient. Again, modeling, application, and reflection are needed to build the practical knowledge required to attain competency (Slotnick, 2001). Determining when a particular sonographic image is optimal for the case in hand cannot be taught from a book. It must be experienced. The participants in this study all seemed to struggle with the nebulous nature of this skill. They lacked confidence in their ability to take a stand and be sure that the image they had created was optimal. An experienced sonographer or ultrasound educator can
tell them that it takes time and experience, but that is small comfort to them in the early stages of
the program as they struggle to master the concepts and applications.

Hand in hand with image optimization comes analysis of the images that the sonography
students create. Sonographers are constantly analyzing the images they create to determine
whether they are in the desired location, whether the image is properly optimized, whether the
appearance of the structures imaged is consistent with “normal”, and whether or not the image on
the screen should be stored for interpretation by the physician. This is yet another example of
the practical knowledge required in order to reach clinical competency for sonographers.

Due to the complexity of the tasks involved in the creation and analysis of diagnostic
ultrasound images, sonography students have high expectations for their own performance. The
participants in the program expressed anxiety about appearing less knowledgeable than they
should when they begin clinical rotations. They anticipate that the clinical preceptors will also
have high expectations for their level of knowledge and skill and are afraid of falling short. The
independent and responsible nature of the sonographer’s professional role also contributes to the
high expectations that sonography students have for themselves and that their mentors have for
them.

All of the themes discussed thus far contribute to a major distracting theme of high
cognitive load. The pressure to achieve is great for sonography students. They are typically high
achieving students who are accustomed to academic success. The transition from the
“traditional” classroom to the application based scanning lab definitely contributes to the
cognitive load experienced by the participants in this study. All of them expressed discomfort
with the constructivist atmosphere in the ultrasound scanning lab. In addition, the multiple
complex tasks involved can seem daunting in their own right. Each of the themes discussed
involves ill-structured complex problem solving that is taxing for most beginners. When they are all combined together, the load can seem overwhelming at times.

As sonography students progress through the program and put all the pieces together, a synthesis of codified knowledge, application, and experience occurs and the students get closer and closer to their goal of clinical competency. The participants in this study were chiefly concerned with making sure that they were capable of fulfilling their professional role upon completion of their education. They expressed the sentiment that all the stress and hard work would be worth it as long as they could provide compassionate and competent patient care when they entered the workforce. This goal is shared by the educators involved. Most sonography educators could be more successful at least financially in the clinical workplace than they are in education. Experienced sonographers generally become ultrasound educators because they want to ensure that the future generation of the profession is competent and will contribute to the advancement of the profession.

Lessons Learned

Generation of the three-dimensional mental representation of the anatomic relationships of the area being examined is a crucial key to the success of sonography students as they learn to create diagnostic sonographic images. It could be argued that the success of the other learning themes of manipulating the transducer, optimizing the image and analyzing the image all hinge on the successful development of this mental anatomic guide. Visual spatial ability also plays a logical role in this element. Therefore, knowledge of students’ or applicants’ visual spatial ability is useful to educators and students alike if it is used as a means of detecting those students who potentially need extra guidance or help to achieve successfully complete their education and to achieve clinical competency which ultimately defines success for both students and their
mentors. Understanding of the role that visual spatial ability plays in the generation of this mental anatomic representation enables sonography educators to better design instruction to meet students’ needs by encouraging and aiding its development. While it is true that sonography programs routinely have more applicants than available seats and are therefore in search of more accurate means of predicting which students are most likely to succeed upon admission to the program, the primary goal of this research is to better understand the process by which sonography students learn to scan and to develop ways of helping them to achieve success, not the development of a tool for “weeding out” applicants.

Sonography students endure a very high cognitive load due to the large number of complex and completely foreign tasks that they are required to undertake at virtually the same time combined with their own expectations of success for themselves and the performance expectations, real and perceived, of others for them. The pressure of such a large cognitive load can be overwhelming at times and is certainly a source of frustration for the participants in this study. They want to know everything they need to know very quickly. Sonography students are accustomed to and comfortable with academic success, often with less effort than many of their peers previous to admission to the sonography program. When they are confronted with such new and complex tasks in a foreign learning environment, the students may perceive themselves as failing even if the instructors see their progress as satisfactory for the stage of the program they are in. If educators and other mentors can find ways to begin the process in a more gradual manner so that perhaps the mental anatomic representation is more fully developed before students are expected to begin to learn scanning protocols, the cognitive load could be reduced somewhat. Also, if sonography students better understand the stages of progress that are expected of them, perhaps their own expectations would not be quite so high, thus further
reducing the cognitive load by relieving them of some of the pressure to “know it all right now”. The fact of the matter is that sonography education programs, even those that are university based, have a short time to cover a lot of material in depth and detail. Educators will have to be quite creative at developing ways to help students reduce their cognitive load without diluting the curriculum in a way that hampers students reaching clinical competency by the completion of their educational program. However, we all like a challenge if the cause is a good one, and it seems the participants in this study would certainly benefit.

The ultimate goal and definition of success is shared by sonography students, educators, and mentors. Achieving clinical competency is the overreaching theme for this study and it is related to the theory that emerged. As sonography students work to generate their mental representation of the anatomy, manipulate the transducer in a way that the sonographic images created make sense in the context of the mental anatomic representation, and to work on the details of optimizing and analyzing the sonographic images so that they are meaningful, their main concern is clinical competence. The participants in this study are drawn to careers in sonography partially because of the level of clinical competency and expertise required. They want to have an active role in patient care, to have a positive impact on patient outcomes. The same characteristics of the profession that make it attractive to them make it challenging to achieve clinical competence. These students are not looking for an easy way out and they don’t want to just know enough to scrape by. They want to be competent professionals who can contribute to healthcare in a meaningful way and are willing to expend the time and effort required to do so. The participants were concerned about the potential for them to do clinical harm to patients if they don’t know what they are doing. Students in sonography education programs are making a huge investment of time and effort as well as money. They deserve to
have those involved in their education be equally invested in their success to the extent that every effort is made to understand their needs and to design instruction that maximizes their chances of successfully achieving their goals.

**Limitations**

The participants in this study were students at a university based sonography program which grants a minimum of a bachelor of science to its graduates. The majority of sonography education programs in the United States are two-year, community college or technical school based programs that grant associate degrees. Historically, sonography education began as hospital based programs that granted certificates and many sonographers were trained on the job. That avenue of entry to the profession has been eliminated in recent years by making it impossible to get credentialed by the national registry board without formal sonography education. Still, the majority of sonographers entering the profession in the United States at this point are not coming from university based programs. The process for sonography students in a community college or technical school based program is arguably different from that of students in a university based program. The process has to have similarities, however, because the standards for clinical competency are universal for the profession regardless of the educational background of the sonographer. Further study involving participants from other types of sonography education programs would provide further insight into the research questions raised here.

At the time of writing, this study is limited by the number of participants. As the study continues, gathering and analyzing multiple sources of data from the other 16 participants, the emerging theory will either be further validated or adjusted to reflect the additional data. The
opportunity to glean more insight into the students’ viewpoints of their learning process is exciting and has the potential to have a dramatic impact on instructional design.

**Implications for the Future**

The quantitative study looking at the possible link between spatial ability and ultrasound scanning achievement has been expanded into a multi-center study involving community colleges and private vocational school programs as well as university based programs. Looking at the results of both the quantitative and qualitative methods of research on this topic should be very enlightening and provide a fresh and long overdue look at just how sonography students develop clinical competence and become sonographers. Formal ultrasound education programs have been in existence for more than 30 years now. It is high time that researchers spent time developing an understanding of the students, their needs, and the processes they undergo. Students and educators both spend too much time, money, and effort producing the next generation of sonography professionals to waste time not doing it well. The theory that emerged in this study is the beginning of a potential pathway to better preparation of pre-sonography students as well as better instructional design within sonography education programs. If the students understand up front the elements that are essential for success and the steps that seem to be fairly universal for all sonography students, their cognitive load should be reduced and their expectations should be more realistic. If the educators and mentors understand the same principles more deeply, they can more readily identify potential sources of trouble for struggling students and more efficiently design instruction to enable them to succeed. This is just the beginning. The potential for the future is exciting indeed.
References


Figure one depicts the theory *striving for clinical competence* that emerged from the study. The key learning elements combine to contribute to the high cognitive load described by the participants. As the learning elements are applied and begin to be translated from codified to practical knowledge, synthesis occurs and the sonography students move closer to their ultimate goal of becoming clinically competent.
APPENDICES

Appendix 1: Informed Consent

CONSENT FORM TO PARTICIPATE IN A RESEARCH STUDY

INVESTIGATOR’S NAME: SHARLETTE ANDERSON, MHS, RDMS, RVT, RDCS
PROJECT # 1176501

FOR HS IRB USE ONLY
APPROVED

________________________________________________
HS IRB Authorized Representative Date

EXPIRATION DATE: ________________________

STUDY TITLE: DO YOU SEE WHAT I SEE? A QUALITATIVE EXPLORATION OF SPATIAL ABILITY AND STUDENT SUCCESS IN ULTRASOUND SCANNING

(Title changed after IRB approval to Understanding Student Success in Ultrasound Scanning: A Grounded Theory Study)

INTRODUCTION

This consent may contain words that you do not understand. Please ask the investigator or the study staff to explain any words or information that you do not clearly understand.

This is a research study. Research studies include only people who choose to participate. As a study participant you have the right to know about the procedures that will be used in this research study so that you can make the decision whether or not to participate. The information presented here is simply an effort to make you better informed so that you may give or withhold your consent to participate in this research study.

Please take your time to make your decision and discuss it with your family and friends.

