E-Learning Design Principles & Methods Final Project

Vascular Surgery of the Lower Extremity for Plastic Surgeons

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Final Project
E-Learning Design Principles & Methods - Fall 2018

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Table Of Contents

Overview

The Need for E-Learning in the Domain of Plastic Surgery

Plastic surgery is a complex field that requires mastery of a vast corpus of knowledge and surgical techniques that apply to the entire body, in contrast with many specializations that focus on a narrower anatomic area. Despite having 4-6 years of post graduate education following medical school, residents and attending plastic surgeons often complain that the volume of content to be learned is disproportionately large with relation to the time that residents have to master it.

The Department of Plastic Surgery at the University of Pittsburgh has been employing a variety of educational technology to make plastic surgery education more efficient and effective. One of the more successful programs has been the implementation of the Plastic Surgeon Education Network (PSEN), an e-learning system that supplements the resident's in class education. Students complete one or two modules of learning on the PSEN system every week and then meet in a conference setting to discuss their learnings. This is an effective example of the "flipped classroom" environment.

We collaborated with the University of Pittsburgh's Department of Plastic Surgery to explore ways that these e-learning modules and flipped classroom teaching could be improved.

Project Focus: Vascular Surgery of the Lower Extremity

PSEN consists of nearly 100 modules broken down into 8 units. Upon consultation with the educators at the Dept. of Plastic Surgery, we narrowed down our focus to the sixth unit, "Plastic Surgery of the Lower Extremity". This unit was chosen as the timing of delivery matched with the project timeline for our final experiment and the scope for this unit is smaller than some of the other units like Breast Surgery, which would require e-learning units of much greater length than the scope of this project.

Within the Plastic Surgery of the Lower Extremity, we chose the specific module of "Vascular Surgery". Vascular surgery is not generally the direct purview of plastic surgeons, but plastic surgeons often collaborate with vascular surgeons to address the complications of vascular surgery. It is therefore important for plastic surgeons to understand the nature of vascular disease, how it is diagnosed and treated, and what complications commonly arise following vascular surgery.

Overview of Existing E-Learning Solutions in the Domain

The Plastic Surgery Education Network is being used by resident programs across the United States and is developed and maintained by the American Society of Plastic Surgeons (ASPS). The online learning system is sophisticated and combines a number of different modalities such as slideshows, audio, and articles, as well as pre and post assessments. It is updated annually by a committee of plastic surgeons from across the country.

However, PSEN modules are designed by plastic surgeons and not by formally trained educators, as such, there are gaps in the implementation. We identified four ostensible deficiencies in the existing online courses that might be improved by the application of e-learning design principles and methods:

1. Lack of segmentation - all topics in a module are covered in the same slideshow.
2. Redundancy in narration - slide contents are repeated in audio narration.
3. Not enough of a good thing - too few interactive/multimedia elements.
4. No formative assessment - there is a general dearth of assessment and practice opportunities.

Project Objective and Scope

The primary objective of this project is: "To develop an interactive, informative and engaging online course to teach plastic surgeons vascular surgery of the lower extremity."

This module is taught at UPMC in conjunction with another module and as such is smaller in scope than other modules in the PSEN. Our scope was to create a module which would take less than an hour to complete, including instruction and assessments.

Goals

Restructuring Existing PSEN Goals

The original PSEN course consisted of 31 learning objectives split into two categories: Pathogenesis/Prevalence and Treatment. A specific goal was stated under the heading of Pathogenesis, namely: “The resident will understand the general pathogenesis of lower extremity peripheral vascular disease and it course as well as the burden of disease on the population.” However, no goal was specified under the heading of Treatment.

The learning objectives themselves ranged in specificity from “Understand that minimally invasive techniques are best with short stenosis segments, single lesions and TASC A & B lesions” to simply “Diagnosis” and often did not fall under the definitions of Pathogenesis and Treatment.

We worked with experts at University of Pittsburgh Medical Center to understand which of these objectives were important and relevant to the actual knowledge and skills that plastic surgeons need in the field. Based on our discussions, we removed two of the objectives and then re-structured and consolidated the remaining into 29 knowledge components.

We identified four key areas of knowledge and skills that plastic surgeons require, they need to know about the incidence and prevalence of the disease, the different anatomical concepts related to the disease, how to diagnose it and how to treat it. Based on this insight, we formulated four main goals. These goals were refined using the ABCD method:

1. When prompted, students will be able to accurately describe the epidemiology and pathogenesis of lower extremity peripheral vascular disease including determinants, distribution, incidence and possible control options.
2. When prompted, students will be able to correctly explain the anatomy related to the lower extremity and how it correlates with vascular surgery.
3. Given a set of presenting symptoms in the lower extremity, students will be able to diagnose the patient effectively and correctly.
4. Given a diagnosis of vascular disease, student will be able to recommend the most appropriate course of treatment for the patient.

Defining Knowledge Components

Knowledge:

Epidemiology:

1. State the 3 stages of atherosclerosis and how this leads to peripheral vascular disease.
2. Understand the overall prevalence of peripheral vascular disease in relation to how many cases receive treatment.
3. Understand that incidence of peripheral vascular disease increases with age.
4. State the main risk factors that have been correlated to the development of peripheral vascular disease.
5. Recite the overall progression of disease from initial symptoms.

Anatomy:

1. Recite the sensory nerves of the calf and their area of innervation.
2. State the three most common patterns of occlusion in the lower extremity.
3. Name the four compartments of the lower extremity and their corresponding neurovascular bundles.

Diagnosis:

1. Recite the corresponding symptoms to Leriche syndrome.
2. Understand the values of the ankle-brachial index and how it relates to the progression of peripheral vascular disease.
3. Know the important non-invasive diagnostic tests and their role in peripheral vascular disease.
4. State the gold standard for diagnosis of peripheral vascular disease.
5. Understand the most common presentation in femoral popliteal disease.
6. Understand the most common presentation in tibial artery disease.
7. Know the indications of surgical interventions.
8. Explain the mechanism of reperfusion injury and its corresponding treatment.

Treatment:

1. State the different patency rates for both femoral-popliteal and femoral-distal grafts at 5 years.
2. State the possible complications of lower extremity vascular surgery.
3. Understand the basics of minimally invasive techniques in peripheral vascular disease.
4. State the medium through which bypass grafts are performed. (Treatment)
5. For each common occlusive pattern, state the best surgical treatment options in those meet surgical indications. (Treatment)
6. State three conservative interventions that can halt the progression of peripheral vascular disease. (Treatment)
7. Describe the surgical steps required in a four-compartment fasciotomy. (Treatment)

Skills:

Diagnosis

1. Perform diagnosis of lower extremity disorders.
2. Differentiate between exercise induced claudication and other forms of lower extremity pain.
3. Differentiate between peripheral vascular disease and venous stasis ulcers.
4. Explain the correct technique for measuring ankle-brachial pulses.

