

Listen Before You Auscultate: An Active-Learning Approach to Bedside Cardiac Assessment

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Abstract

Introduction: Bedside cardiac assessment (BCA) is deficient across a spectrum of noncardiology trainees. Learners not taught BCA well may become instructors who do not teach well, creating a self-perpetuating problem. To improve BCA teaching and learning, we developed a high-quality, patient-centered curriculum for medicine clerkship students that could be flexibly implemented and accessible to other health professions learners. **Methods:** With a constructivist perspective, we aligned learning goals, activities, and assessments. The curriculum used a “listen before you auscultate” framework, capturing patient history as context for a six-step, systematic approach. In the flipped classroom, short videos and practice questions preceded two 1-hour class activities that integrated diagnostic reasoning, pathophysiology, physical diagnosis, and reflection. Activities included case discussions, jugular venous pressure evaluation, heart sound competitions, and simulated conversations with patients. Two hundred sixty-eight students at four US and international medical schools participated. We incorporated feedback, performed thematic analysis, and assessed learners’ confidence and knowledge. **Results:** Low posttest data capture limited quantitative results. Students reported increased confidence in BCA ability. Knowledge increased in both BCA and control groups. Thematic analysis suggested instructional design strategies were effective and peer encounters, skills practice, and encounters with educators were meaningful. **Discussion:** The curriculum supported active learning of day-to-day clinical competencies and promoted professional identity formation alongside BCA ability. Feedback and increased confidence on the late-clerkship posttest suggested durable learning. We recommend approaches to confirm this and other elements of knowledge, skill acquisition, or behaviors and are surveying impacts on professional identity formation-related constructs.

Keywords

Bedside Cardiac Assessment, Humanism in Health Professions Education, Point-of-Care Ultrasound, Cardiovascular Medicine, Clinical Reasoning/Diagnostic Reasoning, Clinical Teaching/Bedside Teaching, Competency-Based Medical Education (Competencies, Milestones, EPAs), Flipped Classroom, Online/Distance Learning, Professional Identity Formation

Educational Objectives

After completing this curriculum, learners will be able to:

1. Describe how to apply the systematic approach to bedside cardiac assessment (BCA) when caring for patients.
2. Interpret clinical findings related to each step of BCA.
3. Use the systematic approach to improve listening and diagnostic reasoning skills.

4. Correlate cardiac pathophysiology with associated findings on BCA.
5. Reflect on ways that patient-centered communication is fundamental to BCA.

Introduction

Bedside cardiac assessment (BCA) exemplifies an ability fundamental to several of the Association of American Medical Colleges’ core entrustable professional activities for entering residency.¹ Its performance is deficient across a spectrum of noncardiology trainees²⁻⁶ and, often, their faculty instructors.^{2,3} Learners who are not taught BCA well enough to become competent may eventually become instructors who in turn teach poorly, creating an urgent and self-perpetuating problem.^{2,6}

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BCA-related core entrustable professional activities require clinicians to gather a history and perform a physical examination, integrate data with knowledge of pathophysiology to update and prioritize differential diagnoses, provide timely and appropriate care, and communicate with the patient or family (Figure).¹ “When [BCA] is performed correctly... [it] enables more appropriate and expedient diagnostic and therapeutic management decisions.”²

Given the benefits of multimodal cardiac assessment and point-of-care ultrasound,⁶ should health professions education still bring clinicians to the bedside? Is BCA still relevant? The answer from many experienced clinician-educators is a resounding yes.^{2,3,6-8} The power of a diagnostic tool depends on the competence of the clinician wielding it and their understanding of its indication, strength, and limitations. In a literature review of emergency ultrasound, the need for proper training and attention to clinical context highlighted a “lack of attention to the clinical history and examination, lack of communication with the patient,” and faults related to diagnostic reasoning as common sources of diagnostic error.⁹ Competence in bedside assessment is a necessary prerequisite to interpreting information from diagnostic technology and avoiding unnecessary testing¹⁰ or harm from its overuse.¹¹

The literature offers many possible evidence-based approaches to reversing a cycle of deficient learning and teaching of BCA.²⁻⁶ However, there is no consensus on optimal approaches within a competency framework.⁶ Several high-quality publications aim to improve BCA-related abilities but focus only on preclinical medical students¹²⁻¹⁵ or auscultation.¹²⁻¹⁴ Some incorporate a diagnostic reasoning framework but require standardized patients¹⁵ or simulation mannequins,¹³ expensive resources that limit equitable access without prioritizing patient-centered communication.

