

The Intersection of Technology and Medical Education. The Cardiac Implantable Electronic Device Educational Application for Educating Cardiac Anesthesiology Trainees: Tutorial

Ahmed Zaky, Aisha Waheed, Brittany Hatter, Srilakshmi Mallempati, Sai H Maremalla, Ragib Hasan, Yuliang Zheng, Scott Snyder

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Abstract

Methods: development of CIED curriculum proceeded through the Kern's 6 step approach of problem identification, determining and prioritizing content, writing goals and objectives; selecting instructional strategies; implementation of the material and evaluation and applications of lessons learned. This was followed by the delivery of the curriculum in the form of user-study app and administrator-type-app with functionalities in assessment of the learners' gains, experience and satisfaction as well as the administrator's capability to update the educational content based on the feedback of the learners and the emerging technology. As such, the CIED App allows asynchronous learning at the pace of the learners and allows, through a multiplicity of educational materials, the ability to digest this complex and understudied subject. We benefit from the experience of a multidisciplinary team of anesthesiologists, computer scientists and educators in accomplishing this project.

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Original Manuscript

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Abstract

Despite the exposure of cardiothoracic anesthesiology (CT) trainees to patients with cardiac implantable electronic devices (CIEDs), there is a paucity of formal curricula on this subject. Major impediments for educating CT anesthesiology trainees on CIEDs include busy clinical schedules, short staffing, inconsistent trainees' exposure to CIEDs, multiplicity of vendors and a 'millennial' mentality of the new generation of learners. As a result, CT anesthesiology trainees graduating from their residency and fellowship programs may lack the competency to manage patients with CIEDs. Herein, we report our systematic approach of designing, validating, mapping, evaluating, and delivering a CIED curriculum on the first mobile application of its kind on this subject. Development of CIED curriculum proceeded through the Kern's 6 step approach of problem identification, determining and prioritizing content, writing goals and objectives; selecting instructional strategies; implementation of the material and evaluation and applications of lessons learned. This was followed by the delivery of the curriculum in the form of user-study app and administrator-type-app with functionalities in assessment of the learners' gains, experience and satisfaction as well as the administrator's capability to update the educational content based on the feedback of the learners and the emerging technology. As such, the CIED App allows asynchronous learning at the pace of the learners and allows, through a multiplicity of educational materials, the ability to digest this complex and understudied subject. We report the pilot phase of the project. We benefit from the experience of a multidisciplinary team of anesthesiologists, computer scientists and educators in accomplishing this project.

Introduction

Cardiac implantable electronic devices (CIEDs) are electronic devices placed in patients who suffer from permanent life threatening arrhythmias. They include pacemakers, implantable cardioverters defibrillators (ICD) and cardiac resynchronization therapies (CRT). The number of cardiac implantable electronic devices (CIEDs) implanted is increasing rapidly worldwide.[1] Due to increased longevity and technological advancement,

the number of patients with CIEDs undergoing surgical procedures is steadily increasing.[2] With a growing sophistication of the technology and the potential for preventable adverse events related to CIED dysfunctionality in the perioperative period, [3], there is a need for anesthesiology trainees to gain the knowledge and skills necessary to manage CIEDs perioperatively.[4]

Despite an increased exposure of anesthesiology trainees to patients with CIEDs, and the availability of anesthesiology led CIED services[5], there have not been formal curricula to educate trainees on this complex subject. Furthermore, busy clinical schedules, staff shortages, relatively short duration of the cardiothoracic rotation, the unpredicted and inconsistent exposure of trainees to patients with CIEDs, and the 'millennial' mentality of current generation of learners[6], all has challenged synchronous teaching and learning modalities. Consequently, currently graduating anesthesiology trainees may lack the competency needed to manage patients with CIEDs in their future career.

Mobile learning (m-learning) is a learning mode that uses a mobile device or tablet. It allows self-directed asynchronous learning at the pace of the learner and hence frees the learner of time and physical constraints. M-learning was shown to be associated with higher learning gains compared with conventional learning in a multitude of medical specialty education.[7-10]. At the time of writing of this manuscript there are 4 programs in the country where CIED are perioperatively managed by anesthesiologists. The trainees in these programs are exposed on online videos of device interrogations and programming and are given a textbook as a reference.

To remedy the current gap and challenges in educating CT anesthesiology trainees on CIEDs, we report our systematic approach to developing a high-quality CIED educational curriculum for anesthesiology trainees and delivering this curriculum through a mobile application platform. This manuscript should be of interest to anesthesiology educators

seeking to incorporate new competencies and rubrics related to CIED into residency training programs.