Principles:

Epidemiology

1. Explain the relatively high incidence of groin wound complications in vascular surgery.

Treatment

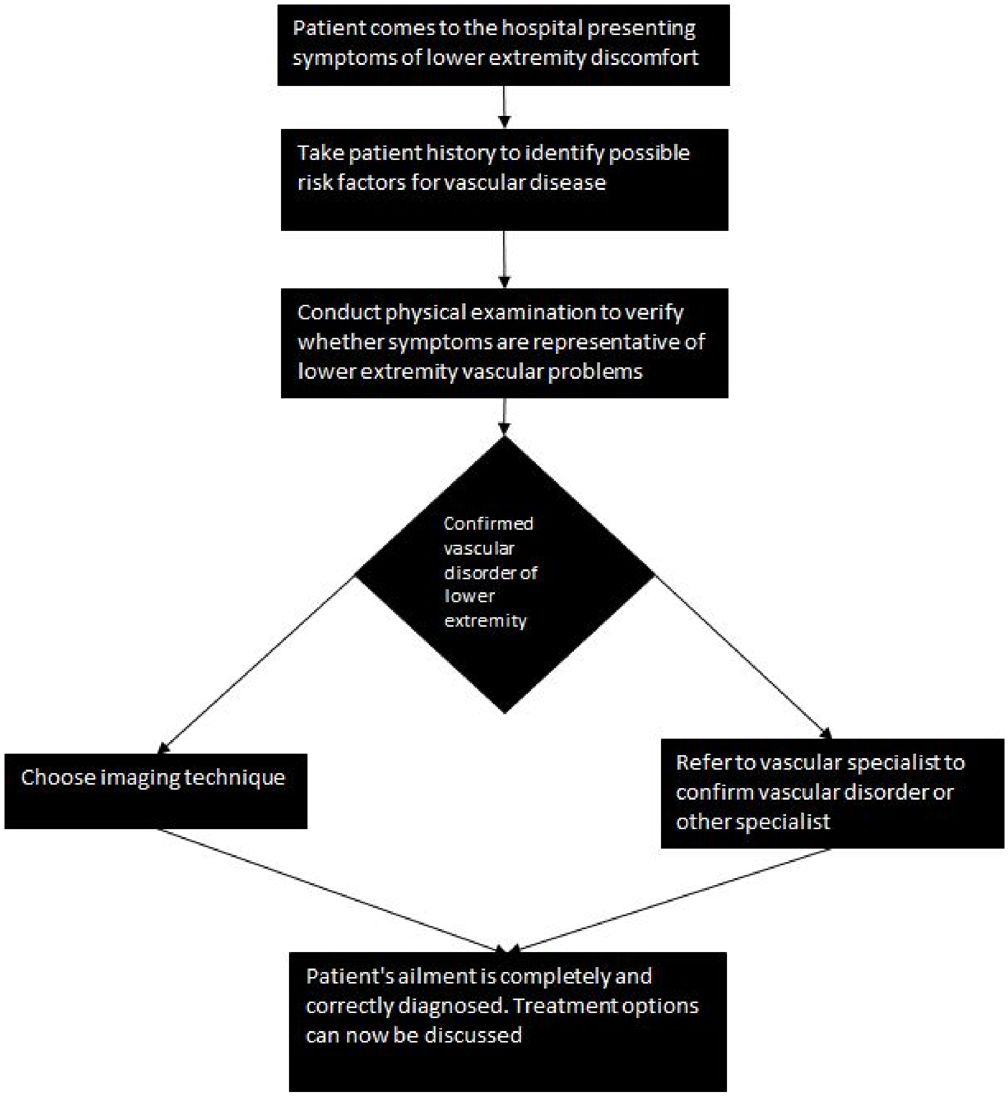
1. Understand that minimally invasive techniques are best with short stenosis segments, single lesions and TASC A & B lesions. (Treatment)

Models and Insights

Theoretical CTA and Cognitive Model of Diagnosis and Treatment Tasks

We performed theoretical CTA on the task of Diagnosis based by finding intermediate states between the initial and goal states, Patient Symptoms -> Diagnosis. For the Treatment task, we did not create an initial model as are prior knowledge and intuition were insufficient to formulate a useful cognitive model of this process.

Diagnosis



Empirical Cognitive Task Analysis

Think Aloud with Expert Plastic Surgeon:

We conducted out empirical CTA with DR-1, PGY-4 Resident and Research Fellow at UPMC in the department of Plastic Surgery. As a 4th year resident, DR-1 has studied the vascular surgery of lower extremity module earlier and has also come across different cases of peripheral vascular disease while on duty as a resident at UPMC hospitals.

The CTA lasted for over an hour and a recording of the conversation can be found here.

A summary description of the two CTAs with DR-1 is below:

a. Think aloud to discuss the last time he diagnosed a case of lower extremity vascular disease at the hospital.

   Key Insights: DR-1 highlighted the exact steps that he would take to diagnose the patient. While most of the steps aligned with our theoretical CTA, in particular the steps that he skipped based on insights from earlier steps were not well represented in our initial mapping.

b. Think aloud while solving diagnosis related questions from module assessments,

   Key Insights: In addition to information about how to approach each specific question, we were able to learn how to approach entire categories of questions and we also gained an idea of the important elements of information in a question that students look out for. The think aloud also highlighted the structure and order in which the students solve the diagnosis questions.

Structured Interview with Dr. Vu Nguyen, Senior Educator at Dept. of Plastic Surgery

The CTA with Dr. Nguyen focused on generation and verification of assessment questions. Additionally, a large part of this CTA focused on understanding the jargon and knowledge associated with diagnosing PVD, particularly diagnosis lesions and differentiating between the kinds of lesions.

This CTA also lasted around an hour and the recording can be found in two parts here. We followed this CTA up with several unstructured interviews to seek validation for our designs as we completed them.

