EduPace: A Simulator for Temporary External Pacemaker Training

Süheyla Nurlu (5978637), Adrien Joon-Ha Im (4999924), Cees Vlasman (5708273), Ashley Jacobi (5973503)

E-mail: snurlu@tudelft.nl, aim@tudelft.nl, cvlasman@tudelft.nl, ajacobi@tudelft.nl

Abstract

Temporary external pacemakers are used to stabilise patients with acute bradycardia and atrioventricular conduction disorders. Because these devices are rarely used in daily clinical practice, nurses have limited opportunity to develop confidence in their operation. EduPace was developed as a training simulator based on the Medtronic 53401 single-chamber temporary external pacemaker. The system replicates the device's appearance and controls using a microcontroller-based interface with rotary encoders and a graphical display, while a desktop application simulates electrocardiogram signals and pacemaker behaviour in real time. Feedback from nursing staff indicated that EduPace provides a realistic and intuitive hands-on training experience. EduPace offers an accessible tool for temporary external pacemaker education.

Keywords: *Training tool, Medtronic 53401, Single-chamber external temporary pacemaker, Ventricular pacing*

1. Introduction

A temporary external pacemaker is a device that stimulates heart contractions to maintain a sufficient cardiac rhythm in patients suffering from various forms of cardiac arrhythmia [1]. Unlike permanent pacemakers, temporary pacemakers are not surgically implanted and are used to transiently stabilise a patient's cardiac rhythm. They are often used during surgical procedures, or while awaiting implantation of a permanent pacemaker, to manage slow heart rhythms (bradycardia), caused by sinoatrial (SA) node dysfunction or various levels of atrioventricular (AV) blocks [2].

Temporary external pacemakers contain a pulse generator that produces an electrical signal to stimulate heart contraction. This pulse generator is connected to the heart via heart leads. In single-chamber pacemakers, leads are placed in either the right atrium or ventricle, while in double-chamber pacemakers, leads are placed in both chambers. Ventricular pacing is of particular significance in treating bradycardia caused by AV blocks, as these conditions hinder or prevent electrical conduction between the atria and ventricles. The degree of an AV block can be classified as either first, second, or third degree, with a higher degree indicating greater severity. A first-degree AV block is characterised by slow conduction between the atria and ventricles, represented by a long PR interval on an electrocardiogram (ECG) [3]. Second-degree AV blocks result in occasional loss of conduction. This appears on an ECG as a P wave not followed by a QRS complex [4]. In third-degree, or complete AV blocks, there is no conduction between the atria and ventricles, resulting in uncoordinated P waves and QRS complexes. While the intervals between adjacent P waves and adjacent R waves remain constant, the PR interval varies, and P waves occur more frequently than R waves. Thus, this condition is characterised by a lower ventricular rate than atrial rate [5]. Left untreated, AV blocks can cause fainting, shortness of breath and reduced blood flow to the rest of the body [6].

Medtronic is a key player in the market for single-chamber temporary pacemakers, with models such as the 53401, as pictured in Figure 1, popular in hospitals worldwide [7].

Figure 1: *Components of Single Chamber Temporary External Pacemaker (Medtronic 53401) [8]*

The pacemaker senses the patient's intrinsic heart rhythm and paces according to the rate, output and sensitivity settings, which can be controlled using knobs on the device.

1.1 Problem Statement

At the Reinier de Graaf hospital, temporary external pacemakers are rarely used in the Cardiac Care Unit. Accordingly, nurses have limited opportunity to maintain routine proficiency and lack confidence in using them during emergency situations. Existing solutions to this problem include Medtronic's VirtualEPG [8] simulation, but as this tool does not provide hands-on experience with using the device, it does not fully resolve the issue. Accordingly, the EduPace aims to address the shortcomings of the Medtronic VirtualEPG, to provide nurses with confidence in using temporary external pacemakers.

1.2 Project goal

The goal of this project is to develop an educational training tool that helps nurses gain practical experience and confidence in using a single-chamber temporary pacemaker for ventricular pacing. This project builds on a previous student project that successfully took the first steps toward creating a training tool for external pacing.
In the previous project, a physical training device was developed using an Arduino Mega microcontroller connected to a laptop running an ECG simulation. The system responded in real time to changes in the pacemaker settings, allowing users to see the effects of their adjustments. The final prototype of this project served as an important inspiration for the current work.
Based on feedback from hospital staff, several aspects were identified for further improvement. These include the choice of microcontroller and display shield, the overall ease of use, the realism of the simulation, and the ergonomics and appearance of the device. The aim of this project is to improve the initial design by addressing these points and by actively incorporating feedback from nurses and clinical staff throughout the development process. In this way, the final training tool is intended to better match real clinical practice and user needs.

2. Materials and Design

The material selection and overall design of EduPace were carefully considered to provide clinicians with an experience that closely resembles the Medtronic 53401. To achieve this, the design approach was divided in three main aspects.

The first aspect is hardware design, which focusses on the physical electronic components, including rotary encoders, the interactive display and their integration and interaction within the system. The second aspect is software design, which involves simulating ECG patterns of an imaginary patient across various clinical scenarios to support realistic training and evaluation. The third aspect is the physical device design which addresses the casing of the electronic components with emphasis on ergonomics, simplicity and ease of use.

While the hardware and physical device aim to replicate the functionality, appearance and user interaction of the Medtronic 53401 as closely as possible, the software design focusses on realistically simulating the effects of an external pacemaker on a patient.