1 Pedagogical frameworks

A. Development of High-Quality CIED Educational Curriculum

Using Kern's 6-step approach to curriculum development[11], we created goals, learning objectives, instructional content, and pre- and post-assessments to be delivered via m-learning, and user feedback regarding CIEDs. Kern's framework for curriculum development has been applied for training across multiple medical specialties.[12-14] The authors expanded the six steps by including expert review of the instructional objectives.

Due to the perioperative nature of CIEDs, the curriculum focuses on knowledge and skills within the Accredited Council of Graduate Medical Education (ACGME) domain of Patient Care.

The basic process of curriculum development in medical education has been outlined [12-14] as consisting of the following steps:

1. Problem identification
2. Determining and prioritizing content (focusing the needs assessment).
3. Writing goals and objectives.
4. Selecting instructional strategies.
5. Implementation of the curriculum.
6. Evaluation and application of lessons learnt.

Problem Identification:

Several intersecting challenges motivated the development of a curriculum for CIED management. As indicated earlier, technological advances and increased life expectancy has resulted in a steady increase in the number of CIEDs implanted annually.[2] Similarly, there has been an increase in the number of patients with CIEDs undergoing surgical procedures. Due to the rates of postoperative CIED-related complications, CIED-related deaths, and hospital readmissions related to CIEDs there is a specific need for training in the knowledge and skills needed to manage CIEDs in the perioperative period. CT anesthesiology trainees are extensively exposed to patients with CIEDs during their training. Training ranges from a month-long rotation in the cardiac operating rooms and cardiac surgical intensive care units as an elective or core rotation during residency to a 12-month dedicated accredited clinical fellowship. Despite evidence that and initiation of perioperative anesthesiology based CIED service is associated with better patient outcomes, [5, 15-17], there are no published training curricula regarding CIEDs for CT anesthesiology trainees. While these conditions highlight the general need for a curriculum focused on CIED interrogation for CT anesthesiology trainees and fellows, a specific problem prompted the efforts of this project. A problem involving case delays of procedures on patients with CIEDs due to no show of device representatives and cardiology fellows and the occurrence of multiple preventable patient safety events due to perioperative CIEDs malfunction triggered our institution to seek the initiation of an anesthesiologists led CIED service. A dual trained cardiothoracic and critical care anesthesiologist with expertise and training in CIEDs management (AZ) championed this quality and safety initiative. The implementation of an anesthesiologist led CIED service created a need to train anesthesiology trainees with a similar scope of practice to sustain the service. This need was based on an average number of 400 patients with CIED undergoing cardiac and non-

cardiac procedures at our institution per year. Given the frequency of CIED use, complexities of perioperative management of the spectrum of CIEDs, and the patient safety concerns identified above, the absence of a published comprehensive curriculum in this area represents a significant challenge that must be addressed through curricular development.

Determining and Prioritizing Content (needs assessment):

The current didactics on CIEDs do not meet the education needs of CT anesthesia trainees in terms of scope, content, competencies, and delivery. For example, in terms of scope, there is more focus on the more commonly encountered and simpler to program temporary pacemakers with less attention to other more complex and permanent devices. [18] In terms of delivery, there is a paucity of asynchronous means of teaching the CIED subject to anesthesia trainees to adapt to their busy clinical schedule. Furthermore, our nationwide screening of CIED curricula and our informal interviews with trainees from our and other institutions led us to believe that there is a need

for the development of a comprehensive competency-based curriculum that provides anatomical, electrophysiological, and technical foundations; is inclusive of all types of CIEDs, links theory with practice, explains differences between CIED devices from major vendors, emphasizes practice-based management in terms of documentation and seeking cardiology consultation as needed, and is sufficiently flexible to accommodate reforms in CIED technology.

In addition to the need for the development of a curriculum, it is also important to clarify the conditions of instructional delivery that will maximize the opportunities for CT anesthesiology trainees to engage with the curriculum and master goals and associated objectives. An informal needs assessment was conducted involving 6 residents and 8 CV

Anesthesiology fellows at our institution and the Ochsner's Clinic by the fellowship Program Directors. Questionnaire were emailed to trainees and their responses were recorded. The questionnaire sought to describe current CIED institutional educational activities and to identify impressions, barriers, and facilitators of formal CIED education. All trainees responded to the questionnaire. Major findings from the trainees' responses included:

- most trainees had not received instruction about CIEDs during the prior 2 years,
- lecture-based training was the predominant instructional approach trainees experienced and was also the least desirable,
- approximately one-third of trainees rated app-based instruction as their first or second choice of instructional method (hands-on was the most desirable approach),
- almost three-fourths of respondents indicated that most physicians would be interested in using a self-paced e-learning system for training about CIEDs.