We developed a curriculum for medicine clerkship students that emphasizes BCA abilities within a diagnostic reasoning framework and encourages patient-centered communication. It uses e-learning technology and common materials available in low-resource environments. The curriculum can be flexibly implemented with 1.5-2 hours of homework followed by two 1-hour classes or as stand-alone activities, either remotely or in person. The target audience for this implementation was third-year medical students, but the educational resource is applicable to residents and to trainees in physician assistant, nurse practitioner, and other health professions education programs. Basic understanding of cardiac pathophysiology is a prerequisite, and it is our experience that BCA is best taught and learned after learners have some clinical exposure.

Methods

Development of the Educational Resource

To assess learning needs and relevant competencies, we interviewed internal medicine clerkship directors and students and reviewed postseminar clerkship student evaluations of the Systematic Approach to BCA seminar offered from 2010 to 2014 at Boston University Medical Center (BUMC).

We combined curriculum development models focusing on alignment of learning goals, activities, and assessments¹⁶ with constructivist learning theories.¹⁶⁻¹⁹ Constructivism sees learning as a meaning-making process, one in which “[knowledge] is not simply ‘out there’ to be attained.... it [is] constructed by the learner.”¹⁷ The flipped classroom format²⁰ allowed self-directed learning, experimentation,^{18,21} and peer teaching. We wove two threads throughout the curriculum: patient-centered communication and diagnostic reasoning. The former is fundamental to bedside assessment, both to establish trust within the relationship and diagnostically.⁸ The diagnostic framework asks learners to listen before they auscultate, to capture the history of the present illness as key context for a six-step, systematic approach to BCA that follows. Auscultation is the fifth step, situated at this point by context and learners’ diagnostic hypotheses. We conceptualized Listen Before You Auscultate²² as a clinical abilities, rather than just a skills, curriculum to foster BCA-related knowledge, diagnostic reasoning and physical examination skills, and notions of trust²³ related to patient-centered communication.¹⁹ To promote transfer of learning from the curriculum to the bedside, we framed clinical contexts expansively.²⁴

We assembled a team with health professions educators, an instructional designer, a multimedia producer, and a software engineer. We developed and beta-tested preclass assignments (PCAs) that comprised short videos paired with topic-specific cognitive exercises with explanatory answers, in total taking 1.5-2 hours to complete, and a facilitator guide. The exercises activated prior knowledge, unearthed misconceptions,²¹ promoted cognitive rehearsal of new knowledge, and created opportunities for self-assessment. The PCAs also foreshadowed the content of concepts and materials for in-class activities (ICAs) for the two class sessions.

As an example, one learning set asked students to identify a familiar phonocardiogram before challenging them to hypothesize which valvular lesion likely caused a classic clinical presentation. Students then learned an auditory mnemonic, relating valvular pathophysiology to the sound. An on-screen