You are being asked to take part in this study because you are a Diagnostic Medical Ultrasound student.

This study is not being sponsored by anyone.

In order to participate in this study, it will be necessary to give your written consent.
WHY IS THIS STUDY BEING DONE?

The purpose of this study is to further analyze the potential relationship between spatial ability and student success in ultrasound scanning. In a previous quantitative study, it was found that the relationship between spatial ability and student success in ultrasound scanning may be different than the relationship between spatial ability and student success in other fields that have been studied, like dentistry. This qualitative study is designed to further explore the process that DMU students undergo when learning to perform ultrasound scans to develop an understanding of the potential relationship between spatial ability and student success in learning this skill.

This research is being done because a better understanding of the relationship between spatial ability and student success in ultrasound scanning can lead to better instructional design that helps Diagnostic Medical Ultrasound students successfully learn and become competent professionals.

HOW MANY PEOPLE WILL TAKE PART IN THE STUDY?

About 19 people will take part in this study at this institution.

WHAT IS INVOLVED IN THE STUDY?

If you take part in this study, you will have the following tests and procedures:

• Audio-recorded think-aloud exercise as part of the feedback procedure following an ultrasound scan test.
• Audio-recorded interview regarding your perceptions of the thought processes and skills required to be successful at ultrasound scanning.

HOW LONG WILL I BE IN THE STUDY?

We think you will be in the study for 2 semesters (approximately 9 months).

The investigator may decide to take you off this study if you elect to leave the Diagnostic Medical Ultrasound Program before the study is completed.

You can stop participating at any time. Your decision to withdraw from the study will not affect in any way your class standing or grade.

WHAT ARE THE RISKS OF THE STUDY?

There are no anticipated risks associated with this study.

ARE THERE BENEFITS TO TAKING PART IN THE STUDY?

If you agree to take part in this study, there may or may not be direct benefit to you. You may expect to benefit from taking part in this research to the extent that you are contributing to educational knowledge. We hope the information learned from this study will benefit other DMU students in the future.
WHAT OTHER OPTIONS ARE THERE?

An alternative is to not participate in this research study.

WHAT ABOUT CONFIDENTIALITY?

Information produced by this study will be stored in the investigator’s file and identified by a code number only. The code key connecting your name to specific information about you will be kept in a separate, secure location. Information contained in your records may not be given to anyone unaffiliated with the study in a form that could identify you without your written consent, except as required by law.

It is possible that your research record, including sensitive information and/or identifying information, may be inspected and/or copied by federal or state government agencies in the course of carrying out their duties. If your record is inspected or copied by any of these agencies, the institution will use reasonable efforts to protect your privacy and the confidentiality of your research information.

The results of this study may be published in a medical book or journal or used for teaching purposes. However, your name or other identifying information will not be used in any publication or teaching materials without your specific permission.

In addition, if photographs, audiotapes or videotapes were taken during the study that could identify you, then you must give special written permission for their use. In that case, you will be given the opportunity to view or listen, as applicable, to the photographs, audiotapes or videotapes before you give your permission for their use if you so request.

WHAT ARE THE COSTS?

There is no cost to you for participating in this study.

WILL I BE PAID FOR PARTICIPATING IN THE STUDY?

You will receive no payment for taking part in this study.

WHAT ARE MY RIGHTS AS A PARTICIPANT?

Participation in this study is voluntary. You do not have to participate in this study. Your present or future care will not be affected should you choose not to participate. If you decide to participate, you can change your mind and drop out of the study at any time without affecting your present or future standing in the program. Leaving the study will not result in any penalty or loss of benefits to which you are entitled. In addition, the investigator of this study may decide to end your participation in this study at any time after she has explained the reasons for doing so.

You will be informed of any significant new findings discovered during the course of this study that might influence your health, welfare, or willingness to continue participation in this study.
WHOM DO I CALL IF I HAVE QUESTIONS OR PROBLEMS?

If you have any questions regarding your rights as a participant in this research and/or concerns about the study, or if you feel under any pressure to enroll or to continue to participate in this study, you may contact the University of Missouri Health Sciences Institutional Review Board (which is a group of people who review the research studies to protect participants’ rights) at (573) 882-3181.

You may ask more questions about the study at any time. For questions about the study or a research-related injury, contact Sharlette Anderson at 573-884-4369.

A copy of this consent form will be given to you to keep.

Signature

I confirm that the purpose of the research, the study procedures, the possible risks and discomforts as well as potential benefits that I may experience have been explained to me. Alternatives to my participation in the study also have been discussed. I have read this consent form and my questions have been answered. My signature below indicates my willingness to participate in this study.

Subject/Patient*  Date

*A minor’s signature on this line indicates his/her assent to participate in this study. A minor’s signature is not required if he/she is under 7 years old. Use the “Legal Guardian/Advocate/Witness” line for the parent’s signature, and you may use the "Additional Signature" line for the second parent’s signature, if required.

SIGNATURE OF STUDY REPRESENTATIVE

I have explained the purpose of the research, the study procedures, identifying those that are investigational, the possible risks and discomforts as well as potential benefits and have answered questions regarding the study to the best of my ability.

Study Representative**  Date

**Study Representative is a person authorized to obtain consent. Per the policies of the University of Missouri Health Care, for any ‘significant risk/treatment’ study, the Study Representative must be a physician who is either the Principal or Co-Investigator. If the study is deemed either 'significant risk/non-treatment' or 'minimal risk,' the Study Representative may be a non-physician study investigator.
Appendix 2: Interview Protocol

Interview Questionnaire

Understanding Student Success in Ultrasound Scanning: A Grounded Theory Study

Study participants will be asked the following questions in a face-to-face interview. Questions and answers will be audio-recorded with the participant’s knowledge for transcription and coding.

1. How do you like DMU so far?

2. What are your impressions of the DMU program here at the University of Missouri?

2.b. Can you explain how the program has or has not met your expectations?

3. What do you think about the perception that some students find ultrasound scanning easier to learn than others?

3.b. Can you tell me more specifically about this?

4. How important do you think eye-hand coordination/motor skills are for learning to do ultrasound scans?

4.b. Please elaborate and/or give an example.

5. What do you think is the easiest thing about learning to do ultrasound scanning?

5.b. Please tell me more.
6. What do you think is the hardest thing about learning to do ultrasound scanning?

6.b. Please elaborate.

7. What did you do to prepare for ultrasound scan tests?

7.b What do you think you did particularly well when preparing for ultrasound scan tests?

7.c What, if anything, do you wish you had done differently when preparing for ultrasound scan tests?

8. Can you describe the type of person you envision to be best suited to doing ultrasound scans?

9. Is there anything else you’d like to tell me that you think would help me to understand what it’s like to try to learn how to do ultrasound scans?
Appendix 3: Think-aloud Protocol

Think Aloud Protocol
Understanding Student Success in Ultrasound Scanning: A Grounded Theory Study

Participants will be asked to go through the ultrasound scanning procedure that they were most recently tested over. They will be asked to talk out loud about each thing they do. As needed, participants will be prompted with the questions listed below. The exercise will be audio-taped with the participant’s knowledge for later transcription and coding.

Sample Prompting Questions:

1. What are you working toward?
2. What did you expect to happen when you did that?
3. How did you expect that to work?
4. Can you tell me what you were thinking?
5. What do you want to accomplish here?
6. Describe the steps you are going through here.
7. Tell me about your thinking here.

The participant is in control of the exercise. The interviewer is merely an observer and is only to ask questions to remind the participant to speak out loud about what he/she is doing.
Appendix 4: Interview Transcripts

Subject 1—MM (Undergraduate, Female, 22-24, Hometown: Albany, MO)

I: OK, so, um…How do you….how do you like the DMU program so far; what do you think about it?

S: I like it a lot, actually. I was really nervous, but now that we’ve started, I realize that learning stuff that you need to know is so much better than learning about art history or something really awful. So, I really like it, and you guys are good teachers. So, …and you care about everyone ….and it’s really hard, but it’s…I like it a lot better than just undergraduate work.

I: Do you think it’s what you expected?

S: Ummm…Kind of…I thought maybe there would be like more direction when it comes to scanning, but you kind of just put us in there and are like…just start scanning and…figure it out and get used to it. So that was kind of hard.

I: After you’ve done that a little while, do you, do you…How do you feel about that? Do you think it’s helpful or do you think you would rather have more hands on direction?

S: I think it’s helpful because you have to figure it out and you learn by figuring it out yourself. So…I don’t know. I think it’s good and bad at the same time.

I: um hmm

S: Because, if you’re doing something and you don’t know how to do it then it’s kind of hard.

I: Umm, did you…Did you look at other DMU programs when you applied here or…?

S: Umm, I did, but I knew I wanted to be in Missouri, so I didn’t really focus on..out of state, like the ones I could find that were actual, like programs at universities and not just like, like Vatterott College and like those kinds of programs…like you have to go far away for like those kinds of programs.

I: Yeah, there’s only one in any given state, I think.

S: Yeah.

I: So..what are your impressions of the program itself so far here? How do you think this program compares to other DMU programs? Or do you feel like you really have…

S: I think it’s a lot more difficult. I feel like we have to learn more anatomy and more things compared to like radiology and …….I don’t know. I don’t want to say that because I know you have to learn a lot in any program, but, I don’t know; I definitely think this is harder because we are controlling the machines compared to radiology. This is a lot more difficult, I think.
I: Do you think that’s a plus or a minus? Do you think…What do you think about that?

S: A plus. Because we have to know the stuff to be able to do it in real life in a job

I: Mmm mm

I: What attracted you to sonography to start with? What made you think you wanted to do ultrasound?