A summary description of the CTA with Dr. Nguyen is below:

b. We asked Dr. Nguyen to create assessment questions for our KC's and to provide answers, with rationale to justify them. In so doing we both created extra assessment questions, and gained insight into the diagnostic and treatment decision making process

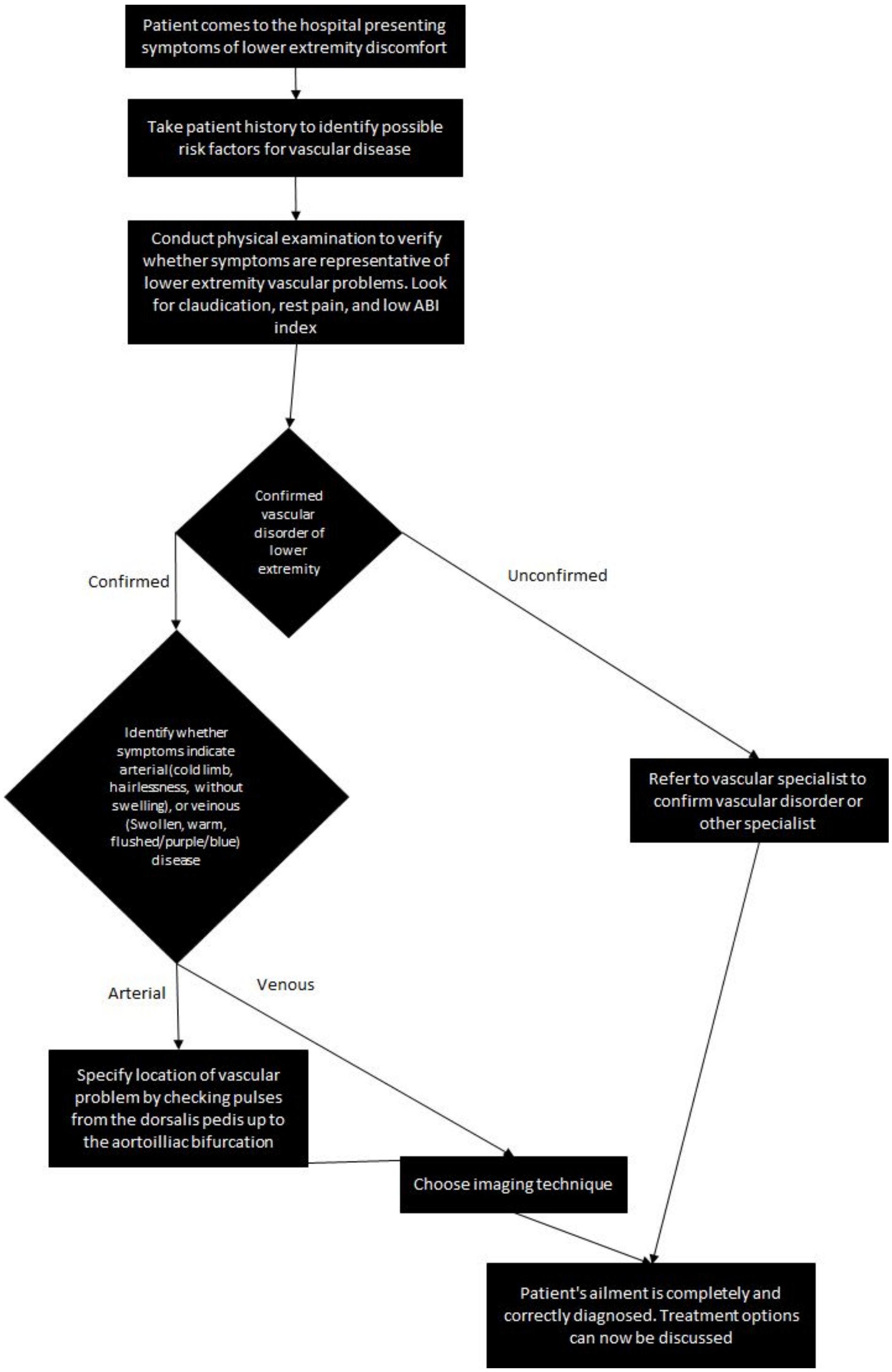
   Key Insights: Dr. Nguyen showed us the significance of differentiating between venous and arterial disease and what the structural difference is between these two (blood trapped in limb vs blood failing to enter limb), and how this presents in symptoms (swelling, warmth, flushing vs coldness to touch, hairlessness and a lack of swelling).

   He also provided the rationale for the use of angiography as the gold standard for diagnosis of peripheral vascular disease (it has highest image resolution, is dynamic, is in real-time, provides more information then a static image), and also provided considerations in favor of other imaging techniques (angiography involves high invasiveness, higher risks related to higher radioactive exposure and is relatively more expensive than other procedures).

Revised Models

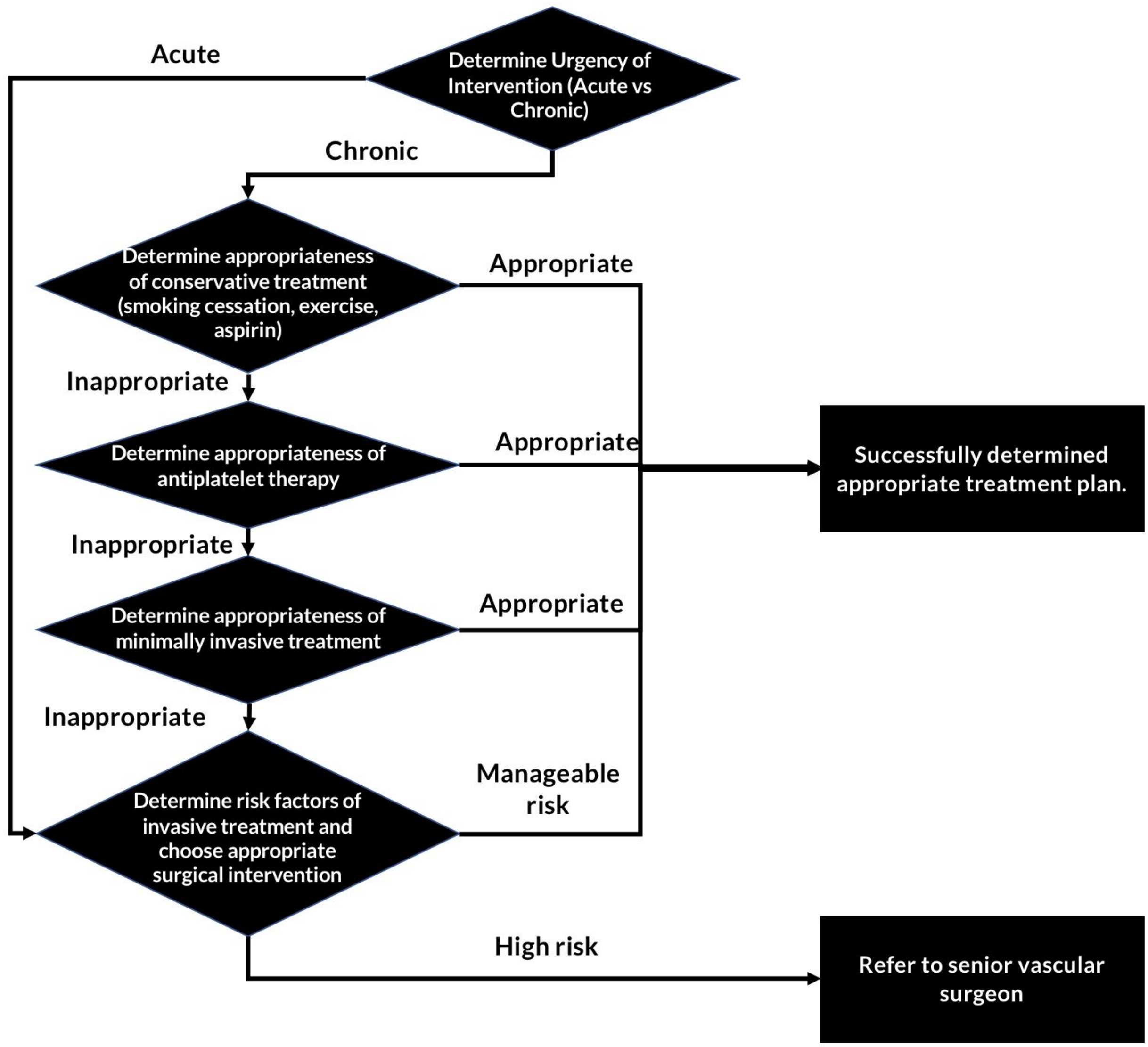
Our think aloud with DR-1 indicated that after confirming the presence of some vascular disorder of the lower extremity, that the location of the lesion or occlusion should be determined by checking pulses from distal to proximal to pinpoint where the blood flow stops. Our CTA with Dr. Nguyen also gave us insight into choosing the right imaging technique for diagnosis and the steps involved in choosing the right steps.

