Push and pull factors impacting the pedagogical approaches used by sonographers to teach scanning skills

Delwyn Nicholls[1,2], **Linda Sweet**[3,1], **Jon Hyett**[4,5] and **Amanda Müller**[1]

[1]College of Nursing and Health Sciences, Flinders University, Adelaide, South Australia, Australia
[2]Sydney Ultrasound for Women, Sydney, New South Wales, Australia
[3]School of Nursing and Midwifery, Deakin University and Western Health Partnership, Burwood, Victoria, Australia
[4]Sydney Institute for Women, Children and their Families, Royal Prince Alfred Hospital, Sydney, New South Wales, Australia
[5]Discipline of Obstetrics, Gynaecology and Neonatology, Faculty of Medicine, University of Sydney, Sydney, New South Wales, Australia

Abstract

Objective: To report the qualitative findings of the inaugural survey of sonographer skill-teaching practices in Australia using the SonoSTePs tool.

Method: A national cross-sectional survey of all qualified sonographers registered with the Australian Sonographer Accreditation Registry. A mix of quantitative and qualitative data was collected. This paper reports on a content analysis of the qualitative data relating to factors that impact on teaching.

Results: A total of 528 respondents provided a range of qualitative data in five extended text questions. Five key themes emerged from the analysis: limited protected teaching time; perceived skill complexity; learner skill level and credentials; avoiding overwhelming the learner; and patient well-being and their willingness to be scanned. Novel teaching interactions between the educator and the student sonographer were identified. Information was provided to learners at four time-points across the continuum of clinical practice performance. The type, quantity and purpose of the information provided by the educator to the learner differed at each of these four time-points and included the following: (i) pre-task clarification, guidance and practice norms; (ii) in-task verbal information and scanning support; (iii) post-task support and information; and (iv) end-task or terminal feedback.

Conclusion: This is the first published study which reports the push and pull factors affecting pedagogical approaches to teach and learn complex scanning skills. These results provide a corpus of new knowledge, and the first analysis and review, about the pedagogical findings related to teaching scanning skills for clinical practice. This study provides a basis for further research and practice improvements.

Keywords: cognitive load, feedback, physical guidance, psychomotor skill, ultrasound.

Introduction

Ultrasound examination is a complex psychomotor skill.[1] There is a lack of evidence about how scanning skills are taught within the sonography profession. To address this, a survey tool, SonoSTepPs, was purposively developed. The SonoSTePs tool contained a mix of quantitative and qualitative questions, to ascertain teaching practices but also explanations of practices and factors that impact on teaching.[2,3] The aims of this research were to (i) determine the approaches being used by sonographers to teach scanning skills, (ii) identify what pedagogical approaches described in the motor-learning literature are being used by sonographers to teach scanning skills, and (iii) explore whether heuristic instructional approaches were being used to teach psychomotor scanning skills. This paper presents the qualitative data that explain factors that impact the teaching practices of sonographers and heuristic approaches uncovered.

Correspondence to email l.sweet@deakin.edu.au
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Methods and materials

A national cross-sectional survey was undertaken of all qualified sonographers registered with the Australian Sonographer Accreditation Registry (ASAR) from September to December 2014 with the SonoSTePs instrument.[2–4] Ethical approval was obtained from the Flinders University Research Ethics Committee (No. 5584). Participation was voluntary and anonymous. The survey was administered electronically using SurveyMonkey™ software, Sydney, Australia. Further details of the survey distribution have been reported elsewhere.[4]

The SonoSTePs instrument[3] comprised of 25 questions, including a mix of Likert-type rating scales about teaching practices, text boxes for clarification on demographics, professional practice and educational preparation, and five extended text questions where respondents were asked to outline and explain their rationale for the instructional practices that they used when they taught scanning skills. The responses to the qualitative data were analysed using content analysis.[5,6] The aim of this paper is to describe the key concepts about the factors which influenced the sonographer's approaches used to teach scanning or psychomotor skills. The principal researcher (DN) reviewed all data and coded for content and whether it related to barrier or enhancer to best clinical teaching practice. A second researcher (LS) reviewed the same data set, and collectively, the researchers developed the final themes.

Ethical approval

The study was approved by the Social and Behavioural Research Ethics Committee at Flinders University, Adelaide, Australia (SBREC project number 5584). Participants recruited September to December 2014. Consent was assumed by completion of the survey.