S: Ummm… I thought it was cool, and I did some….I took Mariana’s class. I thought that was interesting. And I did some shadowing at the hospital in Albany…and I got to go around to CT and MRI and Mammography, and X-ray, and all that, and then I went to ultrasound and I thought that was so cool compared to everything else. It was a lot more interesting and you had to be kind of like….You had to know what you were doing. You had to know what you were looking at when you were scanning.

I: OK. So..what do you think made….I know you told me that you had to know what you’re looking at, but what else was there about ultrasound that you think made it more interesting than other imaging modalities that you shadowed?

S: Ummm….not very many people know about it, I guess. And, for me to learn about it…I guess…I don’t know. It was something different, and…useful….and, I don’t really know. I just thought it was fun.

I: Well. I think that means a lot (laugh)

S: I mean…you go to x-ray and they don’t really talk to patients that much they just kind of tell them what to do and I thought this was kind of more social…too, like social aspect; I don’t know. Like you get to be with patients and talk to them and … I don’t know. It’s just cool.

I: I understand…I understand. Ummmm…So, kind of coming back a little bit, can you explain how the program has or has not met your expectations? Are there things that you expected that haven’t happened?...

S: Ummm, I didn’t expect to have tests every week in Mariana’s class, so that’s been a little rough,…..but I expected it to be difficult and I expected to not get things right the first time.

I: So, you expected the program to be pretty tough and intense?

S: Yeah…a lot of work…a lot of time spent…doing…homework, studying…

I: Do you feel like that it’s worth the time?

S: Umm hmm. Yeah…and, I mean…you really are not spending that much time in school to do this. Two years, I mean, doesn’t seem like..that long…so…yeah…I knew it would be hard.
I: OK. Um…So what do you think about the perception that some students find ultrasound scanning easier to pick up and learn than other students?

S: I think that’s true…because…I think for other students it’s harder to like picture how everything is places in your body and how to use the machines and think about everything put together. So…I think that’s true. Because I’ve noticed that people in lab have easier…some people have an easier time getting the comps down before you actually have to comp and then some people are just kind of behind still…and haven’t … put it together all the way through all of our classes.

I: OK. Umm…Do you, do you think that there’s anything in particular that makes that come together easier…or is there a quality about some…..Is there a skill or a quality about some students that seems to help them have that advantage more than others do you think, or…?

S: I don’t really know…I guess (noise) I guess it’s just, I don’t know how they picture things; how their brain works. I don’t know.

I: What helps you?

S: Ummmmm…I think looking at pictures that aren’t ultrasound…just like graphics of the body. To figure out where the things are…and like using your anatomy class before…trying to look at ultrasound images….and……(pause)I guess practicing (?)….I don’t know. (laugh)

I: There’s not a wrong answer…it’s ok. (Smile). Umm…what do you think is the easiest thing about learning to …the easiest thing about learning to do ultrasound scans…about the scanning part?

S: Scanning…..(pause)…Ummm…(long pause)..I don’t know. I don’t really think any of it’s that easy…because sometimes I don’t know what anything is if I’m looking at it. But,……I don’t know……That’s a hard question. I think that last time I put labeling down as the easiest for the scanning part, but sometimes that’s not easy either. Ummm…………………I don’t know. That’s a hard question.

I: OK. That’s ok. Ummmm Is there….What do you think’s the hardest thing about it?

S: I think, knowing what you’re looking at and figuring out how that’s laid….and…how that organ or structure is laid in the body to where you can move the transducer and see it or ….like knowing how the beam…..That’s one of the things that I had the hardest time in the summer was learning how the beam goes through the structures that you’re looking at….because when you’re putting the beam on top, you’re not looking at it like flat, you’re like taking a slice through it, and I think that was hard for me to realize, but I finally got it.

I: I can see where that would be a difficult concept. So……Do you think that there is anything we could do differently to help people build that road map in their head of how things are laid out?
S: I mean…it was explained, but I …I think it was just me kind of thinking about it…trying to…trying to make it wrong but it was right, but I don’t know. I guess just maybe explaining that more would be better, but …I think some people get that easier than others, so….I don’t know.

I: Do you think if there was ….a ummm…………I don’t know…is there any other kind of activity we could have done you think might have made it more plain or more real or ….?

S: Ummmm.........I guess if ........sometimes I wish we could have anatomy and lab at like the same time, just like talking about the organs and then using the transducer to show them. But, I don’t know.

I: OK. What do you do to prepare for ultrasound scan tests?

S: Well, practice in lab, and then I usually make a sheet with all my labels, like …..a sheet with the labels that we’ll need so then I can kind of see how to go through it and make a order to stick to, and then just go over images and our handy dandy cheat sheets that Russell made us (smile)…..so….I think just looking at your images and trying to remember your order to go through.

I: OK. Ummmm….Is there anything that you wish you had done differently in the scan tests you’ve done so far; is there anything preparing for them that you wish you’d done differently?

S: I keep telling myself that the day before, the lab before the scan test, I just go through it and act like it’s the real test, but I never do that….because I won’t go in order. I’ll work on things that I think I have problems with. Instead of go through it like it’s an actual test. And usually, we don’t really have enough time in the lab for everybody to do…to take 30-40 minutes at one time on the GE machines, so …that usually doesn’t work. (smile)
I: I can see where that would be a problem. Ummm…Is there a particular type of person that you picture in your mind as being best suited to do ultrasound, to being a sonographer?

S: Ummmm………(pause) Someone that likes physics (laugh), but ummm, I think…..people that like to learn about the body and I think …..maybe think a little bit more about their job and think about what they’re doing.....and what you’re looking at and what you should be looking for, and what’s wrong…what kind of things are wrong…..and, ………I don’t…people that want to be in healthcare and ………I don’t know.

I: OK.

S: I think anybody can do it; it’s just whether they’re interested in it enough to learn everything that you have to know.
I: to put out the effort
S: Yeah, to put out the effort to learn it and spend the time.
I: Do you think that there’s anything in particular that gives one person an advantage over another when they’re learning this? Is there any, um…..I don’t know….any……mental quality or skill or …..

S: Well……you have to be……logical about things and …..I mean, you have to know you have to remember your anatomy and physiology. You have to be able to retain information, but…I don’t want to say you can’t be stupid (laugh), but I mean, you can’t be….ummm….I don’t know…..I mean, you have to be smart to get here, so …..

I: That’s true. You have to have some kind of screening….

S: Yeah (smile)

I: Umm…Is there….is there anything you can tell me….what’s it like….if somebody off the street asked you what’s it like to try to learn how to do this, what would you?

S: I would say, it’s really difficult, but, …..I can’t really picture myself doing any other program or majoring in anything else, so….I’m glad I’m in this program, it just takes a lot of work and it’s just really difficult to learn and it’s challenging, but….I think we’ll all get through it in the end and be ok.

I: Is it…..can you be specific about what makes it difficult?

S: Ummm…I think remembering all your classes…..remembering everything you have to do in each of your classes every week and studying for every test and…..sometimes your tests on the same day….and just I think time management. Because I’ll get home and my roommates have been home for 6 hours already and I’m just getting there and I have homework to do, so…..I don’t…..It’s just time consuming, but you have to do it, so…..I don’t know what else to say.

I: Yeah…that’s fine. There’s not a right or wrong…. Ummm, let me think how I want to ask what I want to ask. (Pause) If you mentally…kind of mentally; this isn’t the actual think aloud exercise, but kind of mentally picture yourself going through a protocol—your favorite protocol…any protocol, and try to describe for me the things you have to think about, the things you….what's your mental checklist you go through?

S: I think I kind of….figure out what… like I have to do my labels usually first because then that helps me think about what I’m trying to image and then I have to get that image and usually I forget about like the focus and TGC and all that junk but I have to remember that, and….I think just trying to get a better image. I’m not really thinking about anything else besides…..the test, the competency, so ……….I mean, there’s not much going on besides working with the machine and trying to position the transducer to get the best image I can get.

I: So….when you’re, ummm….trying to get your best image you can get, how, what do you….what is your….like when you’re looking at something and you…how do you decide what you have to do to make it better?
S: Ummm…….I guess just thinking about how it should look or how I picture it looking from an image in my head or ……………picturing it how it lays in the body and trying to …position it so it’s looking at the right things and …..I don’t know. (nervous giggle)

I: You’re ok—you’re fine. Umm, so, once you have your anatomy on there, what else do you…how do you decide whether you have a good image or not?

S: Well, knowing what you’re looking at, like what type of structure it is tells you if you should turn your gain down so it’s anechoic inside or..if you should be able to turn your focus up to see it better or………………decrease or increase your depth so you can see the structure better and…………mmmmmm…………………………..(giggle)

I: It’s ok. OK. Um….let me think. (Pause long) Is there…..any ummm ………outside of the materials you’re given in class, is there any on-line resource or any other resource you’ve come across that helps you look at or helps you with your studying to do ultrasound?

S: No, not really. I think a lot of the materials from the summer I use for these classes. For physics and for your class and for Dr. Hdeib’s classes, so…that’s really all I use.

I: So do you find things to be pretty cumulative so that you have to use stuff you did before?

S: Um hmm Yeah….yeah. I think some of Dr. Hdeib’s you have to Google it and try to look it up somewhere, but other than that you can usually find it in one of the books we have or stuff from summer.

I: OK….ok. IS there anything else you can think of that you think I ought to know about or that would be pertinent to help me understand how people learn to scan?

S: I don’t think so….I don’t know. I’d have to think about that for awhile….think about what I’d change.

I: ok. Well, think about it and if you think of something, shoot me an email or come talk to me or whatever you would like to do about that would be great. I really appreciate your time.