Diagnosis


Patient comes to the hospital presenting symptoms of lower extremity discomfort
Take patient history to identify possible risk factors for vascular disease
Conduct physical examination to verify whether symptoms are representative of lower extremity vascular problems. Look for claudication, rest pain, and low ABI index
Confirmed vascular disorder of lower extremity
Confirmed
Unconfirmed
Identify whether symptoms indicate arterial(cold limb, hairlessness, without swelling), or veinous (Swollen, warm, flushed/purple/blue) disease
Refer to vascular specialist to confirm vascular disorder or other specialist
Arterial
Venous
Specify location of vascular problem by checking pulses from the dorsalis pedis up to the aortoilliac bifurcation
Choose imaging technique
Patient's ailment is completely and correctly diagnosed. Treatment options can now be discussed

Treatment

Based on the CTA findings we created the new cognitive model for the treatment task as follows:



Assessment Design

Overview and Alignment with KCs

Based on the insights from our cognitive task analyses and interviews, we chose Diagnosis and Treatment from our four goals as the key topics to focus on as these are the far transfer goals for plastic surgeons.

It was not sufficient to test our 29 KCs with one assessment question per KC as some complex KCs could not be sufficiently captured in just one assessment. On the other hand, we could not design too many assessment questions due to the time limitations. To compromise between these two situations, we chose to limit some of the KCs to only formative assessment and focused on the key topics for summative assessment.

Ultimately, we designed 37 assessment questions, 17 of these are formative and 20 of them are summative. These were divided amongst the four goals as shown below:

Goal	No. of Assessments
Epidemiology	8
Anatomy	3
Diagnosis	14
Treatment	12
Total	**37**

Sources of Assessment Questions

Given the complex nature of the subject matter and our lack of domain expertise, we relied on a number of different sources to generate assessment questions. First and foremost, we extracted whatever questions we could from the PSEN module, however, there were very few questions that were useable as many lacked sufficient feedback or did not align directly with the KCs. There were also many KCs that were not assessed at all in the PSEN module.

Next, we gained access to some in-service exam questions from previous years, these are the end of course assessments that plastic surgeons give at the end of their residency and as such are the exact type of assessment PSEN aims to re-create. We were able to gain some useful questions from here, however, there is no module specifically discussing vascular surgery of the lower extremity in these exam question banks and as such we had to comb through hundreds of lower extremity surgery assessments to pick those which specifically target vascular surgery.

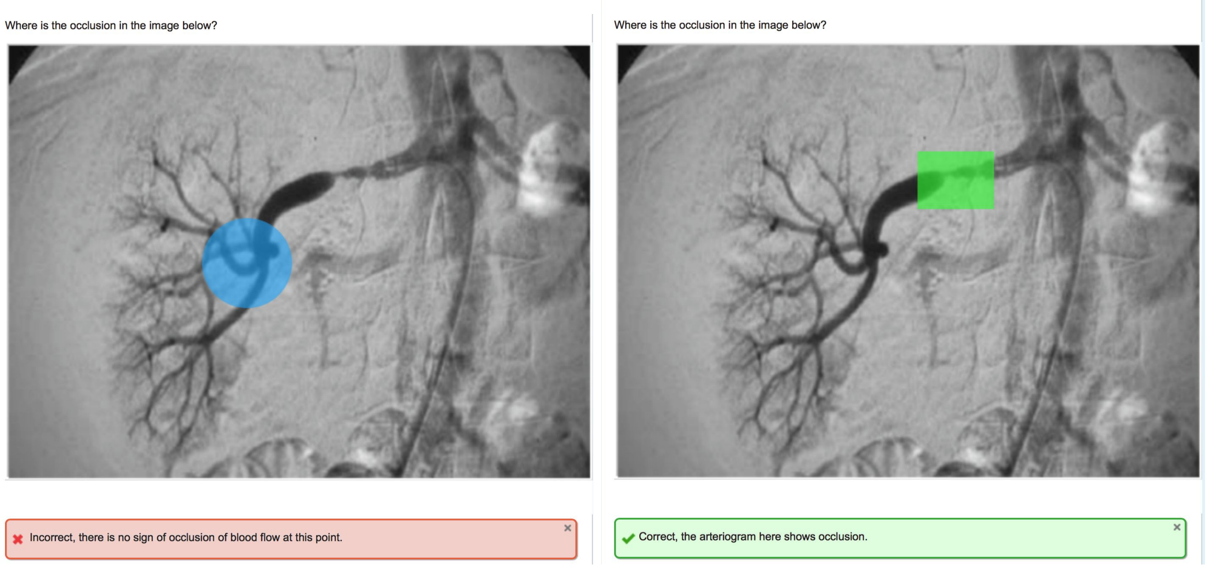
Beyond these two main sources, we also generated questions from the instructional materials and medical journals based on our own intuition, and then refined these with experts during our interviews to fine tune them and ensure that we did not miscommunicate any information.