Results

A total of 528 complete surveys were received.[4] The number of responses to each text question varied from 43 to 247. A total of 780 responses were received among the detailed open text questions about teaching practices, rationales and challenges. Five key themes emerged from the content analysis of these open text responses which are interrelated and interconnected. These are limited protected teaching time; perceived skill complexity; learner skill level and credentials; avoiding overwhelming the learner; and patient well-being and willingness to be scanned. Additionally, heuristic teaching approaches were evident from this data in relation to providing information to learners at four time-points across the continuum of the whole clinical practice performance.

Factors impacting teaching

There were many factors identified which influence the skill practice opportunities available to a learner when they are acquiring scanning skills on the job. As will be seen, these are complex and interrelated.

Theme 1: Limited protected teaching time

Many respondents identified that they had little regular teaching time because they were teaching within fully booked and busy departments. Therefore, many practice settings provided unpredictable, ad hoc or opportunistic teaching opportunities. One respondent explained, 'There is very little time to teach students in a private practice. Today it is all about productivity' and another wrote, 'Just grab whatever time we have with the patients that come in'. Many respondents pointed out that there was a lack of protected teaching time, and this was problematic for the teaching of scanning skills, as one explained, '. . .the teaching is much more "ad hoc"' and another highlighted that 'I just grab whatever time we have with the patients that come in'. This impact of this on teaching was nicely described here:

> If there is no formal time set aside for training and it is on the job training often you do what you can when you can. This means you may have time to teach a whole technique or it may have to be taught piecemeal as time allows.

Overall, this limited teaching time resulted in opportunistic, rather than planned, approaches that resulted in maximising opportunities, all of which served to influence the pedagogical approaches used by the respondents.

Theme 2: Perceived skill complexity

Most respondents reported that before teaching a scanning skill they subjectively assessed the degree of difficulty to learn the specific skill. They proceeded to grade the skill into two categories, either simple or complex skill. The outcome of this judgement or classification determined how much of the skill the responder taught the learner in one teaching session. One person explained it 'Depends on what skills are being taught, more complex skills need to be broken down into different parts'. For those skills which were categorised as being complex, the respondents identified that they performed task deconstruction and commenced by first teaching the simpler skills and then advanced to those which were more challenging. This practice is referred to as scaffolding.[7] For example, one respondent explained, 'Complex skills need to be broken down into different parts. . . Simpler skills can be taught in one session. . .'. Another respondent pointed out that it 'Depends on skill being learned', while another respondent pointed out that it 'Depends on how complex the exam is. Obs [obstetrics] is broken into sections, thyroids all in one go'. Finally, a cardiac sonographer respondent wrote:

> . . .cardiac sonography is mostly performed as a comprehensive examination; an echo [ultrasound] is complex, multi-layered; training requires breaking down those layers to fundamental 2D methods, and then adding more information e.g. spectral Doppler and building up the physiologic as well as anatomic layers to the story.

The assessment of complexity was an individually perceived activity and there was no mention of guidelines or general rules about this. This again shows a semi-formalised approach, whereby the pedagogical practice was based on self-discovery and past experience.

Theme 3: Learner skill level and credentials

Respondents pointed out that the perceived skill level and credentials of the learner influenced their skill-teaching approach. The educator would make a judgement about the learner's scanning level and capabilities, and this affected subsequent practice. For example, a qualified sonographer was expected to know how to scan, so the whole scanning skill was often taught in one session. Thus, one respondent wrote, 'If teaching a qualified Sonographer, I would usually limit to teaching to one session'. In contrast, when the learner was a student, there was little expectation about their scanning ability, so it 'depends on level of trainee'. Therefore, skills were deconstructed and taught in parts to the level of the learner's experience. For example, one respondent wrote, 'If the skill is short and has few elements or is taught to an experienced sonographer then it may be taught in one session', while another pointed out that they 'Base the teaching [approach] on their [the learner's] ability. If they are less able, they work on one aspect at a time'. Therefore, contrasting teaching approaches are used to teach a student and qualified sonographer. A respondent reflected on this:

> [It] depends on the level of skill of the person learning, if a competent sonographer is learning new areas such as MSK/vascular... the whole scan can be demonstrated, if a newbie [beginner/student sonographer], then I break it down into small bites.

The concept of teaching to a learner with prior experience or credentials seemed to result in a set of expectations of their performance capability regardless of the complexity of the scan being taught.

Theme 4: Avoiding overwhelming the learner

Respondents realised that teaching the theoretical content and the scanning skills related to performing an ultrasound examination in one session can overwhelm the student learner. Indeed, many respondents highlighted that teaching a scanning skill in one session hampered learning and to do so was possibly pointless. For example, one person wrote, 'Cardiac is too long to teach in one session', and another wrote that teaching a whole scanning skill in one session '...would overwhelm them. It is better to break it down, so it is better absorbed'. Similarly, other respondents pointed out that it 'Depends on how much information there is to pass on and also the person and whether they are going to be able to take it all in...' and 'Too much information can confuse the student and therefore not be a useful learning process'.