2.1 Hardware Design

The hardware of EduPace is designed around the Arduino Giga R1 microcontroller along with its compatible display shield. Three incremental digital rotary encoders are integrated to adjust the rate, output and sensitivity parameters.

2.1.1 Microcontroller

A microcontroller is a computer on a single chip. It includes a processor (CPU), memory (RAM/ROM) and input/output (I/O) peripherals designed to perform specific tasks. Arduino is one of the most widely used microcontroller platforms which comes with its own integrated software (IDE). One of the main advantages of Arduino is its simplified programming language based on C/C++ along with a large collection of libraries, as it is an open-source platform. Further, Arduino supports a wide range of electronic components such as display shields.

Among the different Arduino boards available, the Arduino Giga R1 has been selected instead of the Arduino Mega, which was used in the previous version of EduPace. The primary reason for this choice is that the Arduino Giga R1 display shield is only compatible with the Arduino Giga R1 board. Furthermore, the display unit requires a more powerful microcontroller to run graphical libraries efficiently and provide a smooth user interface. The Arduino Giga R1 meets these requirements, as it is significantly more powerful than the Arduino Mega.

2.1.2 Display Shield

The display is a crucial component of EduPace, as it enables effective interaction between the device and the user. In the previous EduPace design, no graphical display was included and instead, three 7-segment displays were used to indicate current parameter values as shown in Appendix 1, Figure 1.3. However, the Medtronic 53401 includes a full display screen that shows not only the parameter values, but also labels, units, lock/unlock status of the device and LEDs for pacing and sensing activities.

To better align EduPace with the Medtronic 53401, the transition from 7-segment displays to an Arduino Giga display shield was considered an appropriate design choice, as it improves user interaction and provides greater freedom in design. The Arduino Giga display shield features an 800x480 RGB touchscreen and supports the LVGL framework, an open-source graphics library for creating user interfaces on a wide range of microcontroller and processors. Thus, the ability to use LVGL represents a significant advantage of development using Arduino.

2.1.3 Rotary Encoders

The Medtronic 53401 has three rotation knobs to adjust rate, output and sensitivity values. The knobs are incremental and provide a slight click at each step. Based on these design constraints, digital incremental rotary encoders were selected, as they closely resemble the behaviour and user experience of the Medtronic controls.

Each rotary encoder is powered by a 5V supply provided by the Arduino, with a common ground connection. The encoder's CLK (clock) and DT (data) pins are connected to the Arduino's digital input pins. As the knob is rotated, these two pins generate square-wave signals that are phase shifted by 90°. An algorithm created on the Arduino continuously compares the states of the CLK and DT signals to determine the direction of rotation. A difference between the DT and CLK states indicates clockwise rotation while matching states indicate counterclockwise rotation.

2.1.4 Layout and Graphics

When designing the layout and graphics of EduPace, similarity in design to the Medtronic 53401 and user friendliness were key considerations. EduPace starts with a splash screen (Appendix 2), so the user can click on START when they are ready to practice. Once activated, the main interface is displayed.

As shown in Figure 2, the main screen displays three indicators: Rate, Output and Sense. Each of these parameters is also represented numerically and visually through corresponding dials. At the top left and right of the screen, there are two LEDs displayed to indicate pacing and sensing. At the bottom left of the screen, there is a touchable power button, and on the bottom right, there is a Lock/Unlock button. Additionally, there is also a symbolic battery icon to make it more realistic.

Together, these elements reflect all visual features of the Medtronic 53401 while keeping the interface realistic and easier to use. Although the dials are not present on the Medtronic 53401, they are found on model 5392. They were intentionally added to improve clarity and usability.

Figure 2: *EduPace main user interface*

2.1.5 Device Functionalities

As shown in Appendix 2, similar to the reference device, EduPace has numerous user interfaces depending on the device state. Although the EduPace device is already powered when connected to the computer, the user is still required to press and hold the power button to begin transmitting signals. To create the impression that the device is powered off, the background colour is dark grey and numerical values are replaced by two dashes. When activated, the power button turns green, default numerical values appear and the background changes to white to indicate active operation. Like Medtronic 53401, to power off the device, the power button should be pressed for more than 2 seconds, and the device must not be in the lock state.

Another key feature is the Lock/Unlock function. On the Medtronic device, locking prevents accidental changes to parameter values and the system automatically locks after 60 seconds of inactivity. EduPace follows the same principle. When the user presses the lock button, the border colour of the button turns yellow, and the background turns soft teal. Any rotation of the knobs does not affect the parameter values while locked.

Although the model 53401 has two physical LED indicators, these are simulated on the EduPace display, instead of using physical components. The left LED flashes green during pacing events, while the right LED flashes blue during sensing events. These indicators operate based on commands received from the computer.

2.2 Software Design and Architecture

To simulate the behaviour of the external temporary pacemaker, a desktop application was developed. The user can connect the EduPace device to the computer and launch the EduPace application following the instructions in the user manual (Appendix 11).

2.2.1 EduPace Desktop Application

As seen in Appendix 3, the EduPace desktop application has four main pages. The first one is the main dashboard, where the user can select the training scenario, see recent practice attempts, and track their progress. The training tab is the main page that allows the user to practice setting the correct parameters to the temporary external pacemaker. It renders the ECG waveform and responds to the rate, output, and sensitivity parameters of the connected device. After each session, the user is given feedback on whether they were successful in stabilising the patient, and how much time it took them to do so. A session log tab is also present for the user to view their previous sessions, and finally, an instructions page for quick troubleshooting.