Types of Assessment Questions

Authentic assessments are a key part of plastic surgery education and medical education in general. Most questions that doctors answer, both during training and then during continued medical education, are case based and require application of knowledge rather than recitation of fact. Keeping this in mind, we followed a similar pattern and chose to use case based questions for our summative assessments and limited the recitation-based questions to formative assessments. We additionally included formative assessments targeting key skills and principles from diagnosis and treatment where possible.

Further, PSEN assessments only include multiple choice questions which are not sufficient to test the capabilities of the surgeons on the wide array of topics. For our assessments, we wanted to include the multimedia capabilities of OLI and designed a wide array of questions of many types. Some examples of our assessments can be found below:

Image Hotspot:



Here the student has to select a spot on the image by clicking it to highlight the area where the stated problem lies. We used this question to help assess the image recognition KCs, as analysis of imaging results is a key part of diagnosing a vascular disease.

Ordering:

What is the correct order of progression of PVD?

- Ulceration & Gangrene
- Limb loss
- Rest pain
- Claudication

Check My Answer

We used ordering for questions where progress of the disease or a process had to be assessed. Here, students have to drag and change the order of the steps.

Drag and Drop:

Drag choices to the correct numbers to indicate prevalence of PVD

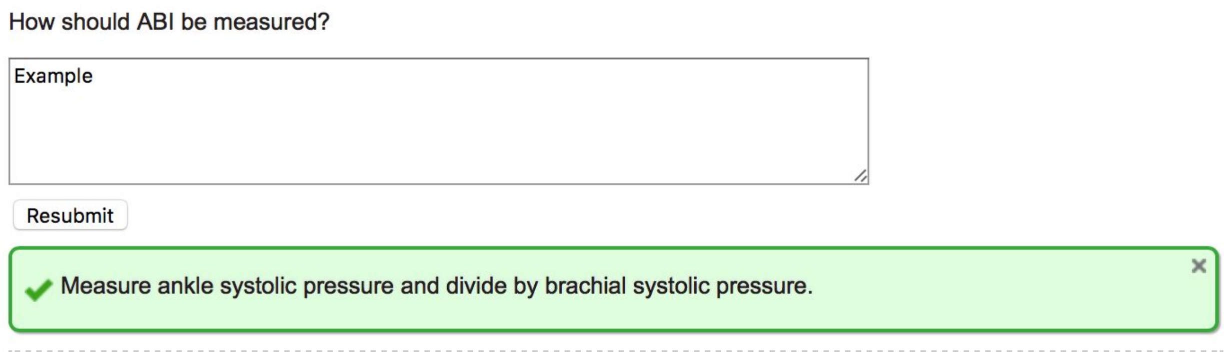
Total	Asymptomatic	Symptomatic Treated	Symptomatic Untreated
10 million	5 million	1.25 million	3.75 million

Here the students have to drag the options to the correct box to match the numbers. This provided a more interactive interface for the fact based KCs.

Multiples Choice:

To make our align diagnostic MCQs with actual medical practice, we added multimedia elements to more closely emulate the real world scenarios.

Short Answer:



For reflective questions, or questions where it was not possible to generate many options, we used short answer questions where the user types the answer. We only used this type of question in the formative assessments to avoid manual grading in the summative which we could not do ourselves easily due to lack of domain expertise.

Refinement of Assessments

Our initial assessments lacked appropriate feedback and in many cases were not sufficient to test the KCs, we revised these with help from our experts and also formulated more assessments throughout our course design.

Initial assessment tasks and sample questions are included in their own draft document here.

The initial KC-Goal-Assessment alignment can be found in a table here.

The refined assessments with the corresponding solutions and feedback can be found in their own document here. (There may be some differences between this document and the final assessments on OLI based on final revisions and expert feedback)

Instructional Design

Overview of Instructional Principles Chosen

We sought to implement 4 multimedia principles for e-learning, 3 of which were not previously in place in the existing PSEN modules:

1. **Modality:** splitting verbal content between visual and auditory (narration) elements (already in place in PSEN instruction).
2. **Redundancy:** Eschewing overlap between visual and auditory content.
3. **Segmentation:** Chunking instruction into separate sections addressing related goals.
4. **Deliberate Practice with Feedback:** use of various kinds of formative assessment with immediate feedback to give residents opportunities to practice and improve over time.

We created two versions of the course. One which emulated the instructional design of the original PSEN content (Control - OLI Course ID **vsle-01**), implementing only the Modality principle, and another which additionally implemented Deliberate Practice with Feedback, as well as the Segmentation and Redundancy Principles (Treatment - OLI Course ID **vsle-02**). Instruction was provided using the Open Learning Initiative (OLI) platform.

Deliberate Practice with Feedback

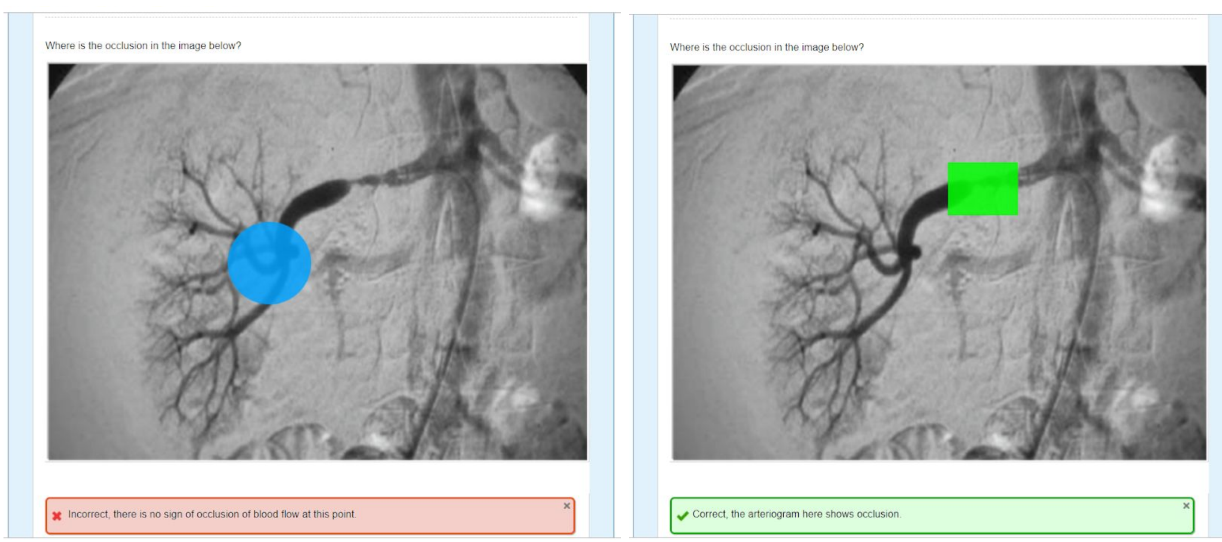
There is a dearth of assessment items available in plastic surgery education. Question generation is a challenging process that requires significant time and expertise in both surgery and pedagogy. It is common among modules on PSEN for there to be significantly fewer assessment items than learning objectives. The existing PSEN module on Vascular Surgery of the Lower Extremity is not out of the ordinary in having 31 objectives but only 10 questions. This means that not only are residents not given practice on the assigned learning objectives after the pretest, but that often the majority of learning objectives are not directly assessed at all, or are only assessed on items aligned to multiple learning objectives.