LOs, AAMC Core EPAs	How LOs Were Assessed		Was LO achieved?
	Formative Self- or Peer Assessments	Activities Observable by Facilitator	
<p>1. Describe how to apply the systematic approach to BCA when caring for patients</p> <p>AAMC Core EPAs 1-3, 10</p>	<p>Pre- and postcurriculum quiz</p> <p>PCA learning sets A-L2</p> <p>ICA Classes 1 and 2</p>	<p>ICAs</p> <ul style="list-style-type: none"> Trust discussion Simulated clinical encounters Curriculum recap <p>Pre- and postcurriculum quiz</p>	Yes
<p>2. Interpret clinical findings related to each step of BCA</p> <p>AAMC Core EPAs 1-3, 10</p>	<p>PCA learning sets B-L2</p> <p>ICAs</p> <ul style="list-style-type: none"> BCA patient discussion Right heart assessment: JVP exercises Name That Heart Sound! team game 	<p>ICAs</p> <ul style="list-style-type: none"> BCA patient discussion Right heart assessment: JVP exercises Name That Heart Sound! team game 	Yes
<p>3. Use the systematic approach to improve listening and diagnostic reasoning skills</p> <p>AAMC Core EPAs 1-2</p>	<p>Pre- and postcurriculum quiz</p> <p>PCA learning sets B-L2</p> <p>ICAs</p> <ul style="list-style-type: none"> BCA patient discussion Right heart assessment: JVP exercises Name That Heart Sound! team game 	<p>ICAs</p> <ul style="list-style-type: none"> BCA patient discussion Right heart assessment: JVP exercises Name That Heart Sound! team game <p>Pre- and postcurriculum quiz</p>	Yes
<p>4. Correlate cardiac pathophysiology with associated findings on BCA</p> <p>AAMC Core EPA 2</p>	<p>Pre- and postcurriculum quiz</p> <p>PCAs</p> <ul style="list-style-type: none"> Learning sets C-J, including Making Sense of the Pathophysiology cases embedded in learning sets H-J Supplemental video M, The Cardiac Cycle <p>ICAs</p> <ul style="list-style-type: none"> Right heart assessment: JVP exercises Name That Heart Sound! team game 	<p>ICAs</p> <ul style="list-style-type: none"> Right heart assessment: JVP exercises Name That Heart Sound! team game <p>Pre- and postcurriculum quiz</p>	Yes
<p>5. Reflect on ways that patient-centered communication is fundamental to BCA</p> <p>AAMC Core EPA 2</p>	<p>PCA learning sets A, E, F, H-J</p> <p>ICAs</p> <ul style="list-style-type: none"> Trust discussion Simulated clinical encounters 	<p>ICAs</p> <ul style="list-style-type: none"> Trust discussion Simulated clinical encounters Debrief after simulated clinical encounters Curriculum recap 	Yes

Figure. LOs, relevant core EPAs, and means of assessment. EPA 1: gather a history and perform a physical examination; EPA 2: prioritize a differential diagnosis following a clinical encounter; EPA 3: recommend and interpret common diagnostic and screening tests; EPA 10: recognize a patient requiring urgent or emergent care and initiate evaluation. Abbreviations: AAMC, Association of American Medical Colleges; BCA, bedside cardiac assessment; EPA, entrustable professional activity; ICA, in-class activity; JVP, jugular venous pressure; LO, learning outcome; PCA, preclass assignment.

instructor offered an analogy and an evidence-based bedside prediction rule and contrasted the findings with another systolic murmur. Learners self-evaluated in the question set that followed and then, in the ICAs, peer-taught clinical findings presented in the PCAs.

We used the plan-do-study-act (PDSA) cycle as a tactic for iterative quality improvement,²⁵ avidly seeking feedback from course directors, facilitators, and student participants after each implementation. We used this collection of scripts and pitfalls to create the facilitator guide and tips and pearls for facilitators, which are included as appendices. This also led us to incorporate several best practices for blended learning^{24,26-28} (Table 1).

Appendix A is a 3-minute introductory video that orients users to the curriculum. The home page of Appendix B, a zip file containing the PCAs, is a table of links that learners click to access the introductory video, an overview of the curriculum and its structure, and the 14 video-based learning sets. Appendix C is a tool kit that course directors use to manage the curriculum. Facilitators have guides to the ICAs in Appendix D and in the more detailed tips and pearls for facilitators document in Appendix E. Materials needed for the first and second class-session ICAs are in Appendices F-H and I-K, respectively.

Implementation

We implemented the curriculum with approximately 268 students on 6- to 8-week inpatient medicine clerkships at BUMC (Massachusetts), Kansas University Medical Center (KUMC), Central Clinical School Monash University (CCSM; Australia), and Tan Tock Seng Hospital (TTSH; Singapore) from March 2017 to June 2018.

Students completed 1.5-2 hours of PCAs before participating in the two 1-hour ICA class sessions that course directors had incorporated into usual didactics schedules. The ICA sessions occurred in the second to fourth weeks of the clerkship. In the first session, learners engaged in a think-pair-share discussion using the BCA approach to reconstruct a familiar case and then in a large-group discussion of what it meant for one's clinical skills to be worthy of patients' and colleagues' trust.¹⁹ The session concluded with three jugular venous pressure (JVP) measurement activities. The second class began with a recap, followed by a team competition to identify heart sounds according to corresponding illness scripts. The final activity, simulated encounters, included two realistic scenarios where, ringed by observers, a volunteer clinician had to understand the patient's predicament to communicate urgent

treatment recommendations effectively. The pair debriefed after each scenario, followed by a large-group debriefing. The session concluded with a recap and a pocketable summary of the curriculum. For detailed implementation instructions, we refer readers to the facilitator guides (Appendices D and E).