We reasoned that CT anesthesiologists would be ideal target learners for an m-learning curriculum focused on CIEDs given extensive exposure to patients with CIEDs.

Conceptual framework

Conceptual framework represent ways of thinking about a problem and responding to the complexity of an educational phenomenon. Adding a conceptual framework to best practice approaches such as Kern's 6 step-approach for curriculum design helps constructing goals and objectives. Furthermore, this integration helps selecting the educational intervention to achieve the educational goals and objectives, determine the evaluative methodology of the educational intervention, which will eventually determine the outcomes to be assessed and the evaluative strategy to determine the success of these outcomes[19]. Overall, both best practice and conceptual framework contribute to the rigor of the educational scholarship.

Two theories contributed to the design and development of the CIED curriculum, based on the needs assessment. The Self-Regulated Framework, attributed to Zimmerman and

Schunk, entails that learners plan, monitor and evaluate their own learning to achieve their goals[20]. The self-regulated theory is applicable to the busy schedule of CT Anesthesiology trainees that interfere with synchronous learning, and importantly, to the maturity level of trainees at his stage of their career. The self-regulated theory thus calls for the design of asynchronous learning method in the form of m-learning. The Self-Regulated Framework was used to formulate the research question: Whether an app-delivered CIED curriculum is a suitable delivery method for CT Anesthesiology trainees?

Kolb's Experiential Learning Cycle that describes the 4-stage learning cycle in the form of concrete experience, reflective observation, abstract conceptualization, and active experimentation is another framework that influenced the design of the practical modules of the curriculum[21]. The framework guided formulating the research question: whether video-recording of the interrogation and programming procedures of CIEDs by vendor will allow trainees to gain the skills needed to perform these procedures through the Kolb's stage of reflective observation?

Establishing goals and objectives

Based on a review of textbooks and consultation with colleagues, the first author developed an initial draft of seventeen major goals and associated instructional objectives (5-15 objectives for each goal). Overall, curricular goals focused on knowledge, psychomotor skills and attitudes of the learners and were tailored in a stepwise fashion from acquiring foundational knowledge to applying this knowledge to acquiring the skills in managing CIEDs. For example, the curriculum progresses from understanding and recognizing electrocardiographic patterns of pertinent tachy- and brady-arrhythmias to understanding the basics of CIED indications, structure, and function of CIEDs, to recognizing pacemaker rhythms and understanding the four

basic parameters used in interrogating and programming CIEDS on different vendors. The final modules of the curriculum are in the form of recorded videos of performance of device interrogation and programming on the 4 contemporary device vendors. Assessment of psychomotor skills of the trainees will be in the form of video recording of the trainee conducting the 4 steps of device programming and interrogations of in the form of 1. Identification of the vendor, 2. Identification of the device, 3. Assessment of pacing dependency, and 4. Performance of battery and leads functionality in the form of: a. battery longevity, b. Leads impedances, c. sensing amplitude and capture threshold. An assessment rubric was created to grade the performer's skill (Appendix1).

Following the development of seventeen goals and objectives associated with such goals, we sought to evaluate the proposed goals and objectives by surveying a group of 17 CIED subject matter experts (SME) on whether (a) the objectives are critical or important to CA learners, (b) the instructional objectives fit the learning goals, and (c) whether the objectives as written were clear. After the initial development of the goals and objectives, the process to evaluate the objectives was similar to methods employed by a previous medical curriculum validation process used in Obstetrics in Canada.[22]

The curriculum validation process involved the identification of a national panel of experts in curricula relating to CIEDs. Definition of expertise of an expert was based on the qualifications: board certification in Cardiology, Electrophysiology, and equivalent certification in CIEDs with greater than 5 years of experience, and an expertise in medical curricular design.

Each panelist received an online survey (Qualtrics) which presented the seventeen major

learning goals of the curriculum and the instructional objectives for each goal (5-15 objectives per goal). Respondents were asked to rate the importance of each instructional objective (not important, important, essential), the fit of the objective to the learning goal (does not fit, aligns), and the clarity of the objective (unclear/ambiguous, clear).