This assessment of cognitive load and its influence on learning was ad hoc, done in an agile manner, and dependant on the task being taught.

Theme 5: Patient well-being and willingness to be scanned

Two notable factors that were identified as influencing teaching practices included the well-being of the patient and the patient's willingness to be scanned. There is an accepted practice norm that when the patient is sick, it is not appropriate for the learner to scan them. As such, we found a respondent commenting that the 'Limitations of the patient when the patient was sick' impacted upon the skill practice opportunities that were provide to the learner on any day. However, the respondents did not identify the medical conditions that would preclude the learner from scanning the patient, although one respondent wrote that it 'depends on the patient, the skill, the skill of the student and the time available', while another explained, 'It will depend on the willingness of the patient. Usually those with the most to learn from are the sickest patients and therefore cannot tolerate long periods of a learner scanning them'. A related response was that it 'will depend on time constraints (workload) & patient consent'. These quotes reflect the general consensus that the opportunity for the learner to be scanned was inextricably linked to the patient being willing to consent to the learner scanning them.

Novel teaching interactions are discovered

Novel teaching interactions between the educator and the learner were identified. Respondents reported through the open text responses that they provided several types and formats of information to learners when they were acquiring and refining clinical practice skills. Respondents described providing information to learners at four time-points across the continuum of the clinical practice performance. The type, quantity and purpose of the information provided by the educator to the learner differed at each of these four time-points and included the following: (i) pre-task clarification, guidance and practice norms; (ii) in-task verbal information and scanning support; (iii) post-task support and information; and (iv) end-task or terminal feedback.

Pre-task clarification, guidance and practice norms

At the commencement of the clinical practice and prior to identifying the patient for the clinical examination, some respondents described providing the learner with pre-task clarification, guidance and practice norms to complete the examination. Prior to the learner commencing a physical scan of the patient, respondents reported that they clarified the clinical question to be answered during the ultrasound examination and provided additional coaching and guidance to help the learner plan their approach to scanning. For example, 'The student has been grilled to know what to look for but also other pathologies. Selecting the correct transducer. Patient prep' and

this clarification occurred 'sometimes at the start. How to provide the most appropriate technique to answer the clinical question'. Additionally, consent was sought by the educator to hold the learner's hand and guide it to the correct position on the patient, also referred to as physical guidance, for example 'Before scan: if student minds being directed with my hand guiding hers on the probe. Or if she would prefer just verbal instruction. . .'. Ensuring learners achieved sufficient exposure to clinical variation was also described, for example 'In breast work the student needs to see different types of tissue before proceeding', as a part of the practice norms.

In-task verbal information and scanning support

Throughout the execution of the scan while the skill was being practised, the sonographers reported that they provided verbal guidance and physical guidance. This is known as in-task information or feedback. An example is, 'Positioning of the scanner [transducer] or student's hand maybe altered during the scan if deemed a simple solution', and 'During the scan, comment is usually limited to a suggestion as to how to improve the image (machine controls) or to re position patient or probe'. Many sonographers reported that one of their roles was to limit and censor the verbal information provided to the learner when the patient was unwell, large or pathology was encountered. One respondent explained 'I tend to avoid doing it during the scan as the patient is listening, it depends on the patient'. Another said:

> The 'when' aspect of providing feedback all depends on the nature of the subject and case. If the matter is one of a sensitive nature, I would often restrict feedback to the end [of the examination] in a private setting away from the subject e.g. Breast Ca [cancer] or some life altering diagnosis. If the nature of the case is not sensitive and the subject is coherent and consents to being involved in a teaching environment (such pt's [patients] are usually ok with it), then feedback can be provided along the way.

Thus, the provision of in-task feedback was dependant on who was present and where the feedback was delivered.

Post-task support and information

During the post-examination write-up period, respondents described providing support and information to the learner to ensure the examination findings were correctly interpreted and written up on the worksheet/report. Respondents reported that this helped with the learner's interpretation of the scan findings and to accurately write-up their examination results. For example, one person wrote that 'image review and report writing with feedback occur at the end in the write up area', and another stated they:

> Often compare [the cardiac scan images] and refer to other patients with similar abnormalities and use a bank of images that we have on hand to demonstrate mild, moderate, and severe examples of the lesions. . .

The post-task information could thus include comparisons of the student's findings to variations from similar situations as a way of contextualising learning.