Of the four principles implemented in our treatment version of the course, facilitating Deliberate Practice was by far the most challenging in terms of time and resources, but also the principle we hypothesized might have the most significant impact on learning. While the other three principles all facilitate learning by reducing extraneous processing, Deliberate Practice with Feedback works by increasing generative processing, which we hypothesized would be more effective for the highly advanced learners in plastic surgery residency.

In addition to textual multiple choice questions like those already present in PSEN, we designed assessment items using multimedia element, such as image identification and image hotspotting, to better align practice with targeted knowledge components (such as diagnosing venous and arterial ulcers, or understanding the basics minimally invasive techniques). Examples of formative assessments are shown below:

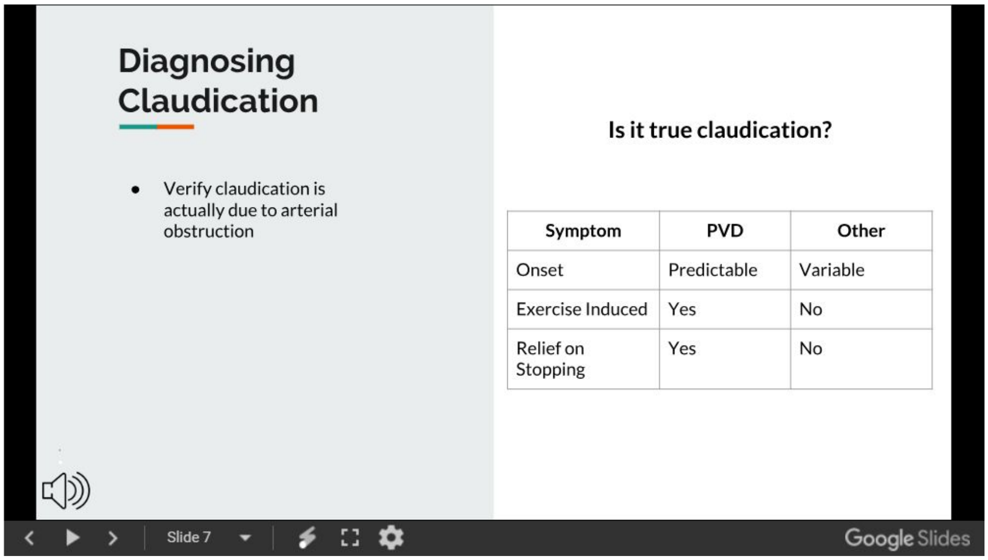
Differentiating between venous and arterial ulcers:

Understanding the Basics of Minimally Invasive Techniques:



Modality and Redundancy

While the existing PSEN content uses a combination of visual and auditory elements in through narrated slideshows, the narrated content often repeats the text on the slide, often without adding information beyond the slide content. We designed the treatment version of the course to only use audio when a topic warranted discussion of more content then could be reasonably included on the slide itself. Many slides were left without narration, and others were condensed to include only supplementary content and to do so as concisely as possible. Below is an example of a narrated slide from the treatment version of the course.



Narration: *Many elderly patients present with symptoms which appear similar to true claudication from PVD, but which in fact originate from neurogenic or musculoskeletal disorders…*

Segmentation

The vascular surgery module on PSEN grouped content from all topics into one 50-slide slideshow. In contrast, the treatment version of the course split the slide content into 3 slideshows corresponding to the reformulated goals (Epidemiology was presented together with Anatomy, as both topics were smaller in scope than Diagnosis and Treatment).

We combined instruction regarding Anatomy and Epidemiology (as these were less important goals with less content) into one slideshow with 11 slides, and 6 formative assessment questions. The Diagnosis segment included 20 slides and 5 formative assessment questions. The treatment segment included 30 slides and another 5 formative assessment questions. This organization was intended to emphasize Diagnosis and treatment, which are the tasks more directly relevant to surgeons.

Experimental Design and Results

Experimental Design, Recruitment and Structure

For testing, we recruited 24 plastic surgery residents at UPMC. We stratified them according to their year of residency and randomly assigned 12 to the control (group A) and 12 to the treatment (group B) version of the course.