To improve the user experience in comparison to the first iteration of EduPace, which ran as a standalone executable, the system was redesigned as a cross-platform web application using HTML, CSS, and JavaScript. This web application was then packaged as an Electron desktop app to ensure compatibility with both Windows and macOS.

The EduPace software was designed using a modular architecture to allow for future expansion. Core components such as ECG waveform generation, clinical scenario logic, and device communication were separated into independent modules. This approach allows new clinical scenarios, pacing modes, or more physiologically detailed ECG models to be added without requiring major changes to the existing system. The full EduPace application is available via a public GitHub repository (Appendix 3).

2.2.2 Communication Protocol

The Arduino works in conjunction with a connected computer running the EduPace software. A physical connection is made using a USB-C cable and all data exchange occurs through serial communication. The serial communication is configured to a baud rate of 115200 bits per second on both the Arduino and the computer. This rate is selected to ensure the balance between transmission speed and the communication stability. The system overview is shown in Appendix 4.

When the user adjusts the rotary encoders, the Arduino sends the updated values for rate, output and sensitivity to the computer. Furthermore, the Arduino sends a power status message whenever the device is turned on or off. These messages are received by the computer and processed by the EduPace software in real time.

The Arduino also receives control signals sent from the computer. There are four kinds of control signals that the system supports: GREEN_ON, GREEN_OFF, BLUE_ON and BLUE_OFF. When one of these signals is received, the Arduino processes the command and updates the corresponding pacing and sensing indicator LEDs on the display accordingly.

On the software side, the serial communication is handled using the WebSerial API. This allows the EduPace interface to establish connection with the Arduino without requiring additional native drivers. Compared to the previous EduPace interface, this design improves the connection stability and makes device setup simple by making it plug-and-play.

2.2.3 Modelling ECG Traces

ECG traces were generated using the Rational Bézier-Bernstein model coded in Python, to simulate clinically realistic cardiac patterns. This approach was inspired by a paper from Chutchavong et al. and the previous EduPace project [9]. As seen in Appendix 5, the Rational Bézier-Bernstein model takes a collection of weighted points and interpolates between these to generate a smooth trace, with additional points improving the accuracy of the interpolation. The previous EduPace project used minimal points to model ECG traces. Accordingly, to improve accuracy, it was decided to obtain additional points through importing ECG traces into the software *Desmos* and plotting points along the trace. As seen in Appendix 6A-E this resulted in realistic models of normal sinus rhythm, ventricular pacing and various heart conditions.

2.2.4 Pacemaker Logic

The functioning of pacemakers is dictated by the sensitivity, rate and output settings. Pacemakers sense a patient's intrinsic cardiac rhythm based on sensitivity. Sensitivity describes the voltage threshold above which signals can be detected. Thus, a lower value indicates that more signals will be detected, and the pacemaker is said to have a high sensitivity. If the signal detected by the pacemaker falls below the set rate, the pacemaker will decide to pace. Pacemakers have an additional setting referred to as “Async”, where sensing does not occur and the pacemaker paces at the set rate, regardless of the patient’s intrinsic cardiac rhythm. Pacing will result in cardiac depolarisation and thus, a heartbeat, if the output current is sufficient. The output threshold above which pacing results in cardiac depolarisation is referred to as the capture threshold.

To understand how to model the behaviour of the pacemaker, a decision tree was created, as seen in Appendix 7. This logic was then transferred to functions in Python that generate an ECG waveform that illustrates how the pacemaker responds to the input simulated patient heart rhythm and pacemaker settings.

2.3 Physical Device Design

The physical device is designed by focusing on the casing, with particular attention to ergonomics, simplicity, and ease of use. The goal was to create a device that closely resembles the look and feel of the original Medtronic 53401, making it familiar to clinicians and easy to use in practice.

Special attention was given to the dimensions, material, and shape of the device. To enhance usability, the casing was designed to be as thin and lightweight as possible, while still providing enough structural support. From an ergonomic perspective, the device was intended to be comfortable to hold and operate with one hand during training sessions. The final 3D CAD model can be seen below in Figure 3.

Figure 3: *3D CAD Model of EduPace Casing*

3. Results

A survey (Appendix 8) was conducted and feedback from nurses was collected. The results (Appendix 9) indicate that EduPace is perceived as a valuable training device. Across respondents, participants indicated that repeated use would help them build or maintain confidence. EduPace received high ratings for ease of use, physical design, and overall usability, which support the suitability of the device as a training platform, especially for nurses that have limited prior exposure to external pacemakers.

However, some limitations were identified, primarily related to clinical realism and ECG behaviour for edge cases. Multiple respondents noted that certain rhythms such as second- and third-degree AV blocks were not always accurately represented. Additionally, issues related to pacing and sensing indicators during threshold adjustments were reported. These findings suggest that while EduPace performs well, further refinement of the ECG modelling and indicator logic is necessary to meet the expectations of more experienced users.

4. Discussion

This project builds on a previous student project that already included real-time ECG simulation and device interaction. This project focussed on three main changes. First, the hardware was updated to better resemble the controls and interface of the Medtronic 53401. Second, the ECG simulation software was adjusted to create more realistic pacing behaviour and clinical cases. Third, the device casing was redesigned to improve the ease of use. Feedback from nurses and clinical staff showed that these changes made the system easier to use and closer to clinical practice.