Evaluation Strategy

We used multiple approaches to evaluate and improve the curriculum. All the competency development activities included formative self- or peer assessments. The ICAs were observable by the facilitator (Figure). From March 2017 to June 2018, approximately 120 students at BUMC and several facilitators provided direct feedback that served as a key source for the PDSA rapid-cycle improvements. To further explore students' experiences, we performed formal content and thematic analyses on post-ICA evaluations at BUMC from November 2017 to June 2018.¹⁹

Finally, from March 2017 to December 2017, we sent the students at all four sites pre- and postcurriculum questionnaires (Appendix L) about their BCA-related confidence in abilities and knowledge. Students either participated in the BCA curriculum in the first 4 weeks of the clerkship or learned BCA per their school's usual instruction. Assignment was by convenience, either concomitant by site of clinical assignment or alternating by rotation block. Data were collected and managed using REDCap tools hosted at Boston University (CTSI 1UL1TR001430).²⁹ We used SPSS version 24 (IBM Corporation) for quantitative analyses.

The Boston University School of Medicine Institutional Review Board (IRB) determined this work to be exempt from further review (IRB #H-34633). The VA Bedford Healthcare System IRB determined this work not to require oversight.

Results

In anonymous feedback after ICAs, BUMC students addressed pivotal elements of the curriculum, including instructional design, utility of the systematic approach, experiences related to patient-centered communication, and temporal elements of the educational experience. Asked to describe the most useful aspects of the curriculum, one student commented that the PCAs "were helpful because they got me thinking [about] what we learned today ahead of time," and another replied, "Pt interaction tutorials." One student wrote, "Excellent session[;] one of the best didactic sessions I've ever experienced." Others explained how they expected to apply BCA to patient care: "Quickly assessing the situation and translating info [into] patient care (realistic ward

Table 1. Select Best Practices for Blended Learning

Practice	Description	Comment
Navigation instructions	Clear instructions to help learners navigate the curriculum	Makes organization of the course easy to understand
Introduction to the blended curriculum	A statement introducing learners to the curriculum and to the structure of the learning	Clarifies the relationship between online and face-to-face components
Video transcripts	Each learning set includes a verbatim transcript of its video	Video transcripts improve accessibility for those with disabilities or different learning preferences
Rehearse new knowledge and skills	The curriculum provides learners multiple opportunities to rehearse new knowledge, listen to heart sounds, and practice auditory mnemonics in the PCAs and ICAs in isolation, in varying clinical contexts, and with feedback	Effective practice supports psychological processes relating to how learners select, organize, integrate, and transfer new knowledge
Explanatory feedback	Learners receive immediate answers for each PCA practice question (“incorrect” or an explanation of correct answer[s])	Explanatory feedback promotes online learning, especially higher-order outcomes
Personalization	Reappearances of the patient, Mr. Smith, seen in the video A case presentation and of instructors’ faces and narration recur throughout, not just in the preclass cognitive exercises and videos but also in the ICAs that follow	Personalization may promote online learning by providing psychologically engaging social cues, using words presented conversationally (rather than formally), politely (rather than directly), and in a natural human (rather than machine) voice
Written summary	Learners are given a brochure summarizing key aspects of the curriculum after the second class session	May facilitate transfer by enabling learners to refer to and revisit key points after they return to their workplace

Abbreviations: ICA, in-class activity; PCA, preclass assignment.

scenario)” and “I feel more convinced that my physical exam will contribute to rapid and accurate diagnosis of a [patient] rather than solely on history and EKG.”

Many students described their experience of participating in the concluding simulated clinical encounters activity as one of the most useful aspects of the curriculum. Representative comments included the following:

- “I agree it was challenging in a good way[,] I had to quickly hear the case and explain it very quickly.”
- “Trying to deliver a somewhat challenging diagnosis to a patient was good to practice.”
- “It’s really difficult to describe what a cath is to a patient! Was good to recognize how difficult cardiac disease is to explain to patients.”
- “Practicing, explaining a difficult scenario to a patient is always so helpful. I prefer to make mistakes... with [simulated] patients.”
- “Learning how to change the language for different patients.”
- “How to address an angry pt.”
- “I assumed Dr. role[;] it was a good simulation and realistic experience.”