S: No problem.
Subject 2: RA (White Male, Graduate Student—BS not DMU—over 40 y/o, Hometown: Columbia, MO)

I: OK, so…tell me R_____. how do you like DMU so far?

S: I’m enjoying myself quite a bit. It’s challenging but interesting to me…so….there’s some physiology to it and there’s some physics to it. I like understanding how things work whether it’s a formula or just the way proteins and amino acids are working….different receptors and, messaging, things like that going on….and…..the scanning, when you have the transducer in your hand, I like that. I don’t feel very confident with that when I’ve got the transducer in my hand, I feel like I’m close, like I have a sense of what I should see and a sense of how I could go about seeing it, but really executing it and controlling it and you know, being able to repeat what I just did. Like, oh, I just found the common bile duct on one person, so if another person comes in, I’ll find it right away on them too….I don’t feel like that. I feel like I would probably have to start from scratch and I may or may not be able to do it. But, so there’s that confidence that I don’t have, but… But I enjoy practicing, and I know I don’t have to be an ace proficient ultrasound student in my first few months, so, no, I don’t feel too worried about it, but I’m trhing to get better, like the….ummm…the feedback, or….. Just haven’t had as much positive feedback and confidence from what I’m trying to do and what I’m getting done with scanning, whereas, my other tests and the other challenges of the program, the feedback’s more concrete, and for better or for worse, you know how you’re doing and it just seems like with scanning, it’s more vague and more nebulous how I’m really doing. But I like the program and I’m happy to be here and I’m working hard and enjoying it and looking forward to the good pay and working where I want to work in a couple of years.

I: So…how do you…..why do you think the scanning is more…can you give me an example ofhow you feel like the scanning is more nebulous than the other parts of the program?

S: Pause—Well, first thing that comes to mind is we’ve got two different machines and they’re not equal and we’ve got the 9 other people in my class their anatomies aren’t equal, and….what we’re trying to scan week to week is changing too….like, I didn’t ….the aorta was the first thing we did…and….I couldn’t scan the aorta in my sleep, you know, when we were done scanning the aorta…you know, I was still wondering about, what exactly should the mid aorta picture look like in long versus the mid-distal, you know….I still had questions that I needed to like, go back andlook up my notes and find out, or go talk to you….I didn’t have that down. And then we move on to something else, and it’s …..ummm…..you’re more struck by the differences of the something else than you are by the similarities…..the aorta’s in the same picture of some of the liver shots, you know, so there are similarities in the new thing that we’re moving on to before I felt like I had the old thing down, but there’s also you know, just so many differences, and so, as a begininnier, you’re focusing on what you don’t know and thrying to know it better. So, that’s part of where ……I don’t really feel like I’m ….I’m climbing a ladder, but it’s hard to really feel that the rungs are solid and that I’m really…that the ladder’s not moving, you know, am I climbing a ladder that’s moving down, you know, at the same time? Because, you know, the people are changing and the machines are different between what’s available and the anatomy we’re looking at is all different and even the same person, well, whatever they’ve eaten or not eaten, they’re different too, so, you know, and you go to another…and you go to physics class
with Mrs. Hdeib, and you’re studying for a test, it’s the same questions you’re studying and they’re the same answers, and there’s just none of that changing like there in the lab and the dynamic nature of the lab and scanning real time, so….I don’t know, I jujust feel like it’s a lot to learn, but I was thinking that it’s good that you guys didn’t lecture on the GE machine and teach us all the buttons and how they’re set up in the lab because eI know that they will be different when we go out in the real world and stuff and we only have so much space in our heads, you know the cognitive load, so you don’t want to fill that up with things that are gonna change, you want to try to fill it up with things that are going to stay the same—relationships of the vessels and the organs, like that. Just the muscle memory that you talk about, you know, just to get to work on that and build that, you know….But, I mean, I feel like on the other hand, if I knew how the machine worked better, if I was more comfortable with the machine, then I would have a baseline of confidence to approach you know a patient, to approach a student that I’m trying to scan if I felt like I…I know, I know the machine, I just have to know, you know, this person’s liver, and how long it is or something….When I was into photography and learning that, I would just go and walk around for the day with my camera. And just play around with different apertures and focusing and just the different lenses and just get to know the camera. And then when I was a photojournalist and I was in a dynamic situation, you know…sports, or the perpetrator’s coming out of the courthouse and you’ve got to get it real quick, I was able to do that because I was just comfortable with the camera. So there’s part of me with my experience, that wishes I knew the equipment better. But we were taught, it’s kind of intuitive..you know, we were taught the basics of freezing the picture and now we’re learning cine loop and we were definitely taught focus and depth and …..but there’s so much about the image quality that other than time gain…I don’t really, I’m just guessing pushing some of the buttons sometimes to try and make things a little better.

I:  So….If you had ………..an opportunity to take your physics material and try to apply that to the machine, do you feel like that would be advantageous?

S: Well, right now we’re a lot of PRF seems to be the hub. The center of the wheel for a lot of spokes you know the frame rate and depth, and stuff are all determined on the PRF and you don’t control the PRF, so I really don’t…I would say no to that…

I:  OK…Now you know that you can control the PR, the frame rate also with your scan, the size of your scan area, the line density, the width of your scan area and your depth, you know because you’re controlling your round trip. I mean there are some physics things we can do and we could look at that.

S: Yeah, like when you change your depth you’re changing your prf.

I: Right.

S: Yeah

I: because you’re changing your round trip time.

S; 13 microseconds
I: That’s it…(laugh)

S: I think what would help me is if we had quicker feedback on our competency exams. Because the student goes in and they spend 30 or 45 minutes taking the exam, and for a day or two after that, they can…for me, I can kind of remember the pictures I took and the specific challenges that I was facing at that time and …and I would be able to …I would just be able to kind of weigh how I did on the exam , my grade on the exam, with what I feel like I did, and compare the two and see if they’re in line with each other or not, but when it gets to be a month or so afterwords… or two or three weeks or something, and there’s been so much, you know, in the student’s mind since then, since that competency, it’s interesting to know how you did, but it’s not as useful as it could be.

I: OK. OK> So you’d be willing to sacrifice scanning time and instructor time learning a new competency the first amount of time that you’re trying to learn something new to get that feedback that quickly.?

S: I don’t know…I don’t know…it’s tough.

I: See, there’s a balance.

S: Yeah, I understand there’s a balance, and there’s time.

I: And I know that with going to conference right after your other exam—your liver protocol, you know, we left and went to Denver, and then I’ve been trying to get this one done this week. And so…I need a TA (laugh) Oh, goodness. OK..So, when you were looking at DMU, did you look at DMU programs elsewhere or did you pretty much concentrate here because it’s home?

S: Yeah, my situation, umm, growing up in Columbia, living in Columbia, having a daughter in Columbia, ummm, being interested in ultrasound….ummm..and knowing, I know I knew the DMU program here was a good program…I didn’t really know , I didn’t look anywhere else, I mean…I didn’t think oh, MU’s the best DMU program or anything like that, I just knew it was really good. You know, I knew it was the only Master’s program…and I think that…I don’t know…I think that’s a really nice feather in the cap…but I don’t really know what that will mean to my starting salary or the number of job opportunities I woul dhave to choose from vs having a BS, so I don’t know all of that but I know it’s good. I know it can’t hurt and I know I just wanted to explore DMU, explore ultrasound somewhere because of the growing field and the pay and the helping people but not being ummm…the totally responsible party in the end, you know. Not being the doctor with all of that responsibility in the end, but being you know, being responsible and being a part of the process, but you know, but not being the last word, you know….I know they get paid more, but they also have the final responsibility and I’d rather be part of it than the total responsible person. Umm, plus it was like 8 years or something to be a doctor, so….I’ve been in school a long time, though with the prereqs and everything…this is almost like a 4 year thing with where I was starting from with no science courses. I bet it was, yeah.
Like Biology 101, I had to start from scratch for this thing so it’s been pretty much a second college experience by the time it’s over. But I’m talking too much, you just said did I look at other programs; nope.

I: No, you’re fine. Um...so, can you, can you tell me how this program has or has not met your expectations? Has it been what you expected it to be?

S: Yeah, pretty much. Um, I knew it would be hard and I knew I was hoping I’d be interested in it and that I would like it, that I would enjoy the process. Because I knew it would be challenging. Um, I thought it would be...I’ve got to say this carefully, because...I...I thought it would maybe be more challenging than it is, you know, I thought it would be... like the final year of a Duke med student or something...I mean I was really building it up to be just amazingly intense for some reason. And, you know, it’s hard and it’s challenging and you have to stay at it every day, you know a little bit, you know you have to keep on it...the work load is significant, you know and it is challenging, but it’s not undoable and not unbearable, it’s totally manageable, it’s totally manageable if you keep at it, so, I thought I may not be able to manage it, but...

I: You think it may be because you’re not 21 and you’re not wanting to go to the bar 3 nights a week and (laugh).

S: That was...yeah, I knew that I’m an outlier gender and age-wise and uh, that’s pretty much what I, I mean it’s pretty much what I expected in every way. I knew it wouldn’t be easy, and thought it might be distracting, but it hasn’t been that distracting....I don’t know.

I: You thought what would be distracting? Being different age-wise than the group, or...what did you think would be distracting? (Pause) You don’t have to answer me if you feel uncomfortable about it.