While the previous EduPace served as inspiration, the new iteration of the device had to be designed from scratch (see Appendix 1 for a comparison between the versions), which was very time consuming. Several challenges slowed down the development process. The 3D-printed casing had to be redesigned multiple times because early versions were too small or there were problems with the 3D printer. Rendering smooth ECG traces in real time was technically difficult, which is why the ECG display is not yet fully smooth. After feedback from clinical staff, the ECG logic had to be adjusted to better reflect pacing behaviour. A simplified ECG model was used, so some physiological signal features, such as signal superposition, are not yet included. Getting frequent feedback from hospital staff was difficult due to limited availability. The EduPace team consisted of engineering students only, which meant there was limited clinical knowledge within the team. This made it harder to fully understand the medical background of temporary pacing.

At this stage, EduPace only supports ventricular pacing modes. Atrial pacing and dual-chamber pacing are not yet included. Later versions could add these modes and include more clinical training cases. EduPace is a step towards a practical and user-focused training tool for temporary external pacemakers. With future additions in pacing modes, ECG realism, and training scenarios, the system can grow into a useful tool for pacemaker education.

Acknowledgements

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References

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Appendix

Appendix 1: Medtronic 53401 vs EduPace

Feature	Medtronic 53401	EduPace 1.0	EduPace 2.0
Screen	Present	Not present	Present
Rate, output and sense indications and units	Present	Present in the form of text on stickers	Present
Rate, output and sense current values	Present	Present on 7-segment display	Present
Rate, output and sense values visual indicators	Not present, present on model 5392	Not present	Present
Rate, output and sense rotary knobs	Present	Present, not similar to Medtronic	Present
Power button	Present	Not present	Present
Lock button	Present	Not present	Present
Pacing status indicator LED	Present	Present	Present on the display
Sensing status indicator LED	Present	Present	Present on the display
Lock indicator	Present	Not present	Not present, indicated by lock button colour change
Battery indicator	Present	Not present	Present but not functional
Asynchronous mode indication	"async" text shown, "--" instead of sense value	Present as LED	"async" text shown, "--" instead of sense value
RAP indicator LED	Present	Not present	Not present
Hand-held size	Present	Not achieved	Achieved
Protection cover	Present	Not present	Not present

Figure 1.1: Medtronic 53401

Figure 1.2: EduPace 2.0

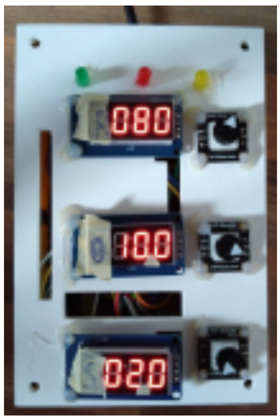
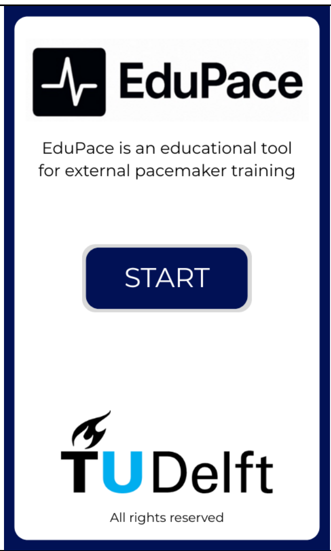
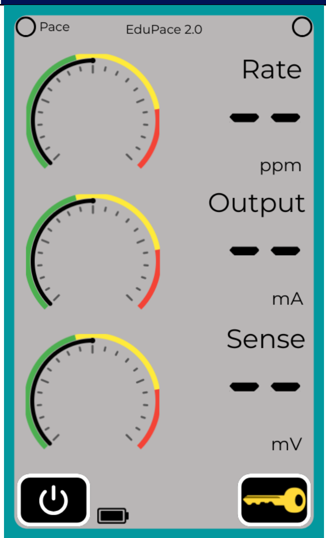
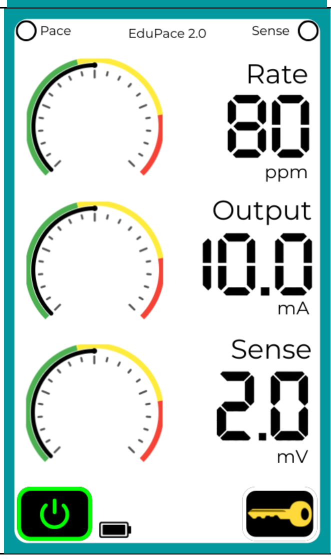
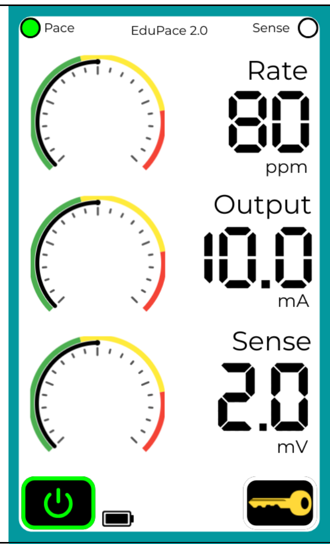
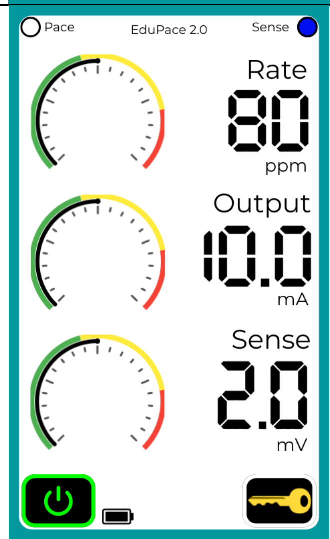
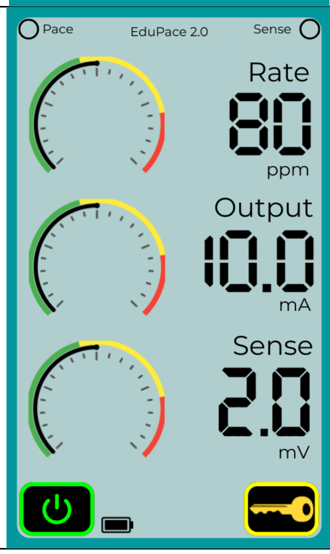