Asked about least useful aspects of the curriculum or opportunities to improve it, students variably wished for more, less, or different timing of the experience. Representative comments included “Why should I trust clinical skills likely more relevant of a discussion start of 3rd year,” “Difficult to thoughtfully watch videos due to no dedicated time,” and “I think with more time to do the role play exercise it would’ve been even

better.” Many students offered suggestions for changes to the instructional design.

Facilitators observed active learning in the ICAs, illustrated by a Singapore-site course director who commented, “My [facilitators] said that the students were quite engaged.” Two other facilitators (both curriculum codevelopers) observed that students applied the curriculum in other clinical contexts, reflected on ways that patient-centered communication was fundamental to BCA when caring for patients, and retained learning. One, at BUMC, recalled that few students, asked about their bedside measurement skill before the JVP exercises activity, felt competent. By the following week’s class, most said they had measured patients’ JVPs. Another facilitator, a hospitalist attending at KUMC, similarly reported that during the end-of-year objective structured clinical examination (OSCE) with a cardiopulmonary case, faculty evaluators unaware of the curriculum observed that students who had participated in it were “more consistently evaluating patients’ JVPs.” He also observed that students were more likely to explain their role and ask standardized patients how they felt rather than listing standard pain descriptors. Students seemed more likely to “pair and share” during clinical rounds, which he attributed to increased collegiality and collaboration after participating in the ICAs.

From our formal content and thematic analyses of the post-ICA evaluations emerged themes relating to successful learning and opportunities to improve the original instructional design. The analyses suggested that the learning strategies were effective, and students found peer encounters, skills practice, and encounters with educators meaningful.¹⁹

One hundred fifty-eight students (BUMC $N = 49$, KUMC $N = 50$, CCSM $N = 46$, TTSH $N = 13$) responded to the pretest questionnaire about BCA-related confidence and knowledge. Due to a data-collection issue, we were only able to analyze scores for smaller numbers of students. For confidence items, this required a nonparametric analysis, a z test of a difference in the proportion of students in each group with a net positive change in confidence ratings. Pre/post changes in paired confidence ratings were computed for 31 participants in the BCA curriculum and 21 participants in the usual instruction groups. For each student, we calculated a net percent change by subtracting the percent of ratings that were lower pre to post from the percent that were higher pre to post. The difference in proportion of positive changes between BCA curriculum and usual instruction groups was evaluated with a z test of independent proportions. We found a higher proportion of BCA students with positive changes in confidence in their abilities to (1) estimate right heart filling pressures accurately, (2) distinguish normal and abnormal points of maximal impulse, (3) identify classic murmurs of mitral regurgitation and aortic stenosis accurately, and (4) identify left-sided gallops (S3 and S4) on cardiac auscultation accurately, with an aggregate effect size of .40. For identifying atrial fibrillation correctly on ECG, a skill not taught in the BCA curriculum, there was no difference between BCA curriculum and usual instruction students' confidence (Table 2).

For BCA knowledge items, on the pretest at baseline there were no differences in average percent correct between BCA curriculum and usual instruction groups (63% and 62%, respectively). When combined, a two-way analysis of variance (ANOVA) testing for differences in the pre/post change for the curriculum and usual instruction groups showed a significant ($p = .006$), statistically equal increase in percent of knowledge items answered correctly. The BCA curriculum group had an average of 63% before and 75% after the curriculum. The usual instruction group had a similar increase from 62% to 78%. There

was no statistically significant difference in average posttest correct (75% and 78%, respectively; $p = .78$; Table 3). There was no interaction effect for the ANOVA, meaning that the two groups increased a similar amount. Scores for two items intended to assess patient-centered attitudes were high at baseline and remained so on posttest.

Discussion

We aimed to improve BCA teaching and learning by developing a high-quality, patient-centered curriculum, based upon a diagnostic reasoning framework, that could be flexibly implemented and accessible to a wide spectrum of health professions learners. The curriculum provided students with an opportunity to participate in active learning, representing day-to-day clinical competencies and explicitly incorporating notions of trust. Integrating several evaluation strategies, we concluded that students and facilitators found the curriculum's instructional design and content to be effective tools for teaching and learning BCA. Students who participated in the curriculum reported increased confidence in their BCA abilities and knowledge gain comparable to their peers. Students' real-time comments supported the theme of meaningfulness, a gratifying outcome of the constructivist approach. We also saw early evidence of application, or transfer, in facilitators' comments and students' self-reports that they measured their patients' JVPs more frequently as the curriculum progressed, which aligned with the positive change in confidence seen on the JVP-related item in the questionnaire.