S: I just thought that it would be distracting having um...being like maybe the 1 or 1 of 2 guys in a class of 20 girls....I just thought that might be like distracting like...Whereas if they were more equal.....the only time I was such a loner as a guy was in a..at a high school journalism camp.. I was the only guy in a class of like 15 other girls. We were all the same age, and we were all teenagers (laugh) so, that was more distracting, so this is different. Times have changed and this is a different situation, so it’s not that distracting. I’m just here to try to you know, umm, not do any clinical harm when I get out there. Not mess anything up too bad and uh, most importantly just not look like a total horses ass too much of the time, you know, Look like a little ass a little of the time is going to happen....you know, like people who....who I encounter that think “He’s trying hard and he’s doing really well for you know, for where he’s at. He’s not a 5 year experienced person, but, but, you know, he seems to know more than he should or we might expect him to know”. I’d like to be a little ahead. That’s kind of my goal.

I: That sounds like a good goal to me. Ummm What do you think about the perception that some students find ultrasound scanning easier to learn than other students seem to do?

S: What do I think about the idea that some students pick it up faster than others?
I: Mmm hmmm

S: Well, I think it’s just like anything. Some people pick things up faster than other people…and umm…it’s interesting to try to figure out why for sure. Ummm…sometimes you are better because of effort…..ummm…sometimes you’re just better at something than somebody else. I haven’t….my ….I haven’t really noticed in my class…in my lab class…that …that there’s a big difference in people…ummm..that really get it. I mean, I haven’t really …may…I’m just not in tune enough to what everybody else is doing to have that sense that well these 3 people are really good at this, these 3 people, you know, can barely find the liver, you know…I feel like we’re all pretty much pretty close, you know. I dont think we’re all obviously equal, and even, but I don’t think there’s a big disparity in skill yet, but I could be wrong about that. I don’t feel like I’m…I feel like I’m pretty much in the middle…so…

I: Yeah, …as a….over year’s of experience, in any given group, usually I have one or two that really don’t seem to struggle at all…and then the bulk of the group are pretty much within fractions of each other, and then I’ll have one or two that really seem to struggle. And so, I guess what I’m looking for is what is it….what is it that causes those one or two…what is it that the others are seeing or is clicking for the others that those one or two people is just not there. And it’s not always, I mean sometimes you can attribute it to the effort they put out, but not always…not always.

S: Yeah, not always. My theory is it’s a general approach some people have to life where their default to new situations is…is to be daunted, that’s just, “Oh this is going to be daunting, this is a big deal” rather than, “Oh, ok, pick up the transducer, see what happens on the screen. You know. We’ve all studied some anatomy, OH, ok, that’s there. You know, and they just, “what if I do that?” What if they rather than “Oh, this is, I’m scanning a person…I’m sending soundbeams into them…I don’t completely know the anatomy like the back of my hand” you know. Some people think about what they don’t know and they think about big situations they come across and they just see it as “it’s daunting, it’s just too much for me to think I’m really gonna get it.” And those people, hopefully have the will to push through that, you know, to keep the effort, you know to see their skills build and they build that confidence over time to maybe where some people have that confidence at the beginning based on nothing other than that’s how they walk through life is to say “Ok, I can do this, I can try that, why not? What if?” That’s kind of my theory about that.
I: That makes sense to me.

I: How important to you think eye-hand coordination or motor skills are for learning to do ultrasound scans?

S: Umm, I think they’re important.

I: OK. Can you, can you give me an example or elaborate on that?

S: (Long pause—thinking) Umm…well, it just kind of helps you to know if your scanning somebody’s liver and you move your hand left just to know that you’re really moving to the right of their liver…and to kind of know that that’s what’s going on. I guess that’s not totally hand-
eye coordination; that’s …anatomical position knowledge, but…I don’t know…just to kind of know that …..when you move your hand left, the transducer, you know, if you tilt the top of the transducer to the left, the bottom of the transducer’s gonna look off to the right. I guess that’s what I was trying to say, just to kind of have that intuitive wiring helps that that’s what’s going on, that helps. (Pause) But, mostly, it just seems to be about knowing your anatomy…is what helps more than hand eye coordination because it’s not (gestures with hand)…scanning isn’t a skill involving a lot of speed like keeping a video game with lots of different buttons and you’ve gotta press them real fast, you know, it’s not a real speed intense activity as much as it is accuracy…and subtlety, so you know, it’s really important, hand eye coordination, but…but…it’s not even so much about subtlety for us as just beginners who are like trying t look at the right lobe of the liver, there’s not a lot of subtlety in that transducer window or in that position of the transducer, you know, if you found the liver, you can find the right liver without too much subtlety, and then if you get to the common bile duct, there’s a lot more subtlety involved there. So, you know, it just seems to me about…umm… if you really know your anatomy, that’s just…it can overcome a deficiency of hand eye coordination that you might have because it’s just not a heavy speed intense activity, so…if you have terrible hand-eye coordination, it seems like it wouldn’t show up that much. You wouldn’t be having to tap into a lot of hand-eye coordination that you don’t have because it’s not really speed intensive. It’s just about knowing what you’re seeing and moving your hand to see something different and know what that is and know which one is the best, the most meaningful.

I: OK. Um…what if you tie that….ok, so you talk about knowing your anatomy, moving through your anatomy. Is it…can you…can you relate the, the…relating the 2-D image on the screen to the 3D anatomy of the person you’re scanning? Can you kind of talk about that?
S: (Pause) Well, yeah, that’s I think what I mean when I say really knowing your anatomy is to know…to have all those pictures in all the books in your head enough and to memorize what the pictures are showing you know, the little line showing this is what the left splenic vein is—it’s going to that part of that picture. Then the left splenic vein is in a different part of different pictures, obviously, which are showing the body from different angles, so, when I say really knowing your anatomy, I mean having this …building your own little virtual 3D picture in your head of the abdomen and if you really have that 3D picture accurate and complete, then it’s so much easier to associate the image on the screen with your picture in your head if you just if you really know…um…you know, what percentage of the abdomen the liver is taking up, you know, it just….that’s kind of how I thought about it is….think about all the major players, the liver, the pancreas. Think about how big they are…what portion of this abdomen are they filling up? And them do they relate to each other? The pancreas is not up top of the liver, no, ok let’s move it down in your picture, let’s kind of push it behind, you know….if you just kind of have that 3D picture in your head, then ummm… you’re looking, then when you’re scanning, you’re sitting there in front of the person to the side of them and then so you just first of all just throw that 3D picture like kind of overlay it over their body….ok, and then you’ve got the transducer, so you know, “I’m gonna look at little slices of my picture in my head” and I’m kind of testing the accuracy of my picture in my head…the liver should be here, and it should be small because I’m off near the left of the body so I’m not looking at the big bulk of the liver anymore, so the liver should be small and it should be at the top of the picture….because of the way I’m holding my transducer, I’m cutting through the top of the liver and the stomach and coming in right here (demonstrates on his own abdomen)…(long pause).
I: I was just waiting to see if you were still thinking or…that was a really good analogy. So what do you think is the easiest thing about learning to do ultrasound scanning?

S: Hmmmm….let’s see…easiest………………I think the easiest thing is that there is, when you know so little and you’re so bad at it, that any little progress is noticeable, you know, that there’s so much room to get better, that it’s not hard to find it. It’s not like you’re looking for a little umm ………There’s just so much space to get better that it’s not hard to find it, so that’s easy. It’s easy to feel like you’re getting better every day. Like, I didn’t even …if you don’t even have a great period, you know, if you, like a great lab session to me is where I would duplicate the next protocol where I would just take all the pictures that I think I need and label them all, that would be ideal. And I’ve never done that. I’ve come close a couple of times. But even if I don’t come close to that, I can tell I just got a little more comfortable, you know? It was just a little less daunting. Like the other day, I was switching probes and I just set the probe on the girl as it was loading and then it popped up and exactly what I thought would be there was there and I couldn’t have done that in September, you know. Like there was the kidney in kind of a medial view with the liver right above it…that’s what I thought would be there cause that’s where I put the transducer, and…..so that’s my simple answer to that question, is just that it’s none of it’s really easy, that’s a good question because it’s all relative. I don’t think there’s anything easy about doing it well and really learning as much as you can…I think it’d be easy just to you know let …. what progress comes come, you know, but really trying to get better at it is never easy about anything, but when you’re bad at something, it’s not hard to get better. (laugh) It’s easy to get better.

I: So, how did it, um, how did it make you feel when the machine came up and what you expected to see was there?

S: It was just an encouraging hoot (laugh) and it quickly you know moved on to you know struggling to get a cineloop you know where you can ….get a pretty picture of the kidney from top to bottom or from side to side you know and record it so that you’re not recording gibberish before the loop or after the loop. That was harder, so I got right into that and that wasn’t as easy. But, yeah, that was just a hoot to see that kidney there…a perfect….hypoechoic right where it should be.

I: that’s a woohoo! (laugh)

I: So what do you think is the hardest thing about learning ultrasound scanning? What’s the hardest thing about learning to scan?

S: Hardest thing….ummm..probably trying to get that textbook picture….ummm….Long pause A lot of times when I’m scanning I don’t have a textbook picture in my mind of what I’m going for, at least it’s not that clear. I have a general idea of what the picture should look like. But, when I have a much clearer idea like the picture in the book or the picture in the slideshow showing this is the picture in the protocol that we should try to get you know and trying to get that is sometimes hard, but I guess it depends on what picture it is…uh…….yeah, I think the hardest thing for me is just to get to feel confident, just that feeling of confidence. You know,
like I said, I wasn’t confident with the aorta protocol but we took the competency and moved on to the next one, and I wasn’t really confident… I might have been competent… I know I was where I should have been, but just, that real…. I’m just seeking that real feeling of confidence that will probably only come 3 or 4 years about some of the things we’re trying to do…. so…. 

I: I think if you talk to some people that have graduated you’ll find that a lot of confidence comes about halfway through your summer clinical rotation when they get out there and realize, you know, that I really can do this. But, um, it can be hard.