End-task or terminal feedback

At the completion of the practical performance, after the patient has left the scan room, the educator often provided end-task or terminal feedback to the learner: reflected in this comment, '[I give] feedback at the end of the session'. Many respondents stated that the information provided to the learner once the examination had been completed targeted three particular areas of clinical practice: (i) gathering feedback about how the examination could be improved, (ii) exploring how their communication with the patient could have been improved and (iii) linking the feedback to future learning goals. For example, one educator wrote that they '. . .provide feedback on the trainee's interaction with the patient. . .often ask if [what] they think they could do differently, and how would they deal with it next time'. After the feedback has been provided, a respondent wrote that they '. . .discuss learning action plan for continuing educational needs'. Clearly, the feedback was oriented not only to performance review but also towards future learning.

Discussion

In the open text questions in the SonoSTePs survey, the respondents provided explanations of and justifications for their teaching practices. The respondents explained that scanning practice time is limited and multifactorial, and often outside the educator's control; for example, if the patient was not well enough for the learner to scan them, the patient did not provide consent for the learner to scan them, or the department was busy then there were no practice opportunities for the learner. This constraint on teaching practice has not previously been identified in the literature. This situation naturally affects teaching, because when scanning opportunities do became available, the educator would often encourage the learner to practise for long periods. While opportunistic teaching is valuable, it is also important that educators prioritise their teaching role and plan and enact dedicated teaching sessions[7,8] that are frequent and short in duration[9–11] and reduce the sporadic and long-duration practice sessions.[11–14]

The way in which respondents approached teaching a skill was influenced by the perceived complexity of the skill. Many respondents described how they were influenced by the number of parts to be taught, and if many parts or 'complex', then they would teach it over more than one session. Similarly, if there was just one to two parts – considered 'simple' – then the skill would be taught in one session (note that whole ultrasound skills are rarely 'simple'). While recognising the complexity of

the skill to be learnt is appropriate pedagogy, there was no definition or clear descriptions of simple of complex skills and no recognition of the variance between visuomotor skills and visuospatial skills.[1,15] The complexity of a skill to be learnt is related to cognitive load theory.[16] An educator can limit cognitive overload by first undertaking a task analysis to determine the complexity of the skill,[17,18] limiting the number of skills taught at any one time,[19–21] and by limiting dividing the learner's attention between two concurrent information sources such as the transducer hand control and the console hand control.[16] There was some evidence of these practices in the open text response; however, it was not universally evident, for example reports of teaching a whole skill in a single session.

The results of this study found that the majority of respondents used different psychomotor skill-teaching approaches to teach student and qualified sonographers scanning skills. There was a perception that qualified sonographers possess the unique and fine transducer manipulation skills needed to scan a new anatomical structure or when using a new device. However, the motor-learning theories on psychomotor skill acquisition[14,22,23] challenge the ideology that formally qualified sonographers have this skill set. Relying on qualifications alone does not give recognition to true prior learning; a person with a formal qualification may have less clinical experience than a peer without the formal recognition. Sonographers should assess the skill level of individual learners and not base judgement on assumptions or qualifications alone. Essentially, the study results suggest that when the learner was a qualified sonographer, educators thought they could teach both simple and complex scanning skills in one session. However, this assertion is at odds with the cognitive load literature[16,21] which suggests all learners have a cognitive load threshold that needs to be considered.

To explain further, the seminal motor-learning theorists propose that a mental schema or motor map must first be encoded, by any learner, before the skill can be recalled, modified and executed.[9,13,22] For a new anatomical structure or new device, this has not yet happened. When the learner has not yet encrypted a motor map in their motor cortex, they have little to no knowledge of the basic motor movements that are needed to execute the skill. For example, when new multi-planar transducer movements are first being acquired, they must first be taught, learned and then consolidated.[13,23] Research by Lavender *et al.*[24] found that sonographers with (variable) skill proficiency required additional clinical skill education and training to be able to image the fetal corpus callosum in the sagittal plane using 2D imaging, at the 18-20-week gestational age morphology scan. The sonographers had not yet been taught the acoustic windows to image the fetal brain structure or the transducer movements to identify the fetal structure. Therefore, the research by Lavender *et al.*[24] provides the first identifiable evidence in ultrasound that supports the theoretical tenet that the creation of a mental schema is an antecedent step to be able to recall and execute the skill safely and efficiently. Credentials are not a replacement for sound pedagogical practice.