Results and response to validation of goals and objectives

Seventeen SMEs responded to the Qualtrics survey. The results of the validation survey are in the process of publication elsewhere. In brief, all objectives were rated as important or essential by 80% or more of the 17 raters, several goals had fewer than 70% of objectives rated as essential by 73% or more of the experts with 6 goals having no objective that was rated as “essential” by more than 73% of experts. A goal on understanding unique features of individual CIED vendors received the lowest rating given that this subject was not pertinent to CT anesthesiologists.

In response to SMEs' response, we have kept objectives that were either essential or important to greater than 75% of the raters and removed the objectives that were considered important by less than 75% of raters. Furthermore, goals whose objectives were considered important by less than 75% of the raters were removed).

The modified curriculum was then named 'Anesthesiology Prospective- basic curriculum' (Table 1).

Selection of Instructional Modality and Strategies

One focus of this curriculum development project was the commitment to delivering instructional content and resources, assessment, and program evaluation (e.g., utilization, acceptability, satisfaction) of the curriculum via an updatable, accessible, asynchronous electronic platform. An m-learning

platform for delivering the curriculum was considered essential for accommodating the constraints experienced by CT anesthesiology trainees. Delivering the curriculum via modular delivery of content provides a flexible, self-paced, competency-focused approach to instruction and assessment.

In order to develop the m-learning platform within a structure that would be manageable to learners, the retained goals and objectives were distributed among 11 modules and submodules. The use of modules is a common structure for m-learning platforms.[23, 24] Curricular mapping between goals, objectives, the instructional resources associated with each objective, and the assessment for each objective was created for all goals and objectives within the curriculum (Tables 2-4).

Assessment materials were developed in the form of pre- and post-instructional quizzes. Post-instructional quizzes were slightly different in order and content from pre-quizzes. The rationale for this difference is to assess trainees' incremental learning gains after reading the modular instructional material and to assess whether the post quiz responses were due to knowledge acquisition versus memorization of pre-quiz grading of wrong answers. A minimum passing score of 80% was used as the criterion for passing any quiz. Quizzes consisted of both multiple-choice questions (MCQ) and open-ended questions. The former was created to assess knowledge, comprehension, and simple applications while the latter were created to assess deeper level of learning and ability to explain the reasoning behind the responses.[25] Grading of open-ended questions was performed by instructor while grading for MCQs was performed automatically. Quizzes could be taken indefinitely until passing scores are achieved. Assessment for modules that covered skills

were in the form of virtual actual device interrogations. This was in the form of performing 4 basic steps: a. identification of CIED vendor, b. determination of the type of CIED, c. determination of pacer dependency, and 4. Determination of device functionality in terms of battery longevity, leads' function in terms of sensing and capture thresholds and leads' impedances. Programming entailed adjusting the device settings to suit the site of the surgical procedure and the use of electrosurgical interference, applying a magnet when indicated and disabling tachycardia therapy in patients with implantable cardioverters defibrillators. Device restoration included restoring of basic settings of the device after the completion of the procedure and enabling tachycardia therapies for ICDs. The interrogations, programming and restoration were performed under the supervision of the Principal Investigator on the protocol.

- The next phase of the evaluation and refinement of the curriculum and m-platform is to engage a cohort of experts to judge whether instructional content and resources within the app provides valid representation of each instructional objective (instructional validity), and whether the pre- and post-assessment provide a valid measure of the objective and are adequately informed by the instructional content and resources linked to the objective (content validity of assessments). The rationale for engaging SME on instructional and content validity is to consolidate the validation of the alignment of goals to objectives. Engagement will be in the form of Qualtrics survey sent to the same SMEs who will provided with the assessment and instructional and assessment material via email. As such, this will provide validation of the curricular map in the form of alignment of goals to objectives to instructional material to assessment. This validation is conceptually distinct from assessment of learners' satisfaction of the curricular content which is the form of a short survey embedded at the end of each module.

B. Delivery of the Curriculum. Pilot phase

We developed a de-novo a cloud-based system for the project. The CIED app (and the accompanying admin grading app) has two components: the mobile and web front-end, and the cloud-based back-end (Fig.1).

Front-end: The CIED app and the admin grading app are developed using Ionic, a cross-platform mobile app framework. This allows consistent functionality and user experience across iOS and Android devices. It also allows deploying a web app, which can be accessed from mobile phones or tablets as well as desktop web browsers.

Back-end: The back-end of this system is built using the Google Cloud. More specifically, we host the back-end compute, database, and analytics services based on the Google Firebase engine. We used the Google Cloud Firestore database to store the course modules, quiz questions, and per-user data such as grades. We used Firebase's authentication engine to register and manage users.