Figure 1.3: EduPace 1.0

Appendix 2: User Interface States

Splash screen Definition of EduPace and logos are shown	
Power Off Background: dark grey Power button: inactive Lock button: inactive Dashes instead of numerical values	
Power On Background: white Power button: active Lock button: inactive Variables start with default values	

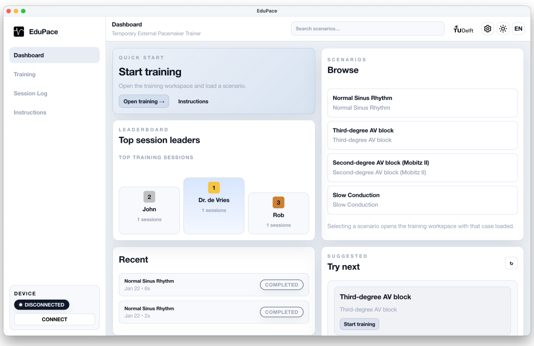
During Pacing Left LED at top is flashing green	
During Sensing Right LED at top is flashing blue	
System Locked Background: soft teal Lock button: active Variable values and dashes do not change	

Appendix 3: EduPace App Interface

EduPace GitHub repository link: *https://github.com/joonhaim/edupace*

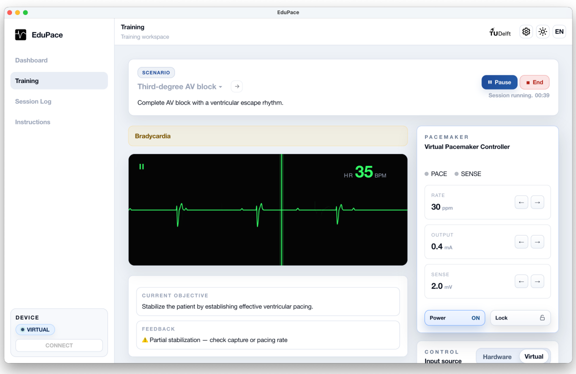
A3.A Dashboard

The dashboard is the main landing screen and includes navigation menus, a list of scenarios, progress tracking, leaderboards, and recommendations for subsequent practice modules.



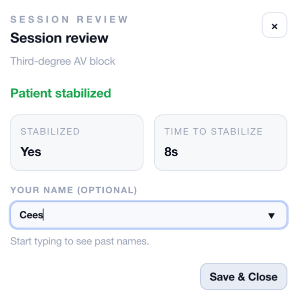
A3.B Training Tab

The Training tab is the main interface where ECG signals are simulated and users can adjust pacing parameters to practice appropriate pacemaker configuration.



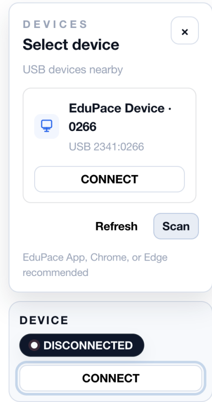
A3.C Session Review

After each session, a review is shown indicating whether the patient was successfully stabilized and the time required to achieve stabilization.



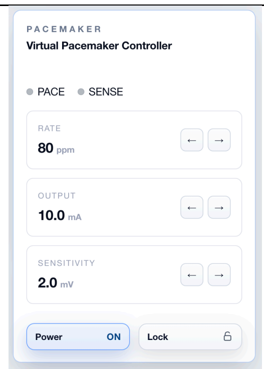
A3.D Connection module

The connection module allows users to connect to a physical EduPace device. Available devices are listed and pressing 'CONNECT' establishes communication via WebSerial.



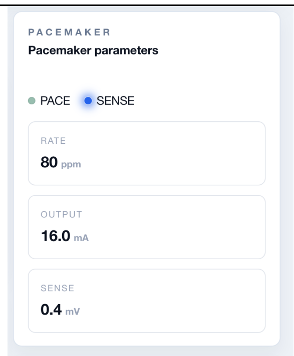
A3.E Virtual Pacemaker

The virtual pacemaker emulates the EduPace device when no hardware is connected. Pacing parameters, power and lock controls, as well as pace and sense indicators, remain fully functional.



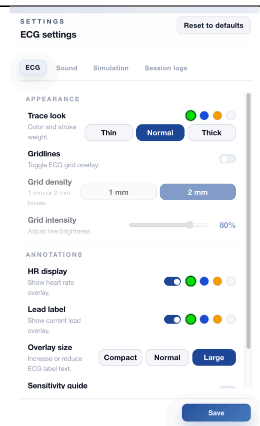
A3.F Pacemaker Information

The pacemaker information panel replicates the display of the physical EduPace device. When connected via USB, parameter values are updated using the physical control knobs.