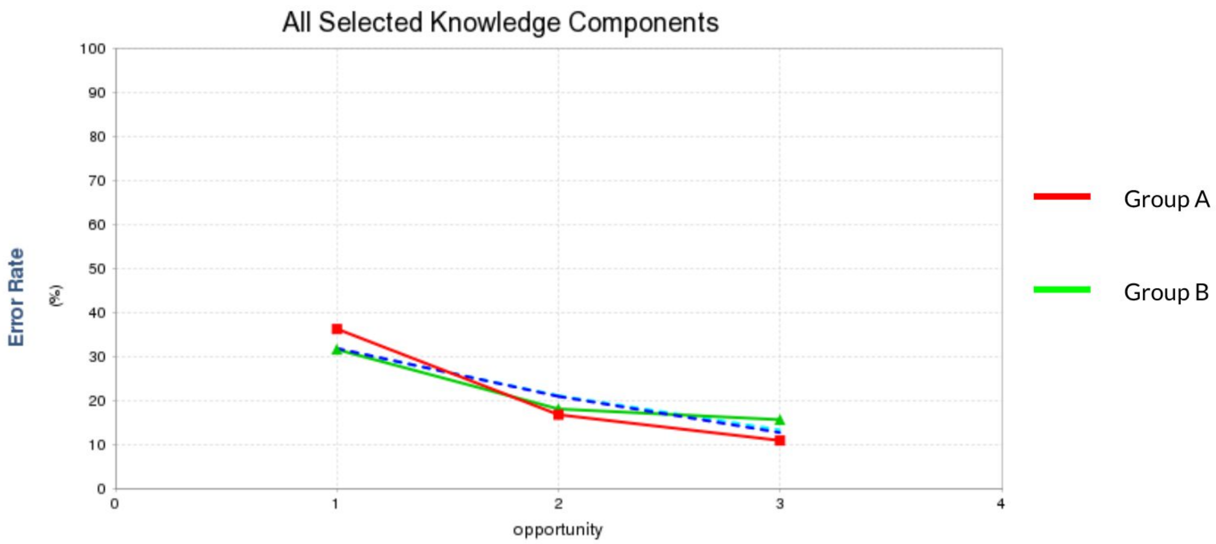
Data Collection and Overview

10 of the subjects assigned to group A and 11 of the subjects assigned to group B completed the course. Log data does not enable us to differentiate between active engagement with the course and leaving the browser tab open, however by ignoring data points where the browser was open for over an hour, we are able to reasonably estimate the average time spent on the assessments (time opened until time submitted) and the time spent on instruction (time of pretest submission until time of opening the posttest) for subjects who ostensibly completed the course in a single session. By these measurements, the average time spent on instruction was ~15 minutes for group A and ~25.5 minutes for group B. On average, group A took ~9 minutes to complete the posttest, compared to ~11.5 minutes for group B.

This data is useful in the identification of the single outlier. The outlier in group B, spent only 3 minutes on the posttest, and dropped 22% from pre to posttest (63% to 41%), with 5 questions answered correctly on the pretest and then incorrectly on the posttest (these were shared assessment items). These factors indicate that the posttest was rushed through and is unlikely to be an accurate reflection of this participants' abilities. For this reason, analysis was performed in exclusion of this single subject's data.

Data Analysis from Performance Data

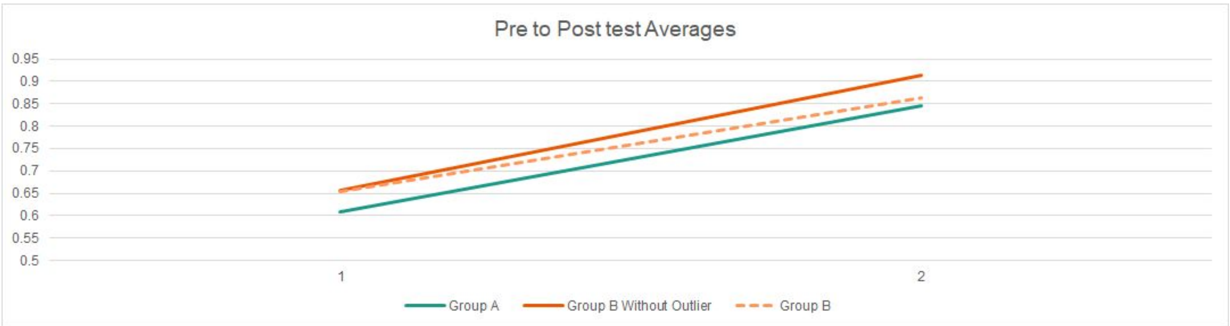
Learning Curves



Here we see error rates across all summatively assessed KC's, capped to three opportunities. We can see that learning is happening in both groups. There is however no obvious difference in performance between the treatment and control groups.

Average Learning Gains

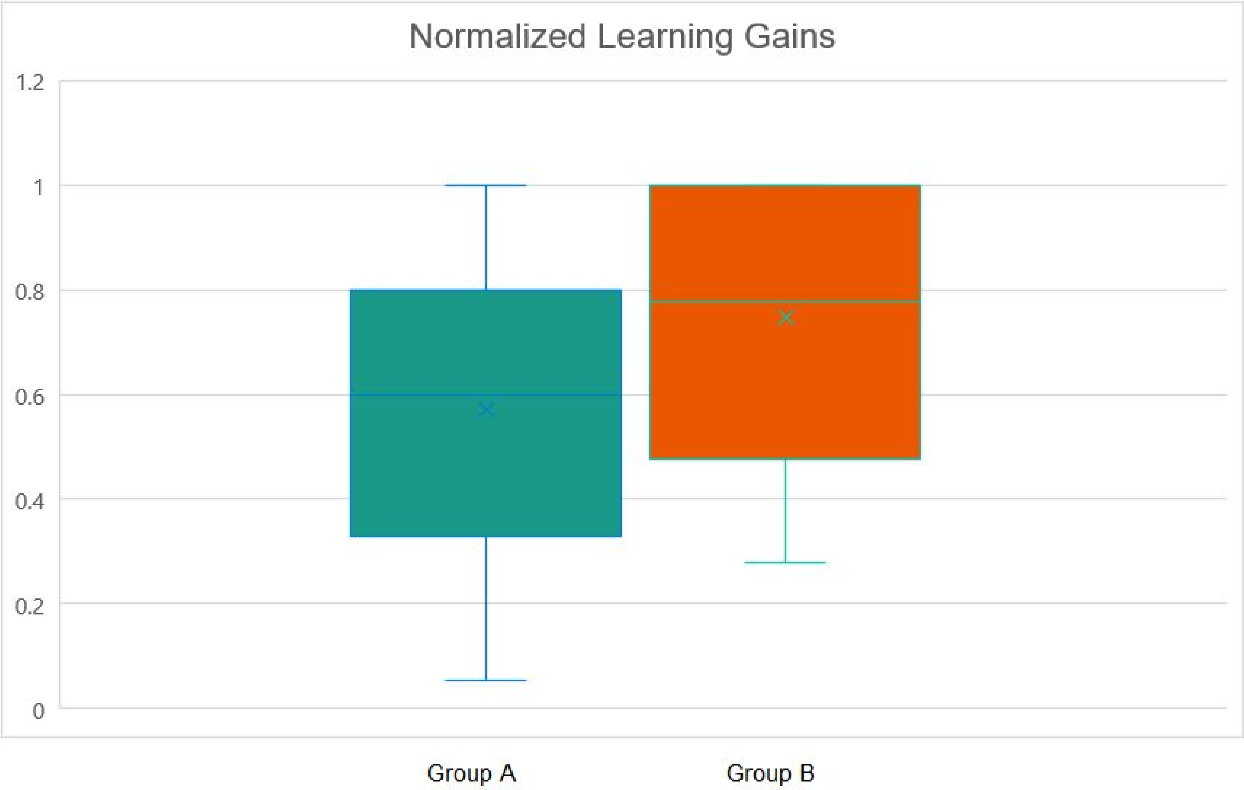
Here again we see that both conditions made learning gains, and that the gains (here visualized as slopes) are similar in both groups. However we also note that group B has higher pretest and posttest averages, reducing the potential for learning gains in group B. This warrants comparison of the gains as a percentage of the possible gain that each subject could have made based on their pretest scores.