Learners' self-efficacy (belief in their own abilities, confidence) and capability (ability to demonstrate transfer of learning to a new environment like the bedside) are core principles of one instructional approach to lifelong learning, with the flipped classroom format well suited to helping learners view their experiences as meaningful.³⁰ It is likely that students who are more confident in their abilities and who experience their learning

Table 2. Confidence in BCA Abilities

Item	Net Positive Change		p^a	Effect Size
	Usual Instruction ($n = 21$)	BCA Curriculum ($n = 31$)		
Estimate right heart filling pressures accurately	29%	81%	<.001	.52
Distinguish normal and abnormal point of maximal impulse accurately	33%	61%	.05	.28
Identify the classic murmur of mitral regurgitation accurately	19%	68%	<.001	.49
Identify the classic murmur of aortic stenosis accurately	33%	61%	.05	.28
Identify left-sided gallops (S3 and S4 sounds) on cardiac auscultation accurately	38%	81%	.002	.43
Confidence in abilities aggregate	30%	70%	<.001	.40
Identify atrial fibrillation on EKG accurately ^b	44%	50%	.57	

Abbreviation: BCA, bedside cardiac assessment.

^az test of a difference in the proportion of students in each group with a net positive change in confidence ratings.

^bItem not taught in BCA curriculum.

Table 3. Mean Percent Correct of Knowledge Items at Pre/Post Assessments

Approach to Teaching BCA	Pretest Questionnaire (First Week of Clerkship)			Posttest Questionnaire (Last Half of Clerkship)		
	%	SD	N	% ^a	SD	N
Usual instruction	62	.23	23	78	.15	6
BCA curriculum	63	.18	81	75	.19	20

Abbreviation: BCA, bedside cardiac assessment.

^aA 2×2 analysis of variance showed a significant ($p = .006$) increase in pre/post average percent correct scores for both groups.

as meaningful are more likely to transfer their abilities to the bedside, become competent, and eventually complete a cycle in which they become instructors who teach BCA abilities well.

Feedback and the thematic analysis also suggest the curriculum may support professional identity formation wherein the learner develops new ways of thinking about and relating to patients and peers.³¹ Listen Before You Auscultate uses key drivers of professional identity formation, including “experiential and reflective processes, guided reflection, formative feedback,... integral role of relationships and role models, and candid discussion within a safe community of learners.”³² Explicitly promoting such characteristics of ideal professional identity as “empathy, mindful attention to patient care,... self-awareness, teamwork, beneficence, respect, and equal regard for all, as well as an eagerness to learn,”³¹ the curriculum offers multiple opportunities for learners to reflect on ways that patient-centered communication is fundamental to BCA, beginning with the curriculum’s title and instructors’ comments in the first PCA learning set. In the facilitated trust discussion in the first class, students often acknowledged feeling unsettled by Mr. Smith’s unexpected question, “Why should I trust your clinical skills?” Facilitators became well equipped to discuss communication challenges faced by learners as they prepared for the simulated clinical encounters activity (Appendix E, pp. 15-23) before facilitating reflection in the debriefing session (Appendix E, pp. 24-25). As noted, many students described their experience of participating in the simulated clinical encounters as one of the most useful aspects of the curriculum.

Listen Before You Auscultate may help educators address clinical abilities deficits caused by COVID-19 pandemic-related educational program disruptions.³³ We updated the facilitator guide (Appendix D) so ICA sessions can be deployed either in-person or remotely. To further increase flexibility and best meet program or learner needs, we suggest stand-alone modules in the course director guide (Appendix C).

Our evaluation of the curriculum had several limitations related to its strategy, how students gain BCA-related knowledge and

confidence, and the instructional design of early versions of the curriculum. We captured feedback from medical students and performed thematic analysis at a single implementation site in the US. The curriculum’s generalizability to learners in other health professions education programs or countries may require further study.