S: On some real live people…

I: On some real live people…

S: It will definitely take that. (Laugh)

I: You talked about the textbook image, and it’s really important I think to have an idea of what normal is supposed to look like, … but do you … expect to be able to match your scan image to a picture in a book when you scan, I mean, when you scan everybody do you expect…

S: In the lab, I do, kind of, in the lab, these young health college girls, um… I don’t expect to find um… pathology or weirdness. I expect that I should be able to find a pretty textbook picture, but I don’t expect that obviously out in the field where people are probably coming in for an ultrasound because something is wrong… signs or symptoms… so I should probably expect to find something but, basically, just know… what, I mean my goal is to know what normal totally looks like and to know what a bunch of different abnormalities look like and not expect anything but just know what both things look like. I mean, that’s kind of where I’m going. But right now, I think, yeah, if I have a pretty clear idea of like the … that oblique view of the pancreas… I feel like I should really… I mean that textbook showed that homogenous, slightly Hyperechoic, look to the pancreas from head to tail, you know, and you could see the borders all the way along, and, and that splenic vein, and the portal confluence were right there, and like the left side of the splenic vein that the… where it’s further from the portal confluence, where it’s coming toward the portal confluence, that started right where the tail kind of bent down… you know that pancreas is kind of like a banana or something, kind of like, you know, that splenic vein filled just that portion of it, and … and that duodenum wasn’t full of gas, or weird or anything, you know, it wasn’t, the head was just clear… the picture in my mind of the abdomen, that 3D image, is not perfect. There’s lots of gaps in it, you know, there’s like black holes, you know, like the back of the liver… I see an H, but I don’t know exactly what all is going on that makes up the H. I know even really what most of it is, but not like, the Ligamentum venosum is the bottom left side or the top right side, or you know… or it’s the bottom but is it the left or right, and the IVC, is it all the way, or is it one side of the H? You know, there’s holes. But yeah, to answer the question, what’s hardest is to feel like you just got a A picture, a gold star picture, like this is the textbook… that is technically and anatomically an awesome picture of the pancreas, because, I’m feeling like, dang, that gas is there, or I just can’t quite… if I do this, I lose that… you know… there’s so many… ways you can change the picture…. and then lose something you might want.
I: What do you prepare for your ultrasound scan tests, for your comps? Is there a…

S: I try to start with a list of all the pictures that you want us to get…a list of all the things that we’re supposed to get, and then I spend time trying to get it, practicing, trying to get those pictures, and then as it comes up, the test comes, I just go back and make sure that I remember everything that I’m trying to get. So I don’t miss anything like a major part of the protocol…so…that’s basically it.

I: OK. Do you think …what do you think that you do particularly well when you’re preparing for your comps, for your scan tests?

S: Nothing, nothing…huh. I mean, I think I have a…I think I know everything I’m supposed to get when I go in there and sit down. I don’t think I’m forgetting anything, I don’t think I’ve forgotten anything…so…I guess I do that well…I know what’s expected of me. So, then it’s just a matter of having the experience and the ability to execute it…to get that.

I: OK. Is there anything that you wish that had done differently, that you, you know, after you finish the comp, is there anything that you wish you had prepared for differently, or anything that you might have done differently in order to be more prepared?

S: umm…I can’t think of anything that I…my feeling when I finished competencies so far has been that I just wish that I was better at it. I just wish I could have done better. I wish it had been easier, you know, I wish I could have done it with more ease. But I don’t know how I could prepare any better other than just um…scanning more, trying harder, spending more time scanning, which I don’t really know how…..I mean, I’m sure I could have a little more scanning time under my belt before competencies, but not that much. Ummm……

I: It seems like you generally make pretty good use of your time. Is there a type of person you envision that would be best suited to…

S: Is there a type of what?

I: Is there a type of person you picture, a type of person you can describe, a personality type you can describe that would be best suited to becoming a sonographer?

S: (pause) um….noooo….I think they have to be smart….smart and caring. I mean to put it in a nutshell. Umm…they have to be smart because you’ve gotta know a lot of different kind of things about technology and um….anatomy and pathology….and….you’ve gotta be caring just because you’re …. Dealing with people you may not really like or who, but who are sick and need help and you can offer them help because you have the experience and you have the skill…and so if you’re caring, then you can…give them that in a good way….so….I don’t know….I’ve enjoyed all the sonographers I’ve met, but I haven’t been struck that they all strike me as a certain kind of person or anything other than they just they’ve all been smart, caring women…except for Doug (laugh)….he’s just smart and caring I guess. (laugh)
I: Um, is there anything else you’d like to tell me that you think would help me understand what it’s like to try to learn how to do this?

S: I think you’ve got about an hour and ten minutes or about an hour of data to go over, so... I got that one thing off my chest about feedback, competency feedback sooner, but, that, and I wanted to make sure I expressed it like as an ideal...like it would be ideal if we could but I know that the way things are set up, your schedule, the DMU schedule, that that’s just not always possible.

I: I’m always trying to do things better.

S: It’s a critique of the

I: Yeah, it’s a critique, and that’s part of why I’m doing this project is to learn to do things better, so if there’s things that you see that we, either me personally or us collectively as faculty can do better, then that’s feedback that I need.

S: Cool.

I: Thank you so much for your time. I really appreciate your input and will be glad to hear any further thoughts you may have.
Appendix 5: Think-aloud Transcripts

Think Aloud 1 LL (Female, Undergraduate, 21-23, From St. Louis Area)

I: So, here we go; we’re doing the think aloud exercise, and we’re doing the Aorta Protocol.

S: So this is the…phased…uh, which probe is it? Uh, 4 curved….ok. And we’re doing the Aorta scan….so I’m starting Transverse…or no, sagittal, long….and I’m starting proximal…. Should I start a new patient, or just start the imaging? OK. Just start the images. (Long pause as subject maneuvers probe) Can you take a deep breath in please, and hold it?

I: so why do you tell the patient to take a deep breath?

S: Because it moves some of the gas out of the way….so…………..(mumbles)…..I’m decreasing the depth to put the aorta in the middle of the screen. I’m trying to adjust the gain so that it takes some of the fuzziness out of the um…noise out of the vessel. Is that a good image?

I: You tell me….you’re taking the image. (Smile)

S: It just looks really fuzzy…Oh, yeah, shoot…I need to adjust my focus. Can you take a deep breath again?

I: What are the landmarks you’re looking…what section of the aorta are you doing?

S: I’m doing proximal aorta. And, uh, Some of the landmarks…you want to get the heart, umm, on the right side of the screen….no, on the left side of the screen……………..Can you breath in again, please?

S: I can’t get the picture I want…….(mumbles)…………She’s kind of gassy a little bit, but….

I: So what are you doing now?

S: I’m scrolling back in my cineloop to try to get a better image….but there’s this gas bubble that just won’t go away….so, I’m going to try again. Could you hold your breath again, breathe in? I’m not very good at getting around gas….I can’t get a good picture….(mumbles)

I: So what do you….how do you….tell me how you measure….what you’re doing there.

S: I’m measuring the width of the aorta, so you go over to the little box on the side and just click long aorta, click proximal, and then scroll over and press measure set on the….on the top wall and then drag it to the bottom and press set and you want it to be parallel to make it like an I shape to make the two parallel and make it like an I.

S: (long pause as scans) Can you take a deep breath for me? (pause)

I: So tell me what you’re doing now?
S: Um, I’m moving my probe towards..Um. caudally, inferiorly…and um…looking for the SMA and the Celiac Axis. (frustrated) How can I get that to move out of the way?

I: So what are you struggling with there? Why does it need to be out of the way?

S: So that you can see the SMA and the aorta and get a good measurement of the mid aorta. I can’t tell if that’s it, or if that’s just….

I: Why can you not tell if that’s it?

S: Because the gas bubble’s like in front of….there’s a break in the aorta, but then the gas bubble covers all, everything above it, so then I can’t tell if it’s just…I can’t tell what it is.

I: So what can you do to ….what do you do to try to work around the gas bubbles?

S: Maybe, different angle, or tell her to breathe in, or push harder….

I: How do those things help? What do they do?

S: Having her breathe in um moves some of the gas out of the way, and pushing pushes, you push harder, the transducer pushes some of the gas out of the way. Will you breathe in again please? (Long pause, scanning) Push….sorry. Oh my gosh…(frustrated) I can’t make it out. (long pause)

I: What are you doing now?

S: I’m adjusting my TGC, to try to get some of the noise out of the vessels.

I: Why do you need to do that?

S: Umm, so you can get a clear…clear measurement, and a clear view of the inside of it, so you can get it better and you get a better measurement of the….the aorta. I still can’t tell (frustrated). I mean, I think that’s it…I don’t know.

I: What makes you think it’s it?

S: Because the that’s the SMA….but I just can’t tell because it’s not like really a distinct break, and I can’t adjust it….

I: Are there other landmarks that you can use to help you figure it out?

S: Uh, the body of the pancreas…and the body of the pancreas, and I can’t see it…Is that a good image?

I: I’m just asking you how you’re thinking, I’m not…
S: (Sigh) Can you breathe in please? (Long pause scanning)

I: What are we doing now?

S: I started back at the top (mumbles) I’m trying to get a better picture, but I can’t (sigh). So I need to change my (indistinguishable). Hmmm, gotcha!

I: So what made this one better?

S: I can finally see the SMA coming off, so …and that’s like the …one of the major landmarks… and I’m pretty sure that’s the body of the pancreas (points on the screen). I measure…..long….mid….So…I’m setting it at the top…and I’m moving it down…(measuring) I think I could move that one a little more down…

I: What could you have moved a little further down?

S: Ummm my cursor, like when you set the top, you move down to the bottom, and I could have moved it down a little more to get a more exact measurement

I: So what are you doing now?