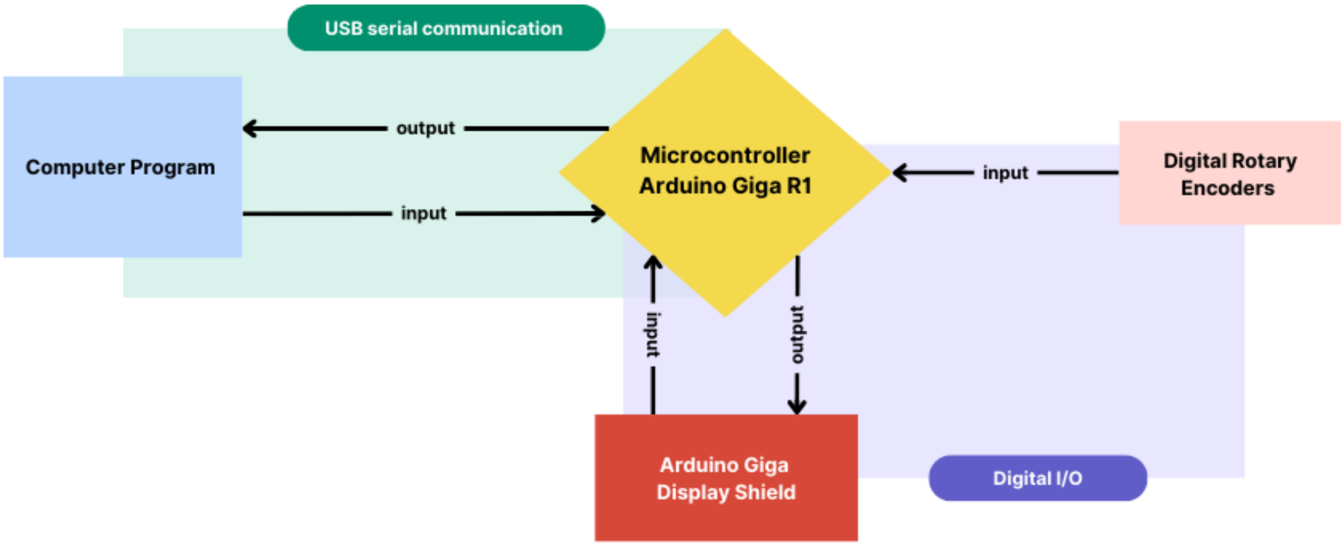


A3.G Settings pane

The settings pane allows users to adjust application settings, including ECG appearance and overlays, as well as simulation parameters such as intrinsic heart rate.



Appendix 4: System overview



Appendix 5: Rational Bézier-Berstein Model

A.

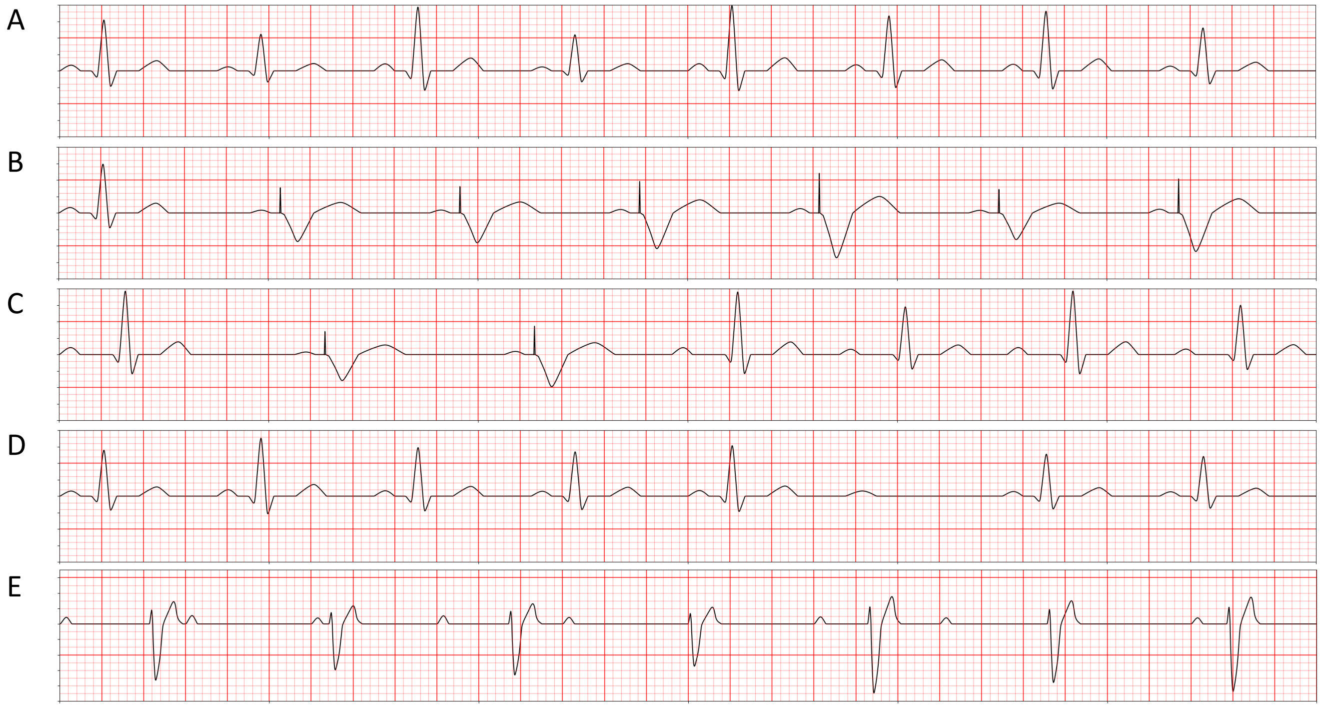
$$R(t) = \frac{\sum_{i=0}^{n} p_i w_i B_i^n(t)}{\sum_{i=0}^{n} w_i B_i^n(t)}$$