Analytics: For detailed user analytics, we used Google Firebase Analytics engine. It provided us with details on how the users interacted with the system and viewed different modules and videos. The per-user data on grades and quiz attempts provides us with information on the quiz attempts and performance. We collected pre- and post-lesson quizzes to compare performance before and after each lesson.

Evaluation of the educational material will occur in three phases: first: performance analytics which will quantify the learning gain after compared to before taking the quizzes. Second, web analytics, will determine the time taken by trainees in studying and answering the quizzes. Through this evaluation, the level of complexity of the material will be evaluated. Third, usability analytics that will assess the learners' satisfaction with the curricular content and app usability.

Two distinct applications were created; the User Study App, empowering CT anesthesiology trainees to enhance their knowledge, and the Admin Grading App, streamlining quiz management and assessment. The successful integration of these apps creates a cohesive ecosystem that fosters growth, engagement, and continuous improvement within the anesthesiology community. Both apps are compatible with Android and iOS platforms.

The User Study App

Is a knowledge hub catering to anesthesiology practitioners' learning needs. It offers a collection of study materials, interactive resources, and self-assessment tools to foster professional growth. For usability testing, we are using the AttrakDiff test (<https://www.attrakdiff.de/index-en.html>). AttrakDiff is a standardized test designed to evaluate the user's experience. It is widely used to assess the attractiveness of a product in terms of usability and appearance.

The User Study App, integrated with the pre-quiz condition (Fig.2). The key features include:

Pre-quiz Requirement: Users must complete a pre-quiz assessment before gaining access to study materials.

Study Materials: A library of articles, multimedia content, and case studies tailored to various anesthesiology topics and expertise levels (Fig. 3).

Interactive Quizzes: Quizzes were designed to complement the study materials and reinforce learning objectives.

Progress Tracking: Personalized user dashboards displaying pre-quiz scores and study progress, aiding in self-assessment and goal setting.

Leaners' satisfaction surveys: surveys on the learning experience of trainees were

embedded at the end of each module. Surveys assess learners' views on the clarity of the educational material, alignment of the educational objectives to goals and to the instructional and assessment material, what areas need further instruction and what technical issues arouse during the navigating the module (Fig. 4).

The Admin Grading App:

The Admin Grading App equips administrators with powerful tools to manage quiz content and evaluate user performance. Key features include:

Admin Dashboard: A secure login portal providing access to quiz management, user profiles, and analytics.

Quiz Creation: A user-friendly interface allowing administrators to create and customize quizzes, tailoring them to specific learning objectives.

User Management: Comprehensive user profiles and progress reports, assisting administrators in understanding individual learning trajectories.

Grading Interface: A grading system enabling assessment of quiz responses (Fig. 5).

Analytics and Reporting: Data visualization tools providing insights into overall user performance, popular study topics, and areas needing further emphasis.

Integration and Security Measures: Fostering a Cohesive Ecosystem

The integration of the User Study and Admin Grading Apps is facilitated through shared databases, ensuring data synchronization and consistency. Security measures, including strong encryption and authentication protocols, safeguard sensitive user information and preserve the platform's integrity.

Table 1. Basic CIED curriculum: Anesthesiology Prospective

Module 1: Basic cardiac electrophysiology
1A. Basics of surface EKG
1B. Heart Blocks
1C. Pertinent Tachyarrhythmias
Module 2: Indications of pacemakers, ICDs, and CRTs
2A. PPM indications
2B. ICD indications
2C. CRT indications
Module 3: Anatomy of pacemakers
3A. Generators
3B. leads
Module 4: Pacemakers modes and codes
4A. Generic pacemaker codes and modes
4B. VVI pacing as an example of single chamber pacing
4C. DDD pacing as an example of dual chamber pacing
Module 5: Anatomy of ICDs
Module 6: Operation of ICDs
6A. ICD recognition of arrhythmias
6B. ICD treatment of arrhythmias
Module 7: Guidelines for perioperative management of CIEDs
Module 8: Magnet behavior
Module 9: Programming and interrogation of CIEDs
Module 10: UAB Anesthesia Clinical Protocol of Perioperative CIED Management

Table 2. Instructional map for Module 1A

Goals	Objective	Instruction	Assessment
1. Understand basics of heart rhythm formation and propagation	1. Differentiate between pacemaker and myocardial cells	Objective 1.a Text	1. Written quiz with visuals
	2. Differentiate the action potential for both pacemaker and myocardial cells		
2. Establish a foundation for recognizing rhythms	3. Understand the ionic basis responsible for different phases of action potentials		
	4. Recognize and define refractory periods on an action potential		