S: I’m putting more gel on the transducer, because it’s getting a little….Sorry, it’s a little cold.

I: What does the gel do?

S: Um…it…it…hmm..it takes some of the….it decreases the um….impedence differences between the two surfaces so that um…it’ll…all of it doesn’t get reflected….trails off. So, now I’m……Can you take a deep breath in again, please? I’m going back down um…passing….right inferior to where I took my mid picture to take my mid-distal picture. (mumbles) Aarrgh (frustration) Breathe out. I’m thinking...(laugh)…Now breathe in again. (scanning) Ummmmm…. Moving inferiorly….change my depth…. (long pause) (mumbles) (scanning silently) Come on…. (deep sigh) OK. Another deep breath whenever you can.

I: So why is it so frustrating?

S: Because there’s a lot of gas bubbles…..and I can’t see anything. (pause, scanning) (mumbles) If I can just get around the gas…. (mumbles) ….breathe (to patient). (Long pause) I’m not really sure…(pause) Freezes image. I don’t know how to measure mid-distal…

I: there’s not a calc package for it.
S: So just hit measure, measuring top to bottom. There’s a little like, split, right where, um the wall…..I don’t know if that’s something…. (mumbles)….place it there. (stores image)
Now we move down to distal, so take a deep breath in again.

I: So how are you going from where you were to distal?
S: I am…moving down…to like about where her belly button is to where it starts to um…taper…it starts to get…and that means that…um…it’s about to split…like right before the bifurcation. So…. (pause, scanning) Breathe in (chuckle), thanks. So…. (long pause, scanning) Arrrrgh! I’m reaching…..can you kind of relax? (mumbles) (sigh)

Patient: When she pushes, I kind of tense my muscles. Does that make a difference?

S: Yeah, don’t do that. Just relax. Let’s see…. (long pause scanning)

I: What are you doing now?

S: I’m um..changing my depth to help me, to bring the aorta into the middle of the screen.

I: why do we want to do that?

S: Um, to bring it into focus. So you can see it better when the image is up close…(mumbles)

I: What are we doing now?

S: I’m scrolling back to look for a good picture…. (pause), but I don’t see one…. Hmmmm….this is hard…. (sigh) Breathe in again when you can. (scanning) Arrrr! Why won’t this gas go away? Oh no!

I: What did you do?

S: I accidentally pressed the wrong button and split the screen. That’s ….I think that might be the iliac…the left iliac, because it goes like that. (Pause) Scrolling back my cine loop…..ok…. Change my depth like that, and move my focus up a little…now adjust my TGC…I don’t know for sure…(mumbles, measuring) OK, (stores image). And now we’ll go transverse. Can you take in a deep breath? Thanks. So…. (scanning) (long pause) Hmmmm…

I: How do you know where you are?

S: um…well, oh, there we go! I can’t figure out…..I can’t figure out which one it is….

I: What are you doing now?

S: I’m increasing my depth.

I: Why would you want to do that?

S: um, so I can get a bigger picture, so I can kind of like see back to her back. Ah…Is that her celiac axis, or…it’s not. Oh, her renal…yeah. (mumbles) I’m getting so frustrated. Can you breathe in again? (to patient) (long pause, scanning) (mumbles)

I: What landmarks tell you when you’re in the proximal section?
S: The celiac axis…coming off the aorta…and…. (sigh) Will you breathe in when you get a chance?

I: Do you have to be above it or below it, or have it in the picture? What’s your rule?

S: about what?

I: the celiac

S: Above it. But I can’t even…. Can you breathe in? (to patient) I can’t find it…

I: Why can you not find it?

S: I don’t know…I don’t know. Breathe in. (Long pause, scanning) (mumbles) Why is this so hard?

I: Is there any kind of structure up there that would cause artifacts or cause problems?

S: Yeah, but I don’t think it would make it blurry, it’s just fuzzy. (very long pause scanning) Breathe in please. (Long pause scanning) Breathe in.

I: Tell me what you’re doing.

S: I can’t get a really good picture…(mumbles)

I: So if you’re scanning a, a regular patient, what are you going to do if you…

S: I guess, try to just get the best image I can…

I: OK

S: I just can’t….Can you please breathe in when you get a chance? (Long pause scanning) I’m scrolling through the cine loop, but I can’t get any better pictures..

I: So what are you going to do…

S: Try again. This is so frustrating… (Long pause scanning) I don’t even know if that’s right… because, I don’t know what that is…um….oh my gosh…I’m still on proximal… See, what is that? I don’t know why it’s connected. (Sigh) (Long pause) (Sigh)

I: Do you think it’s really connected?

S: I don’t know. What is that? I’m pretty sure it’s not, but…(Long pause, scanning) Hmmmm, I don’t know…(Long pause, scanning)

I: So what are you doing now?
S: Um, adjusting my TGC.

I: OK.

S: (Long pause, scanning) It’s like, I can’t measure it because there’s not a wall there…(sigh) (Very long pause, scrolling through cine loop) Measures proximal aorta.

I: So what are you doing?

S: Looking for….mid.

I: OK.

S: Can you breathe in, please when you get a chance? (to patient) (Long pause, scanning) I still can’t see…. (deep sigh) I’m looking for the celiac.

I: What was your big landmark when you were doing the long mid?

S: Um…the SMA. Aren’t I supposed to look for the celiac axis?

I: You look for the same landmark in both planes don’t you?

S: Yeah, you do. Can you please breathe in? (to patient) (Long pause, scanning)

I: What are you doing now?

S: I’m adjusting my depth. AAAHHHH—I had it. I pushed the wrong button! Gosh darn it! (scanning again, long pause) There’s the SMA….OK. Now I measure mid.

I: OK.

Patient: Is there something wrong that makes it hard to see?

S: Oh, no, not at all. Sorry. It’s just…Heaven knows I’m the worst. People don’t want to scan me because I’m always gassy. It just makes things…it’s kind of…it’s like…here, I’ll show you….it just makes a blurry oval over everything and it’s kind of (shows screen to patient)…it’s like clouds kind of. When you breathe in, it gets better, but it’s still kind of….hard to maneuver around. So, now I’m moving down to mid-distal….so, uh, if you could breathe in (to patient). I’m moving down toward the….see, now….I think I found her…. (mumbles) (Long pause scanning)

Patient: Sorry.

S: No, it’s alright. I mean I’m the one…. Breathe in when you can. (Pause, scanning) I think, … (mumbles) ….maybe…. (pause, scanning) I think, that’s close…. (mumbles)…. 
I: So what are you looking for now?

S: Uh, the renal arteries

I: Why is that important?

S: Um…well, it’s a landmark of the mid, but don’t you want to make sure, like they’re not blocked, or anything? (Mumbles) Breathe in when you can, please (to patient) (Long pause scanning) Oh, my gosh (laugh of frustration)(Sigh) OK…breathe in again (to patient). (sigh) (Long pause, scanning)

I: Tell me what you’re doing now.

S: Decreasing my depth to center the aorta on the screen. (Long pause, scanning) (mumbles) Oh my gosh, I can’t believe this. (frustrated) There it is. (pause)

I: Do you have all your landmarks?

S: I think so.

I: What all landmarks do you have at the renals? What other vessels do you see?

S: (pause) Um…(long pause) I don’t know…(long pause, scanning) OH, see, there goes the gas moving right across there. (scrolls through cine loop) So…is that….the celiac? No, is that the SMA?

I: Yeah.

S: Well, ....

I: So, what are you doing now?

S: I’m….fixing…decreasing my gain to clean the noise out of the vessels. (mumbles) Unfreezes image.

I: What are you still looking for?

S: Well, when I measure it, I want to be able to have, uh, like the picture I had, the wall wasn’t really defined. Freeze image. I’ll measure it…. (looking for calc package)

I: this one doesn’t have a calc package one.

S: measures and stores image.

I: So what are you doing now? Tell me what you’re doing with the transducer and machine and everything.
S: I set all my TGC back to normal, and now I’m moving inferiorly….trying to find the……(long pause scanning) Can you take a deep breath and hold it? (to patient) (scanning) Would that be the…?  Oops. Bifurcation to….?

I: Did you see it split?

S: No…(pause, scanning)There’s gas right there. There it is….yep…there I see em. So…(pause, scanning) (sigh) What is that?

I: Where’s your transducer?

S: What?

I: Where is your transducer?

S: OH…it’s her belly button ring. I was like what is that making a shadow?

Patient: I can take it out.

S: no, you’re fine. And so…( long pause, scanning) (mumbles)

I: You’ve gotta tell me what you’re doing and why.

S: Um, I just froze it, well, first, I moved it to make sure it was the order…(mumbles) Well, I guess, (mumbles) a um, moved it, I swept inferiorly…to make sure that I was where I could see if it bifurcated, and it did, so um, I’m measuring the distal aorta. (measures and stores image) Um, now, I’ll do the bifurcation…. (pause, scanning)

I: So what are you doing now?

S: I’m trying, I’m moving, um…. (pause)(yawn) I’m increasing my depth so I can get a bigger picture. I’m trying to get around her…belly button ring to get the aorta bifurcation. (sigh) Here it is.

I: so what do you do with the transducer to get the shadow out of the way/

S: Um, I’m….I guess…kind of fanning, no rocking, um…to her right side (yawn) to get her belly button ring out of the way so I can get a clear picture of the two iliacs. (pause, scanning)

I: So what are you doing now?

S: Measuring the two iliacs…(uses calc package to measure). I should have done another protocol. So, now, I’m gonna try to do the….Oh! Wait a minute.

I: Oh what?
S: I had it! I need to (mumbles)

I: So what do you do to find this coronal bifurcation picture?