B.

$$B(t) = \sum_{i=0}^{n} p_i B_i^n(t)$$

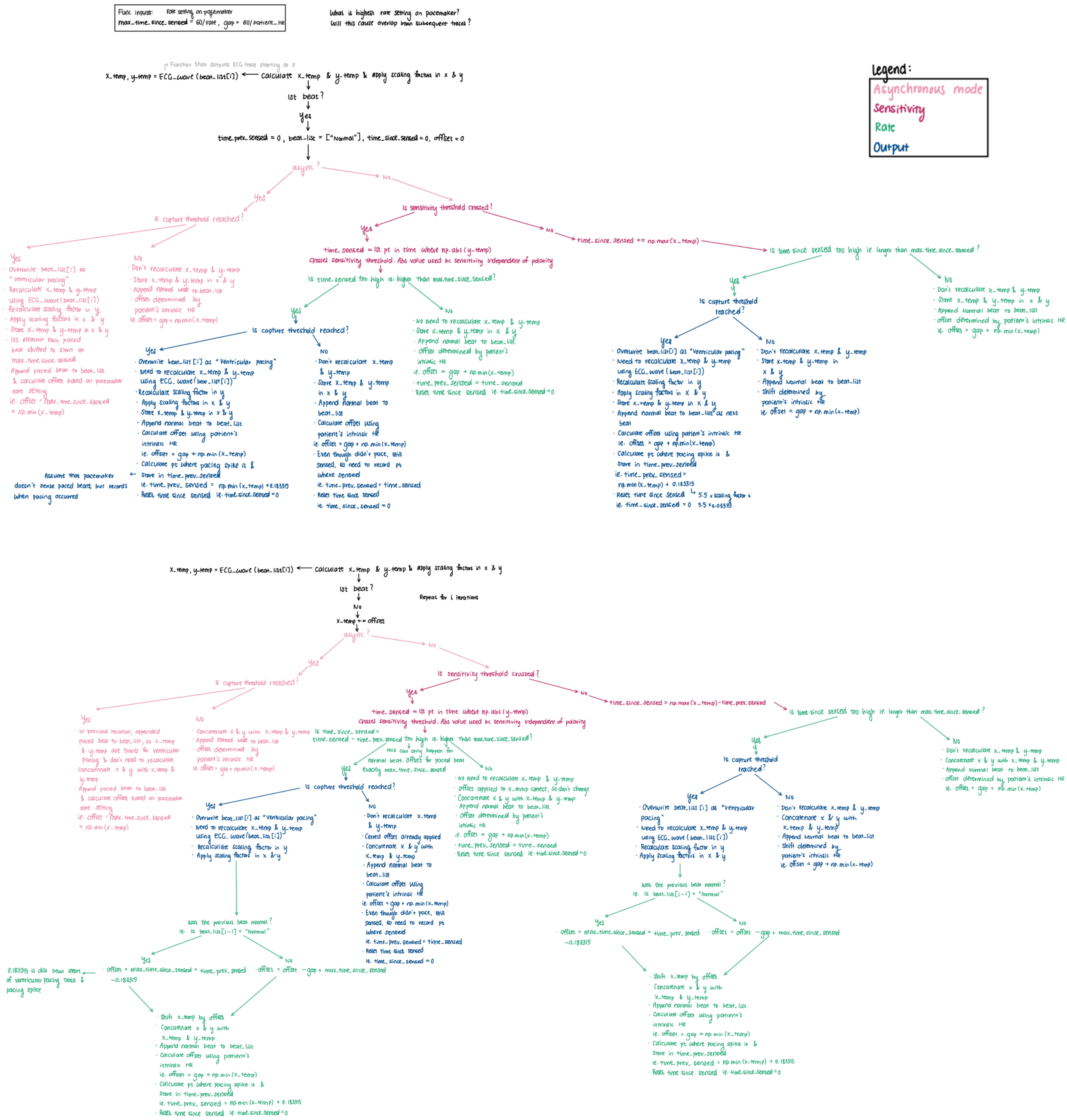
A5.A *Trace R generated using Rational Bézier-Bernstein Model, where p is a point, w is a weighting factor and B is defined as in* ***A5.B***

Appendix 6: ECG traces



A6.A *Normal ECG trace for patient heart rate of 80bpm* ***A6.B*** *Ventricular pacing for patient heart rate of 40bpm (bradycardia), pacemaker rate of 70ppm, sensitivity of 0.5mV and output of 1.7mA* ***A6.C*** *ECG trace for first degree heart block for patient heart rate of 75bpm, pacemaker rate of 60ppm, sensitivity of 0.7mV and output of 1.7mA* ***A6.D*** *ECG trace for second degree heart block for patient heart rate of 80bpm, pacemaker rate of 90ppm, sensitivity of 0.5mV and output of 1.3mA. Pacing doesn't occur, as capture threshold isn't reached* ***A6.E*** *ECG trace for third degree heart block for patient heart rate of 70bpm, pacemaker rate of 80ppm, sensitivity of 0.4mV and output of 1.3mA. Pacing doesn't occur, as capture threshold isn't reached*

Appendix 7: Decision Tree Describing How Pacemaker Responds to Input Signal Based on Settings



Appendix 8: Feedback Form

1- Role/Profession
2- Years of clinical experience
   a. Less than 1 year
   b. 1-3 years
   c. 4-7 years
   d. 8+ years