Table 2. Instructional map for Module IB

Goals	Objective	Instruction	Assessment
1. Understand basics of EKG depiction	1. Determine heart rates on EKG by at least 2 methods	1. Visuals	1. Written quiz with visuals
2. Understand the various types of heart block	2. Identify the axis on surface EKG	2. Text	
	3. Identify different types and levels of heart block on surface EKG		

Table 3. Instructional map for **Module IC.**

Goals	Objective	Instruction	Assessment
1. Recognize the different types of supraventricular tachycardias	1. Describe EKG patterns of SVT a. Determine EKG pattern of atrial fibrillation	1. Visuals 2. Text	1. Written quiz with visuals
2. Understand the differences between ventricular and supraventricular tachycardias	b. Describe EKG patterns of AVRT c. Describe EKG patterns of atrial tachycardias d. Describe EKG pattern of atrial flutter 2. Recognize EKG pattern of VT a. Monomorphic b. Polymorphic c. VF d. Accelerated idioventricular rhythm 3. Understand common SA node abnormalities • 4. Describe wide complex SVT 5. Differentiate wide complex SVT from VT		

Figure legends

Figure 1. Screen shots of the CIED App.

Figure 2. Screen shot of a modular instruction material- user app

Figure 3. Screen shot of a quiz on a modular instruction material

Figure 4. Screen shot of qualtrics survey embedded at the end of each instructional module.

Figure 5. A screen shot of grading of a quiz- administrative app.

Discussion

This manuscript describes the pilot phase of developing the first of its own application for educating CV anesthesiology trainees. This project has engaged, and will continue to engage, experts in CIED content, medical education, and technology to assure that the curriculum is comprehensive, and that the platform provides for effective instruction and assessment. In addition to the scheduled instructional validity and content validity study, the app will gather data regarding platform implementation; user perceptions of usability,

perceived effectiveness in promoting learning, and satisfaction with all components of the app; psychometrics of the learning assessments, and analysis of learning within each module.

While there are no previous studies on this subject to compare our work to, our mobile app goes in line with other studies that used mobile apps for educating anesthesiology trainees. Marty et al.[26] designed a mobile app to facilitate programmatic assessment of anesthesiology trainees and tested its performance in five teaching institutions. The app provided insightful information about feedback completion times and documentation of learning goals. Monroe et al.[27] implemented a mobile app for anesthesiology trainees rotating through a pediatric rotation in an academic institution. Similarly, Herbstreit et al.[28] created a mobile platform formed of several department-specific apps and qualitatively demonstrated high satisfaction rates with the mobile learning content and pace. Compared with the above-mentioned studies, we have followed formal steps of creating a curriculum, consulted nationwide SMEs and developed a curricular map that aligns instructional material and assessment to goals and objectives. Distinctly, our admin app uses web, performance as well as usability analytics, which are either not covered or partially covered in other studies.

Some of the limitations of this project are the relatively small number of SMEs recruited for validation of the curriculum. At the stage of the validation, the project was in a pilot phase. We regard this curriculum as a progressive iterative process with more refinements as more learners become exposed to it. More SMEs will be engaged in the future after being presented with data collected on the learners' experience. Integrating data from trainees and

SMEs is foreseen to elevate the quality of the curriculum. Our choice of SMEs did not focus on anesthesiologists per se. while this might be regarded as a limitation, it might point to the importance of the choice of diverse group of experts who primarily manage these patients outside the perioperative context and who will be interacting with anesthesiologists in the care of these patients perioperatively. Engagement of SMEs outside the scope of anesthesiologists may potentially allow the creation of advanced curriculum that targets cardiology trainees, which will represent an extension of the scope and value of academic anesthesiologists. Additionally, since data about the performance of this curriculum are being collected, the project is subject to modifications and, therefore, is not finalized at the current stage.

Conclusions

The CIED App is a novel application-delivered curriculum on a complex and understudied subject in anesthesiology training. The curriculum adheres to conventional steps of curricular design. The m-delivery of the curriculum and the functionality of the app in the evaluation of the learners' performance and satisfaction responds well to the challenges that face trainees in achieving synchronous learning and engages them in the learning and evaluation processes. As we continue to enhance and expand the CIED App, we envision its instrumental role in elevating the quality of anesthesiology practice worldwide, ultimately benefiting patient outcomes and healthcare excellence.