This study has shown that many sonographer teachers were cognisant of the need to not overwhelm the learner. It is understood that working memory has a finite capacity and that long-term memory had the potential to hold an unlimited supply of mental schemas.[19,25] A learner may experience the effects of cognitive load from three separate sources.[19,26] The first source, intrinsic load, refers to the cognitive demands placed upon the learner when they learn a complex task and they have nominal prior skill knowledge. The intrinsic load increases as the complexity of the skill being learned increases. The second source, extraneous load, occurs when learners use working memory resources to attend to aspects which are not essential to the skill. An example is attending to distractions in the scanning room while scanning. The third source, germane load, occurs when the working memory is purposefully used to modify an existing schema (e.g. to modify a scanning skill due to patient pathology) or to recall a number of skill schemas when random skill practice is scheduled (e.g. scanning the gallbladder, followed by scanning the aorta, and then obtaining the four chamber heart view on an adult). Learners may experience the effects of cognitive overload when one, two or all three of these sources of cognitive load are sufficiently large.[26] While the respondents in this present study acknowledged cognitive overload as an influencer in their teaching practice, this was mostly in related to task analysis and teaching in subparts. It is important to consider other forms of cognitive load when teaching skills.

A major finding of this research was that respondents provided information to learners at four points in time when they supervised a learner performing a psychomotor scanning skill. These occurred before the examination commenced; during the ultrasound examination; prior to the patient leaving the department (as the learner wrote up the examination worksheet and provided an interpretation of their scan findings); and at the end of the ultrasound examination. This is the first time that these clinical supervision practices have been formally identified and documented in the ultrasound profession. The results of the content analysis of the open text responses showed that at each of these time-points, the educator was required to communicate with the learner differently and draw upon different bodies of knowledge to support the learner's clinical practice encounter. The skills to support this teaching role differ from the additional non-technical skills needed to provide a safe teaching and learning environment as well as patient-centred care. Bearman *et al.*[27] describes these non-technical skills as including professionalism, communication, collaboration, management and leadership. Non-technical skills are first taught and then learned, and they enable an educator to perform additional roles other than their primary role as a clinical educator. These interactions are all forms of feedback.

While many respondents described giving positive feedback and some a plan for future learning, the data were suggestive

that most feedback was unidirectional. There is now a significant body of work espousing the benefits of a two-way dialogue model of feedback that involves the learner self-assessing areas for practice improvement in their performance, with the feedback provider responding to this and confirming or providing additional information.[28–31] Educators can achieve this through application of feedback models such as 'Pendleton's rules'.[31] Furthermore, respondents described carrying out some degree of physical guidance and coaching. These pedagogical approaches may be valuable to first learn the fine motor skills, but motor-learning theory suggests these should be minimised and faded over time to reduce the learner's dependence on the tactile feedback.[11,32,33]

Strengths and limitations

The survey instrument was purposively designed and validated, and contained open-ended questions that explored the respondents' experiences of teaching and learning. Open-ended questions provide the opportunity to gather additional insights which may have been excluded by using only closed questions.[34] Furthermore, the results from the content analysis have provided rich data about the complexity and consideration of multiple factors that are experienced by educators when teaching psychomotor scanning skills on the job in busy departments. It is however acknowledged that the survey was based on self-reported information. The limitations of self-reported data are well known and have been previously described.[29,35] Further research recommendations include the following: (i) to undertake a review of the categorisation of the psychomotor scanning skills used to perform an ultrasound; (ii) to determine the optimal skill-teaching approach to use to teach psychomotor scanning skills; and (iii) to identify whether there are deleterious effects on the long-term acquisition and retention of psychomotor scanning skills from practice duration or when in-task feedback is provided during the initial stages of skill acquisition.

Conclusion

This is the first published study which reports the pedagogical approaches to teach and learn complex scanning skills across a nation. These results provide a corpus of new knowledge about the pedagogical findings related to teaching scanning skills for clinical practice. While respondents described applying some aspect of the motor-learning and cognitive theories, further consideration of these is warranted. An important finding of this research was that a learner's clinical performance is supported by the educator's verbal guidance and coaching which is given at four points in time throughout the continuum of the whole practice performance. While feedback is a vital component of effective feedback, not all feedback is supportive of learning. Reviewing approaches of limiting in-task feedback and giving supportive end-task feedback are warranted.

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Author contributions

Delwyn Nicholls: Conceptualization (equal); Data curation (equal); Formal analysis (equal); Investigation (equal); Project administration (equal); Writing-original draft (equal). **Linda Sweet:** Conceptualization (equal); Formal analysis (equal); Project administration (equal); Supervision (equal); Writing-review & editing (equal). **Jon Hyett:** Conceptualization (equal); Supervision (equal); Writing-review & editing (equal). **Amanda Muller:** Formal analysis (equal); Project administration (equal); Supervision (equal); Writing-review & editing (equal).

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