Before Using EduPace: Background

3- Have you previously used the Medtronic 53401 external pacemaker?
   a. Yes
   b. No
4- How long has it been since you last used the Medtronic 53401?
   a. Less than 6 months
   b. 6-12 months
   c. More than 1 year
5- How often have you used the Medtronic 53401?
   a. Rare
   b. Occasionally
   c. Frequently
   d. Very frequently
6- Have you used any other external pacemaker?
   a. Yes
   b. No

Confidence & Expectations

7- How confident are you in using the Medtronic 53401 before using EduPace?
   a. 1 to 10 (Not confident at all à Very confident)
8- Do you believe EduPace will help improve your pacing-related skills?
   a. 1 to 5 (Not at all à Very much)
9- What specific skills would you like to practice?
   a. Basic device setup
   b. Understanding pacing modes
   c. Adjusting output and sensitivity
   d. ECG interpretation
   e. Other

After Using EduPace – Self-Confidence & Learning

10- How confident do you feel after practicing with EduPace?
   a. 1 to 10 (Not confident at all à Very confident)
11- Do you think practicing more often with EduPace would help build or maintain your confidence?
   a. Yes
   b. No
   c. Unsure

12- To what extent did EduPace help you practice the skills you wanted?
   a. 1 to 10 (Not at all à Completely

Product Experience

13- Did EduPace meet your expectations?
   a. Not at all
   b. Partially
   c. Mostly
   d. Completely
14- Which features did you find most useful?
   a. EduPace device
   b. EduPace software
   c. Device layout and controls
   d. Realistic ECG simulation
   e. Pacing modes
   f. User guide
15- How realistic did the training feel compared to a real external pacemaker?
   a. 1 to 5 (Not realistic à Very realistic)
16- How easy was it to navigate on EduPace software?
   a. 1 to 5 (Very difficult à Very easy)
17- How satisfied are you with the physical design and appearance of EduPace?
   a. 1 to 5 (Very dissatisfied à Very satisfied)
18- How would you rate the overall ease of use of EduPace?
   a. 1 to 5 (Very difficult à Very easy)
19- How clear was the user manual?
   a. 1 to 5 (Not clear at all à Very clear)

Overall Feedback

20- What suggestions do you have for improving EduPace? Which aspects of EduPace do you think work well and should remain unchanged?
21- Would you recommend EduPace as a training tool to others?
   a. Yes
   b. No
   c. Maybe
22- Anything else you would like to share about your experience with EduPace?

Appendix 9: Results From Feedback Form

Rol / Beroep	Aantal jaren klinische ervaring	Heeft u eerder de Medtronic 53401 externe pacemaker gebruikt?	Hoe lang geleden is het dat u de Medtronic 53401 voor het laatst heeft gebruikt?	Hoe vaak heeft u de Medtronic 53401 gebruikt?	Heeft u een andere externe pacemaker gebruikt?	Hoe zeker voelt u zich in het gebruik van de Medtronic 53401 vóór het gebruik van EduPace? (out of 10)	Denkt u dat EduPace zal helpen uw pacing-gerelateerde vaardigheden te verbeteren? (out of 5)	Welke specifieke vaardigheden wilt u graag oefenen?	Hoe zeker voelt u zich na het oefenen met EduPace? (out of 10)
CCU verpleegkundige	Minder dan 1 jaar	Ja	Minder dan 6 maanden	Af en toe	Nee	4	4	Basisinstellingen van het apparaat, Aanpassen van output en sensitiviteit	6
CCU verpleegkundige	1-3 jaar	Ja	Minder dan 6 maanden	Vaak	Nee	5	4	Basisinstellingen van het apparaat, Begrijpen van pacing modes, Aanpassen van output en sensitiviteit	8
Verpleegkundige	1-3 jaar	Nee	Meer dan 1 jaar	Zelden	Nee	6	5	Basisinstellingen van h	6
CCU/EHH verpleegkun	Meer dan 8 jaar	Ja	Meer dan 1 jaar	Zelden	Nee	3	5	Basisinstellingen van h	6

Denkt u dat vaker oefenen met EduPace zou helpen om uw vertrouwen op te bouwen of te behouden?	In welke mate heeft EduPace u geholpen de vaardigheden te oefenen die u wilde? (out of 10)	Voldoet EduPace aan uw verwachtingen?	Welke functies vond u het meest nuttig?	Hoe realistisch voelde de training aan vergeleken met een echte externe pacemaker? (out of 5)	Hoe eenvoudig was het om te navigeren in de EduPace-software? (out of 5)	Hoe tevreden bent u over het fysieke ontwerp en uiterlijk van EduPace? (out of 5)	Hoe zou u het algemene gebruiksgemak van EduPace beoordelen? (out of 5)	Hoe duidelijk was de gebruikershandleiding ? (out of 5)
Ja	7	Grotendeels	EduPace apparaat, EduPace software, Pacing modes	4	5	5	5	5
Ja	8	Grotendeels	EduPace apparaat, EduPace software, Pacing modes	4	5	5	5	5
Ja	8	Gedeeltelijk	Realistische ECG-simu	4	5	5	5	5
Ja	5	Gedeeltelijk	EduPace apparaat	5	3	4	4	4

Appendix 10: Bill of Materials

	Qty	Unit Price (€)	Total (€)
Arduino Giga display bundle	1	96.65	96.65
Rotary Encoders	4	2.40	9.60
Jumper cables	1	1.70	1.70
USB C to A cable	1	2.49	2.49
Logo stickers	1	2.25	2.25
Shipping cost			4.99
Shipping cost			6.87
Total			**€ 124.55**