Conflict of Interest

None declared

Author Contributions

AZ: conception of the manuscript, writing of the curriculum, performing the need assessment, writing the initial draft, edited the final draft,

AW: conception of the app, edited and reviewed the final version of the manuscript.

BH: evaluated the curriculum, edited the final draft of the manuscript.

SM, SHM, RH, YZ: conception, design and development of the app, editing and review of the final draft of the manuscript.

All authors agree on the final version of the manuscript.

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Abbreviations

AVRNT: AV nodal reentrant tachycardia

CT: cardiothoracic

CIED: cardiac implantable electronic devices

M-learning: mobile learning

EKG: electrocardiogram

CRT: cardiac resynchronization therapy

ICD: implantable cardioverters defibrillators

PPM: permanent pacemaker

SVT: supraventricular tachycardia

VT: ventricular tachycardia

UAB: University of Alabama At Birmingham

PPM: permanent pacemaker

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Data Availability Statement

No data was collected on this manuscript.

Appendix 1. Rubric for assessment of psychomotor skills during device interrogation				
	Exceptional	Very good	Good	Poor
Communication with instructor	explains the interrogation steps in an organized manner	Explains the majority of steps in an orderly way	Explains the majority of steps in an unorderly way	Misses the communication of > 3 steps of interrogation and programming
4-question device programming (vendor, device, dependency, functionality)	Recognizes the 4 questions of device programming	Recognizes 3 of the 4 steps of device programming	Recognizes 2 of the 4 steps of device programming	Recognizes 1 of the 4 steps of device programming
4-test (battery, capture,	Performs 4 tests of	Performs 4 tests	Performs 3 of 4 tests	Performs < 3 of 4 tests

sensing, impedance testing) interrogation	interrogation orderly	disorderly		
Programming based on surgical site	Appropriate independently	Appropriate with minimal instruction	Appropriate with substantial instruction	Fails to appropriately program according to site