With the questionnaire, we were able to show pre/post knowledge gain within groups but not a between-groups difference. Although we had planned to compare participation in the BCA curriculum to usual instruction, in reality all students experienced usual instruction on the wards in the 6- to 8-week clerkship. Knowledge gain directly attributable to the BCA curriculum might have become apparent had one of the implementation sites offered less robust cardiology exposure than that at the four sites we evaluated. Additionally, the evaluation was underpowered, in part because of a technical error that limited the post-usual-instruction response rate at one site. The questionnaire assessed outcomes relating to BCA-related knowledge because knowledge was where we thought the curriculum would generate the biggest difference. Feedback and thematic analysis, however, suggested effects on learning domains like transfer and professional identity formation, which were not assessed by the questionnaire.

Our challenges with the flipped classroom format mirrored other reports.²⁰ The up-front development effort was considerable; but once developed, the curriculum was easily and repeatedly deployed at multiple sites. Implemented as a flipped classroom, the curriculum requires a facilitator and learners willing to complete about 2 hours of homework beforehand, underscoring the need to set clear expectations of self-direction and motivation. Rather than requiring verification that learners completed the PCAs, our course directors emailed reminders (similar to those in Appendix C) that emphasized the public nature and team interdependence of their performances of understanding¹⁶ in the upcoming class sessions.

Direct feedback and increased confidence on the late-clerkship posttest suggested that learning was durable. End-of-year

OSCEs, deidentified cardiovascular scores on the Medicine Shelf exam, or the mini-CEX³⁴ could be used to further confirm this and other elements of knowledge, skill acquisition, or behaviors. We encourage other investigators to explore whether integration of Listen Before You Auscultate curriculum modules with point-of-care ultrasound training could improve learners' history-taking, examination, patient-centered communication, and diagnostic reasoning abilities. Finally, BCA coauthors are surveying the impact of the curriculum on constructs related to transfer and professional identity formation.

We hope that three hallmarks of the instructional design, which we recall as BC₃A, will be a resource for developers of more general bedside clinical abilities curricula: (1) utilizes Brain science, the application of cognitive science to increase effectiveness and efficiency of learning and teaching; (2) Continuous threads include Clinical reasoning and patient Communication, core tenets of bedside abilities; (3) designed to foster clinical Abilities, not just isolated knowledge or skill sets.

Appendices

- A. Listen Before You Auscultate - BCA Introduction.mp4
- B. Preclass Assignments folder
- C. Tools to Manage Curriculum.docx
- D. Facilitators Guide.doc
- E. Tips and Pearls for Facilitators.docx
- F. CLASS 1 Learning Materials.docx
- G. CLASS 1 Demonstration of Left External JVD.mp4
- H. CLASS 1 JVP Handouts.pdf
- I. CLASS 2 Learning Materials.docx
- J. CLASS 2 Heart Sound Game.pptx
- K. CLASS 2 Summary Handout.pdf
- L. Survey Questionnaire.docx

All appendices are peer reviewed as integral parts of the Original Publication.

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Prior Presentations

Meisel JL, Chen D, March G, Bernard SA, Carmona H, Papps N. Building competence and confidence in clinical skills: a systematic, flipped classroom approach to learning bedside cardiac assessment. Poster presented at: Northeast Group on Educational Affairs Annual Conference; May 4-6, 2017; Rochester, NY.

Carmona H, Chen D, March G, Bernard SA, Papps N, Meisel JL. New world techniques to teach old world skills: flipped classroom approach to teaching the bedside cardiac assessment. Poster presented at: Senior Resident Academic Day, Boston University Internal Medicine Residency Program, Boston Medical Center; May 26, 2017; Boston, MA.

Meisel JL, Chen D, March G, Bernard SA, Carmona H, Papps N. Building competence and confidence in clinical skills: a systematic, flipped classroom approach to learning bedside cardiac assessment. Poster presented at: 12th John McCahan Medical Campus Education Day, Boston University School of Medicine; May 31, 2017; Boston, MA.

Meisel JL, Chen D, March G, et al. Building competence—an active-learning approach. Poster presented at: Alliance for Academic Internal Medicine Academic Medicine Week; March 18-21, 2018; San Antonio, TX.

Ethical Approval

The Boston University School of Medicine Institutional Review Board and the VA Bedford Healthcare System Institutional Review Board deemed further review of this project not necessary.

Disclaimer

Views and content are those of the authors and do not reflect the official policy or position of VA or any other agency of the United States Government.

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