Normalized Learning Gains

Here we see the normalized gains for both groups, calculated as: (posttest - pretest)/(1-pretest).

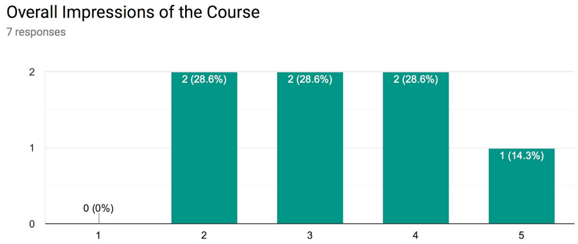
Here we can see that group B has a higher median normalized gain - **77.7% vs 58.8%** in group A, and a higher percentage of subjects who made 100% of their possible gains and achieved a perfect score on the posttest - **4/10 in group B and 1/10 in group A**. While noticeable, the differences in normalized gains are not however statistically significant, as the **p-value after a one-tailed T-test is .09**.



Supplementary Survey Results to Gauge User Experience

Overall, subject opinion was favorable to the treatment version of the course.

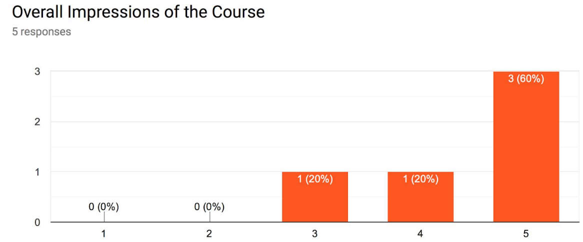
Group A



Average Rating: 3.3

“Similar, but the UI was better as were the question format”

Group B



Average Rating: 4.4

“Much prefer this course and the interactive content”

While improving usability and learner enjoyment was not the fundamental goal of this project, the more interactive assessments, as well as the segmentation of the course were generally appreciated by subjects in the treatment group. This may indicate room for improvement in the diversity of assessment and practice items, and the organizational structure of modules in the current PSEN implementation.

Insights and Conclusion

Insights from User Study

Though some differences in performance were observable between the treatment and control groups, it is notable that these differences were not statistically significant ($p=.09$). Below is an exploration of potentially mitigating factors that may have reduced the efficacy of the implemented e-learning principles.

Deliberate Practice with Feedback

The greatest obstacle to effective Deliberate Practice with Feedback was generating and collating sufficient assessment items. As previously mentioned, each question requires significant time and expertise in both surgery and pedagogy to create. Between the questions we were able to generate ourselves, the ones produced collaboratively with experts, and the ones collated from the existing PSEN module, and in-service exam questions available online, the treatment version of the course included 37 assessment items. While this is significantly more practice than the original PSEN module which including only 10 questions, it is still too few questions to give learners significant practice on all 29 KC's included in the course.

We suspect that the inclusion of more formative assessment items relative to the number of KC's is indeed helpful for learning in this domain and population, but creating this volume of practice is exceedingly burdensome.

Redundancy, and Segmentation

Both the Redundancy and Segmentation principles facilitate learning by reducing extraneous processing and cognitive load therein. Learners in this context (surgical residents) are exceptionally advanced, and likely have significant surplus of available cognitive load, reducing the impact of lowered extraneous processing on learning outcomes. Even so, several positive comments in the exit survey regarding the courses "better focus" and identification of "key points" in the treatment version of the course indicate that these principles may be desirable to learners, even if their impact on learning outcomes is not significant.

Limitations and Challenges

Domain Complexity

The single greatest and most pervasive challenge in developing this course was the immense complexity of the domain. Instructional design required fluency in a large number of prerequisite concepts and terminology. To give a simple example, we did not initially recognize that the words ‘angiogram’ and ‘arteriogram’ were used interchangeably, and this of course obstructed our analysis of the alignment of goals, assessments, and instruction. Medicine and particularly surgery, is fraught with jargon and every topic addressed in our course required a significant body of prior knowledge to engage with as a learner or instructional designer. This meant we needed expert assistance repeatedly at every stage of development.

Limited Recruiting

Due to the technically specialized nature of the course, the pool of potential subjects qualified to take the course was extremely limited, and qualified subjects were heavily burdened by an incredible workload with minimal free time, making it difficult to perform user testing and iterate the course.

Time Shortage

Time is extremely limited in surgical education. Though residents of plastic surgery may have up to 6 years following medical school to complete their residency, residents and educators often remark that there is too much to do in too little time. The scope of the course was actually smaller than most of the other courses on PSEN, yet it aspired to teach over 25 KC’s in a course often taken in less than an hour. This may indicate that reprioritization of the objectives in plastic surgery education may be required in order to realistically align course material with what students can reasonably learn in the time they have.

Analogously, time was a very limiting factor for instructional design. Aligning goals, generating assessments, and generating instruction all required significant time and assistance from subject matter experts. This complicated every step of instructional design.

Implementation Errors

A mistake was made in configuring the posttest for both groups, and automatic grading mis-evaluated two assessment items for some subjects before the mistake could be fixed on the production server hosting the course. The scores were thus manually corrected after all subjects had completed the course.

Conclusions and Future Work

Conclusions

First, domain knowledge is not a strict prerequisite for instructional design. Despite the many obstacles put forth by the domain's complexity, and severe reliance on the subject matter expertise of collaborators at UPMC, we succeeded in creating a course in which residents of plastic surgery could learn about vascular surgery of the lower extremity, and learning did occur in both versions of the course.

Finally, communication and expectation management are key to success of instructional design. Challenges of scope and timelines are best addressed by clear communication with all stakeholders.

Future Work

As mentioned in the Insights and Conclusions section, special considerations should be made during instructional design for expert learners. This has implications for all e-learning principles, especially those involving control of cognitive load. Future work might explore the impact of expertise on the efficacy of other principles, including learner control, or contiguity.

We will deliver a final client report and share the feedback with the doctors at U Pitt Dep. of PS. Depending on their enthusiasm, we could either design another module for them as a formal pilot study to incorporate some of these learning science principles into their regular educational program. A more ambitious goal would be to contribute to the redesign of the PSEN online software, the next update for which is next year and our mentor Dr. Nguyen is a member of the committee for the update.

Acknowledgements

This project would not have been possible without the help and support from a number of individuals.

We would like to give special thanks to Dr. Vu Nguyen, Dr. Lucas Dvoracek and Dr. J. Peter Rubin from the University of Pittsburgh's Department of Plastic Surgery for giving us their valuable time and expert guidance.

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