S: Well, it depends…it depends like on the person. Some people you can find it by like going right, um..gosh…right next to their…right next to their belly button. Like a lot of girls you can do that, but some people you need to come all the way coronal and kind of put your transducer spot against…Ohhh, ohh yeah. There’s her bifurcation right there.

I: So what are we doing now?

S: Cleaning it up….and….ok. (sigh) I’m gonna turn it up (focus), I might actually start with the overall gain…and then adjust my TGC’s to clean the vessel out. Oh, I wish the gas would move out of there. Ah, ok. There it is. (showing screen to patient) That’s your aorta, and there’s your right and left common iliac. OK. So now…I’ll store that. (Sigh) I’m done.
Think Aloud 2 MM (Female, Undergraduate, 21-23, From Albany, MO)

I: OK. So, we’re gonna do a think aloud protocol, of the Aorta ultrasound.

S: Did we usually the Aorta preset, or the Abdomen?

I: We usually use the Aorta preset, but you can choose whatever. Why would you choose one or the other? How do you decide?

S: Because Aorta is for the aorta..(laugh)...and abdominal is for all the other abdominal organs (laugh).

I: that was the kind of answer I would have gotten from my kids. Um...how does the image look different if you use the aorta preset vs the abdominal preset? So, say you’re looking at it in the aorta preset and then what if you imaged the same area in the abdomen preset, how would the image change? How would it look different?

S: The aorta wouldn’t be as clear…and defined...

I: OK. (pause) OK. So what are you doing now?

S: Um...I moved the transducer up to the proximal aorta so that I can see the very...(to patient) Can you breathe in for me?...(Long pause, scanning)

I: So you’ve gotta tell me what you’re doing every time you do something.

S: Moving the focus up so that the beam is focused on where I want to see the aorta.

I: How does that help?

S: Well, if I move it too far up, then the aorta fills up with ... echoes, that I don’t want, so...
OK. So that would be the sagittal aorta, proximal aorta.

I: OK. So... do you measure anything on that?

S: Yes.

I: OK. (Long pause)

S: So, you click on long aorta, proximal, and you measure ....you measure as high up as you can... perpendicular to the vessel... (pause) and then you move on... And that’s proximal.

I: How do you know it’s proximal?

S: Because you can see the heart.
I: OK>

S: And so, we move on to where you have the celiac and the SMA...in the picture and that’s the mid.

I: OK.

S: I can’t quite remember if you measure above or below the SMA for the mid...measure below. Measure perpendicular to the wall.

I: So, when you freeze and image, what do you evaluate to decide whether you like it or not?

S: ummm...you evaluate...the TGC, ... because that can put echoes or take out echoes from the vessel that were there, and then the focus...move it up or down...toward the structure you’re imaging, and...... and........ I don’t really know what else. Your overall gain.......oh, and your depth.

I: what do you do with the depth? How do you determine the depth?

S: Umm, you increase it or decrease it, um......by looking at where the spine is.......you want the spine in the very back of your picture.

I: OK.

(Long pause)
S: And then.........then move distal to the aorta mid-dist. I’m changing the TGC.........to clean out...... the vessel........and then, (pause)measure the..........how do you measure this? Oh, it’s not in the calc package for this one. (Measures mid-dist ao) And then.........you move your ....unfreeze it.......and then move down........to......your distal aorta...... (scanning)... and that’s your........left iliac (?)

I: How do you tell?

S: The way your transducer is angled.

I: OK.

S: OH.........umm, and then take measurement.........of........the distal aorta.........and the left iliac. And then .......I kind of like unfreeze it...and........only move the bottom of the transducer, fanning it over......or not really fanning, but.........I’m moving it, the transducer, over a little to see if I can see the right iliac......(long pause, scanning)......I can’t connect it.........to the aorta

I: so what are we looking for?
S: Um, trying to get the right iliac with the distal aorta. (pause scanning) And, I’m not sure……… if that’s it………(scanning)………Is that it? Here?

I: You’re getting there. So, how do you make sure? What’s confusing about it?

S: Uhh,……because the that’s the vein underneath it…errr..I don’t know. (pause) It’s just hard to move the transducer like that……it’s hard to get around the belly button.

I: Why is the belly button a problem?

S: Because it can be filled with air and there’s lots of shadow behind it. Um……It can cast a shadow and then this you aren’t able to see what you want to see. (long pause, scanning) That might be about as good as it’s gonna get. Hmmmmm, (long pause, scanning). Freeze. I should decrease my depth on that one and move my focus up. But then I would just do the same measurement of the right iliac.

I: OK

S: And then………that’s all for the sagittal……aorta. So……we’ll go to the transverse. (pause, scanning) And find the….umm…distal aorta, and then decrease the depth so the spine is at the back. And….so you find the distal aorta and move down……

I: Is there a landmark on the body you use to find the distal aorta?

S: Hmmmm…..

I: How do you know where to put your transducer when you’re looking for the distal aorta?

S: It’s usually around the belly button. And then it divides kind of right under the belly button, so you can go under the belly button and scan up…… (Long pause, scanning)

I: So what are you working on now? What are you thinking about?

S: I’m trying to get the iliac arteries where they can be measured without…I don’t know…cause if I move it up, it kind of just blends together, and I don’t know…I don’t know…I don’t know…(pause, scanning)

I: So how are you maneuvering the transducer to try to get better…to get what you want?

S: Umm, I’m fanning it up and down…and I really don’t know which picture I want to take (long pause, scanning) Hmmm, ………… (scanning)……… (very long pause, scanning) (Freezes image) I guess I might use that image to measure……transverse……right iliac and left iliac……and…………the right iliac would be this one. (Measures on screen) …on the left side of the image, and so we measure…I think we measure that across. (Long pause) And you measure the… ……left iliac……there. (measures) And that’s all you do for the iliacs. And then……moving up where the iliacs come together and that is your …… distal aorta. And that’s usually right above the belly button. And so……you would take that image and …
measure it distal (measures) And then the distal...you move above.........and usually right in the middle... from under her ribs is where I always stop, for about mid distal, and so you freeze that. And measure it. (measures) And then......for the mid, you move up to find where the SMA and celiac come off. And so, ............then right after the vessels come off, that’s your mid. So there’s your SMA, and there’s your celiac, so right about there will be ......your mid...aorta. So...and then you measure... (measures). And I guess, well, the mid... and then you gotta go... (trails off)

I: So what are you working on now?

S: Is the renal artery image and the mid image—that’s not the same usually is it?

I: Not usually, no.

S: That’s what I thought. (pause, scanning) And so...after that I (Long pause, scanning) Then the renals are .......... distal on the aorta toward the......SMA. So, we usually find the SMA coming off and then move down the aorta...Is that the renal?

I: You have to decide...

S: If it is, it would be your right...renal...

I: Are there any other landmarks that you use to help you decide where you’re at. To help you make sure you’re at the right level?

S: Ummm......Like, well, your renal veins would come off the IVC at ...... should be the same......... time about........ so...... that’s ........renal vein, coming across, ........(scanning) ........ right there....... ........ and then your renal arteries.......I don’t know, I didn’t get this picture on the comp when we did it either. (laugh) That’s the renal vein, so the renal artery’s coming right there...really? OK. (Pause) OK. So you’d take a picture of that and you would label it “renal artery origin”. And then...............so we already did the mid-distal, and the mid.........we’d move up.........after the celiac, or, I mean, I guess before the celiac, move up the aorta..........(scanning) ........and increase our depth.

I: Why do you do that?

S: So, well, the aorta will be out of our image if we don’t increase the depth, so that the spine is at the very back of the image. And so........... I think that would be.........uh......proximal aorta in the transverse.

I: So how do you decide when to freeze the image?

S: Uh, just whenever, and then you can move it back to when it’s um, ...... dilated, I guess, so that you get a good measurement. Then you push measure......that’s not very good..........(scrolls through cine loop). That would be more the area and then we also had to
do long and transverse of the IVC. And I think don’t you hold your breath when I look at the IVC? So and then just, from your aorta, you scan over, and that’s your IVC.

I: Why do you have the patient hold their breath for the IVC

S: Um, because it dilates the IVC because usually it’s collapsed. And so you can get a measurement of it. And then……we find the IVC in well, we just move the probe 90 degrees and then you have your aorta……right beside it… and your spine, and we can decrease the depth and have your focus at the IVC……and then I guess we’ll get the……the……measure the IVC. And that’s it……Oh……the coronal bifurcation! How could I forget! (applies more gel to the patient)
And so, then, for coronal, we move over to her side……and we want to point the transducer to where………her aorta bifurcates. Hmmm……..(scanning) ……..

I: Is there a landmark that helps you know where to put the transducer?

S: Ummm………..I just put it kind of above her hip and …….take it into her side above her belly button.

I: OK

S: (Mumbles) (Very long pause, scanning) I got this really easy when we did the comp, but I can’t find it. Use more gel… (mumbles) (scanning very long pause) (sigh) Hmmmmmm

I: Just tell me what you’re doing.

S: I’m just moving the probe, trying to find…the coronal bifurcation…that’s a good picture………. (Very long pause, scanning) (mumbles) I don’t know… (scanning) (getting frustrated)

I: Are you fanning the probe back and forth or pushing harder, or what are you doing with it?

S: I’m trying to push harder, and changing where I’m pushing in, and I’m trying to fan back and forth. Oh…… (scanning)

I: So what kinds of things make this image harder to get?

S: Umm, I don’t know. I remember doing this and it was easy on her, but now it’s not. Maybe it’s because she’s hungry (laugh). Yeah, if it’s a gassier patient, we can’t see through the gut and you have to try to push the bowel away or find somewhere else. (scanning) I don’t know.