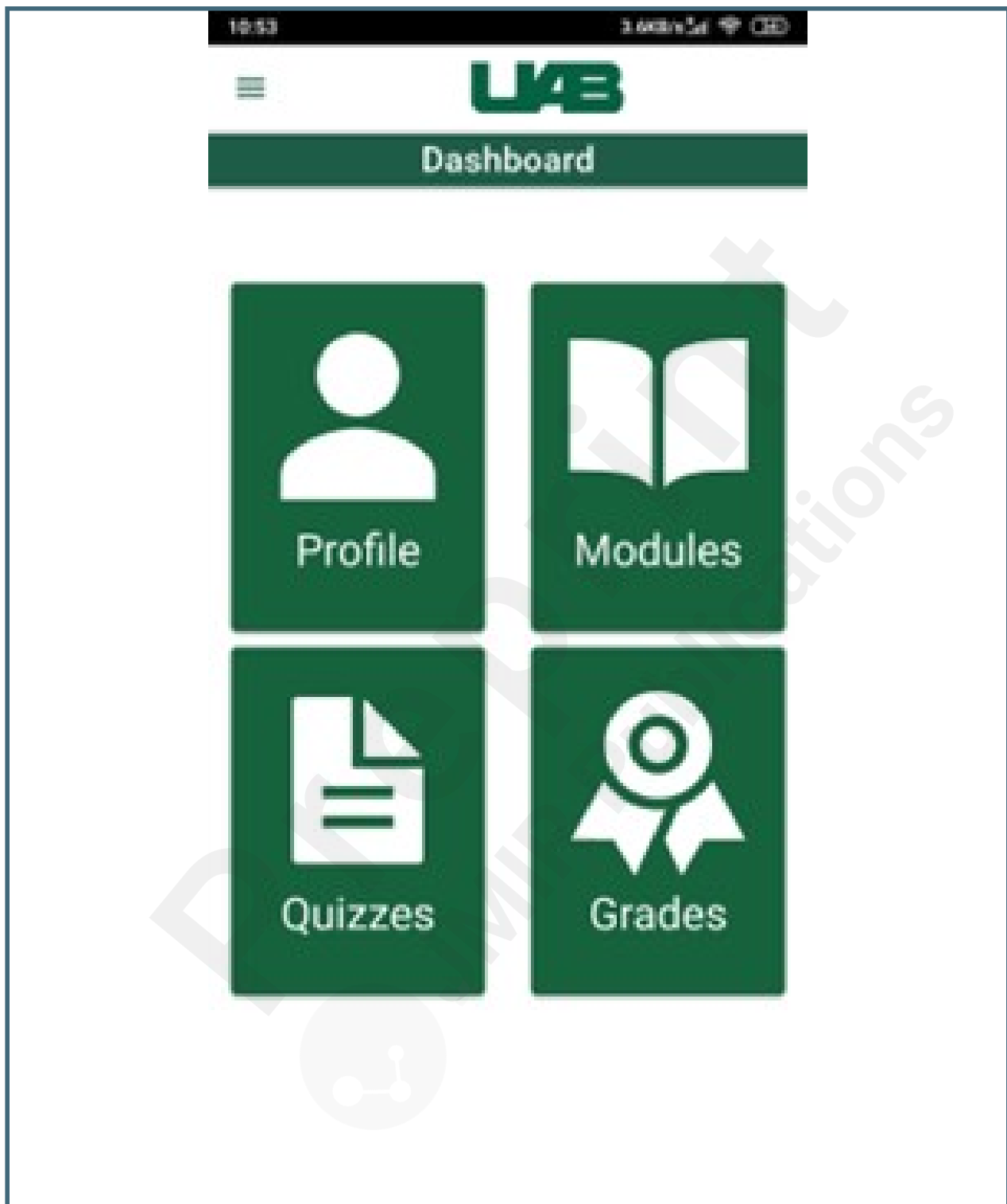
Supplementary Files

Untitled.

URL: <http://asset.jmir.pub/assets/be54d989722921fb284edca5c96d9f88.docx>

Figures

The CIED App.



Modular instruction content material. User App.

Module 1: Basic Cardiac Electrophysiology

1A. Basics Of Surface EKG

Total Earned: 10 / 60

1. Which Of The Following Ionic Fluxes Is Responsible For Phase 4 Action Potential Of A Pacemaker Cell? LO-4

0 / 10

Answer:

a. ☐ I_{Na^+} In

b. ☒ $I_{Ca^{++}}$ In

c. ☐ I_{K^+} Out

d. ☐ I_{To} Out

10. At Which Phase Of Myocyte Action Potential Would A Pacemaker Impulse NOT Capture The Myocardium? LO-3

0 / 10

Answer:

Screenshot of a modular quiz. User App.

Module 1: Basic Cardiac Electrophysiology

1A. Basics Of Surface EKG

Total Earned: 10 / 60

1. Which Of The Following Ionic Fluxes Is Responsible For Phase 4 Action Potential Of A Pacemaker Cell? LO-4

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d. ☐ I_{To} Out

10. At Which Phase Of Myocyte Action Potential Would A Pacemaker Impulse NOT Capture The Myocardium? LO-3

0 / 10

Answer:

Qualtrics survey embedded at the end of a module. User App.

The screenshot shows a mobile application interface for a survey. At the top, the status bar displays the time 7:52 and various icons. The app's header features a hamburger menu icon and the UAB logo. Below the header, a green banner reads "Module 5: Anatomy Of ICDs". The main title "Take Survey" is centered in green. The survey consists of two questions, each with five radio button options. The first question is "1) To What Extent Does The Instructional Information Align With The Objective?" and the second is "2) To What Extent Does The Assessment Align With The Instructional Objective?". The first question has "4 Good Alignment" selected. The bottom of the screen shows a green footer with the text "2024 @Copyrights Reserved - UAB Anesthesiology".

Module 5: Anatomy Of ICDs

Take Survey

1) To What Extent Does The Instructional Information Align With The Objective?

1 ☐ Does Not Align At All

2 ☐ Poor Alignment

3 ☐ Some Alignment

4 ☒ Good Alignment

5 ☐ Perfect Alignment

2) To What Extent Does The Assessment Align With The Instructional Objective?

1 ☐ Does Not Align At All

2 ☐ Poor Alignment

3 ☐ Some Alignment

4 ☐ Good Alignment

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Quiz grading. Administrator App.

Module 1: Basic Cardiac Electrophysiology

1A. Basics Of Surface EKG

Total Earned: 10 / 60

1. Which Of The Following Ionic Fluxes Is Responsible For Phase 4 Action Potential Of A Pacemaker Cell? LO-4

0 / 10

Answer:

a. ☐ I Na⁺ In

b. ☒ I Ca⁺ In

c. ☐ I K⁺ Out

d. ☐ I To Out

10. At Which Phase Of Myocyte Action Potential Would A Pacemaker Impulse NOT Capture The Myocardium? LO-3

0 / 10

Answer: