THE ROLL-UP DIGITAL STEELPAN

Umesh Persad[1*], Keivi Howard[2] and Jorrel Bisnath[3]

[1,2,3]Design and Manufacturing Systems, San Fernando Campus
The University of Trinidad and Tobago, Trinidad and Tobago
[1]Email: umesh.persad@utt.edu.tt *(Corresponding author)
[2]Email: keivihoward@gmail.com
[2]Email: jorrel.bisnath@utt.edu.tt

Abstract*:* The steelpan (steel drum) is the national instrument of Trinidad and Tobago. Over the years, there have been various innovations in the design of the steelpan, including new electronic versions. This paper presents an addition to the family of digital steelpan instruments in the form of a low-cost roll-up digital steelpan (similar to a roll-up piano or roll-up drum kit). The idea as conceptualized is to have a flexible surface with solid steelpan notes following the traditional circle of fifths pattern. The playing surface could then easily roll up for transport and storage. The design of the roll-up digital steelpan is presented together with results on initial testing with musicians. Plans for further development of the product are also discussed.

Keywords: *Steelpan, Innovation, Interaction Design, Product Development*

https://doi.org/10.47412/OVHJ9183

1. Introduction

The steelpan is a percussive musical instrument that is traditionally made from a steel drum. This instrument originated in Trinidad and Tobago in the 1930s, and it is regarded as the only major musical instrument invented in the 20th century [4]. The field of musical instrument design has seen a progression from solely acoustic instruments to fully digital and smart instruments [1]. The influence of digital technology has not by-passed the steelpan instrument, and there are digital versions of the instrument currently on the market or in development. Examples include the E-Pan (Electronic Pan) [2], the PHI (Percussive Harmonic Instrument) [3], and the panKAT. These instruments use technologies such as sound synthesis, sampling and the MIDI (Musical Instrument Digital Interface) communication protocol for generating sound and interfacing with other digital audio hardware.

While these innovative digital steelpan instruments have been developed, factors such as size, weight, portability and cost have limited the accessibility of these products to larger markets. There is a need for low-cost digital steelpan musical instruments that are lightweight and portable. This paper presents the design and initial evaluation of a digital roll-up steelpan which aims to be low-cost and portable similar to the roll-up drum kit or roll-up piano. The paper describes the features of the roll-up digital steelpan as conceptualised, and the results of initial testing with users to demonstrate the viability of the product.

2. Background

The main digital steelpan products are the E-Pan (Electronic Pan) invented by Salmon E. Cupid, the PHI (Percussive Harmonic Instrument) developed by Keith Maynard, Brian Copeland, Earl Phillips and Marcel

Byron and UWI, and the panKAT created by Alternate Mode. The traditional steelpan together with these instruments are shown in Figure 1.

The E-Pan was invented by Salmon Cupid in 2006 [2]. It enables musicians to play in the conventional way without having to relearn another method to master the instrument. With its MIDI capabilities, the E-Pan provides access to the sounds of other musical instruments. The PHI (Percussive Harmonic Instrument) [3] is the second of two steel pan innovations coming out of the University of the West Indies, the first being the G Pan. It merges the facility of MIDI with a physical form and industrial design inspired by the traditional Steel Pan [4]. The panKAT, created by Alternate Mode, is a MIDI Controller for steelpan players. It is mounted on a hexagonal surface and allows the user to play the instrument with drum sticks, mallets and steelpan sticks.

Figure 1: A selection of steelpan innovations (from the left): the traditional tenor steelpan [4], the panKAT, the Electronic Pan (E-Pan) [2] and the Percussive Harmonic Instrument (PHI)[3]

These digital products utilise custom electronics that take input from force or vibration sensors (such as FSRs or piezoelectric elements) and either trigger steelpan note samples (from stored audio data or MIDI output to sound samplers) or utilise digital sound synthesis to generate the sound of the steelpan using appropriate algorithms [5][6]. The costs of these products currently range upward of approximately $800USD. In assessing these existing products, the high cost and limited portability can be prohibitive, providing an opportunity for new product development to address these limitations. The aim would be to develop a product offering that drastically reduces the price, while increasing portability and maintaining sound quality [7].

Taking inspiration from existing products such as the roll-up drum kit and roll-up piano (Figure 2), there is potential to develop a low-cost roll-up steel pan interface [7]. As the name suggests, the roll-up drum kit and roll-up piano are devices that use force sensors to trigger sound samples, but instead of being based on a rigid product housing, the sensors are mounted on a foldable substrate. They can be rolled up for ease of transportation and storage. The product electronics and speakers are housed in a small rigid compartment, and outputs can include audio and MIDI. These devices can cost from $30USD to $100USD.

Figure 2: An example of a roll-up drum kit (left) and a roll-up piano (right)

A roll-up steelpan digital instrument in the same category as a roll-up drumkit or roll-up piano would therefore be lower in price and portable. This new product category would be aimed at musicians who are frequently on the go and need an instrument for practice that is portable and easily stowable. In addition, the roll-up steelpan would be suitable for musicians and students who cannot afford the traditional steelpan or other expensive digital steelpan instruments. Finally, the product could be used as an item for tourism, allowing tourists to purchase a version of the national instrument of Trinidad and Tobago that is easily transportable and affordable.

3. Methodology

The Framework for Innovation with the evolved Double Diamond model [8][9] was used as the primary approach in developing the roll-up digital steelpan concept as shown in Figure 3. This model consists of four phases: Discover, Define, Develop and Deliver with iteration between phases. In the Discover phase, research was conducted into existing products and patents to identify the market need. In the Define phase, design requirements and functional modelling were used to specify the design and market constraints of the product. In the Develop phase, a range of conceptual designs were generated and evaluated using decision matrices. A final concept for the roll-up digital steelpan was selected for further development.

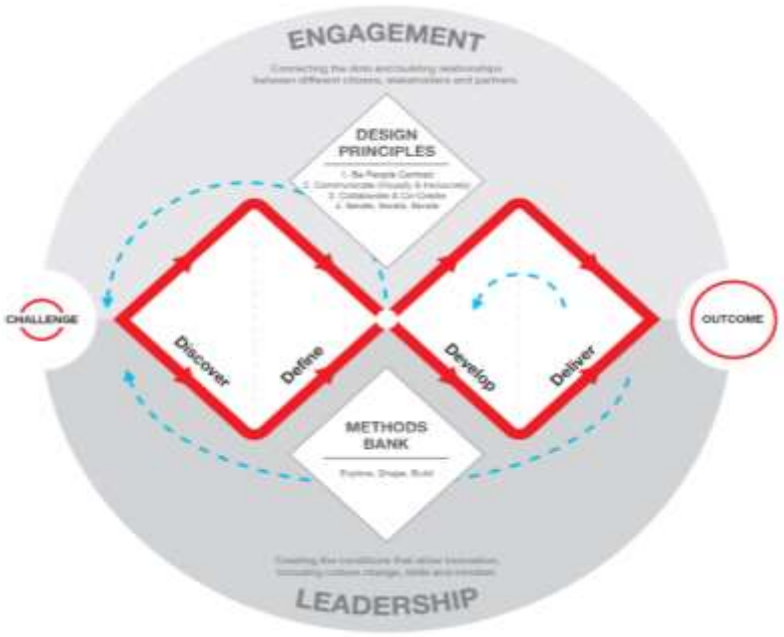

Figure 3: The UK Design Council's Framework for Innovation with the evolved Double Diamond model [8][9]

The project is currently at the Develop phase where the basic design must be validated and improved. This is being carried out via cycles of user testing and product refinement. This paper focuses on the key features of the product design and the initial testing of the product as described in the following sections.

4. Roll-up Digital Steelpan Design

In this section, the final design concept for the roll-up digital steelpan is described as shown in Figure 4. The unique feature of the product is that it is capable of folding or rolling into a small compact size. This

is possible because the rigid notes are mounted on a flexible base layer. The design takes a circular shape of diameter 22" with a thickness of 0.25''. The overall diameter is an inch smaller than that of the traditional steel pan. The note layout is the same as the High C tenor pan with three (3) octaves and twenty-nine (29) notes. All notes were designed in an oval shape and all have different sizes to achieve the same layout and feel as the traditional circle of fifths steelpan layout.

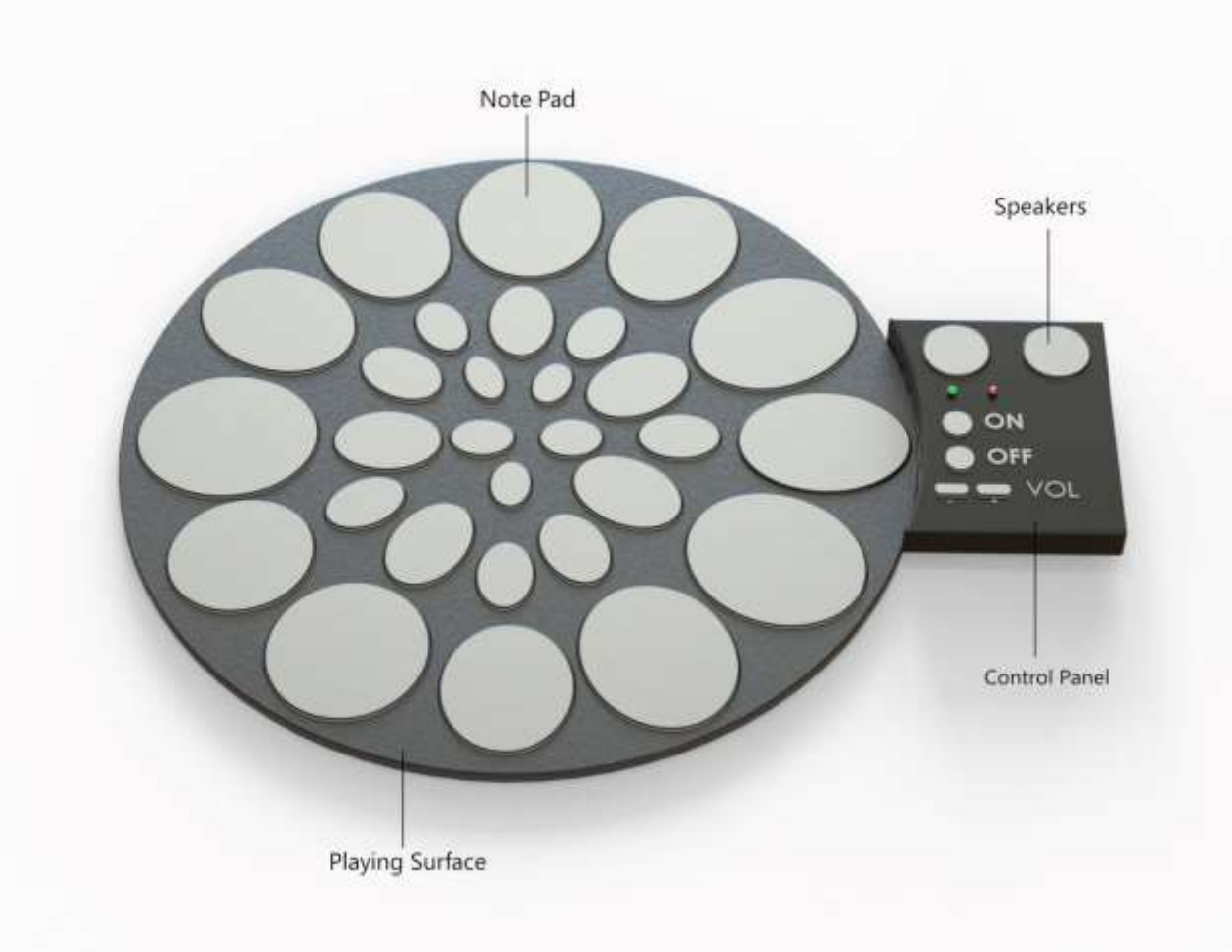

Figure 4: The design of the roll-up digital steelpan

The control panel is 7''x 7'' and attached to the right-hand side of the product and houses the power source (battery) and electronic circuitry of the device. Displayed on the control panel is the control buttons, two speakers and two LED lights to indicate when the device is on (green) and the other to indicate low battery (red). Inside of the control panel is the microcontroller and other electrical components that control the input and output of the device.

The body of the playing surface and the body of the control panel are designed so that they are attached to each other. This was done to protect the internal wire connections from pull forces. The sensors are sandwiched under each note pad and on top the base layer in a position that isolates the vibrations of each sensor when notes are being played (Figure 5). The body of the product can be made of silicone rubber or

fabric, and it is designed to be completely sealed. This flexible material allows the device to easily roll up while also performing the dual function of isolating the force sensors.

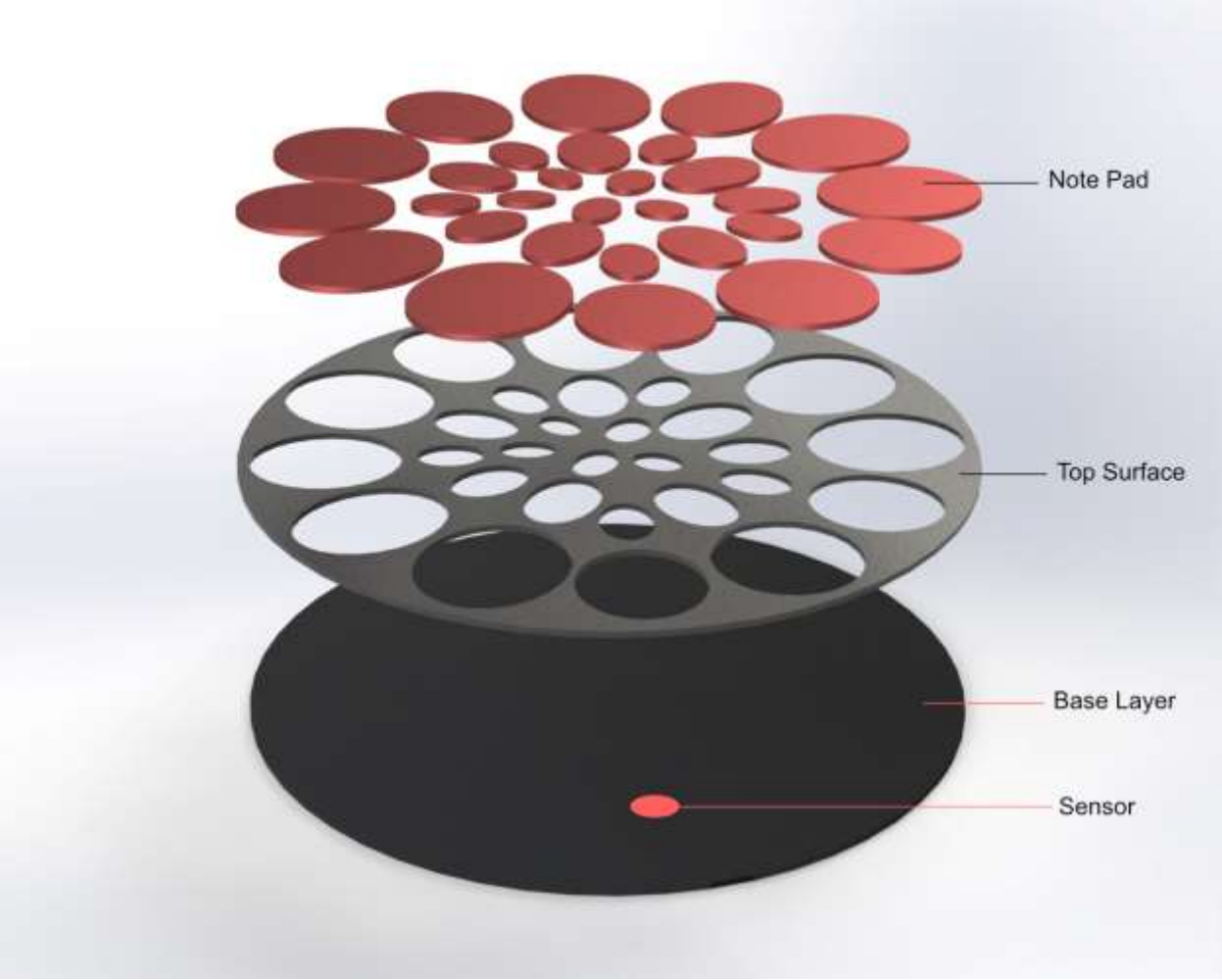

Figure 5: Layered assembly of the roll-up digital steelpan

To use the product, the user first unfolds it onto a flat surface. It is then powered on via the power button. As the device powers on, a string of note sounds will be output through the speaker, and a LED light will illuminate indicated that the device is on and is ready to be used. Using a pair of pan sticks or bare hands, the user can play percussive strokes on the desired note pad which has a piezoelectric sensor attached under the pad. The signal from the sensor is sent to the microcontroller to process the sound output through the speakers in real-time. Sound samples are stored on a memory card that is attached and integrated to the microcontroller. Note strikes are also velocity sensitive giving the feel of a real playing surface. The device can output audio to headphones or an external sound system as well as MIDI data for controlling external samplers.

5. Design Validation

A basic functional prototype of the final design concept was constructed to test the viability of the roll-up digital steelpan. This prototype, shown in Figure 6, shows the roll-up steelpan in its open and folded state.

Figure 6: Design prototype of the roll-up digital steelpan constructed for testing

The prototype was constructed using plasma cut stainless steel sheet 2'x2'(.7mm) for the notes mounted on leatherette fabric. For the electronic components, all piezoelectric sensors were connected via a multiplexer shield to a battery powered Arduino Due board with an SD card module using a 32Gb SD card for tenor steelpan sound samples. Sound was output to 8 Ohm speakers. For this prototype, the notes were covered with the leatherette fabric to dampen the sound of the pan sticks impacting the note surface. The cost of the prototype was TTD$2624.25 (USD$388). The prototype did not implement signal outputs such as audio or MIDI.

The prototype testing phase was executed to test and evaluate the performance of the device along the dimensions of functionality, response, size, weight, appearance and cost. With the evaluation of these areas, it will provide information on the feasibility of the device and ideas for improvement in moving to a market ready product. The user testing phase was conduct by selecting ten (10) lead users who are experienced pan

players, arrangers, tuners and manufacturers to evaluate the prototype. Pictures of participants testing the roll-up digital steelpan are shown in Figure 7.

Figure 7: User testing of the roll-up digital steelpan prototype

Each participant was introduced to the product and played it for a minimum of one (1) minute. An interview was then conducted based on their interaction. In addition to collecting data on basic demographics and experience, each participant was asked the following nine questions:

1. **Experience: What was your overall experience playing the prototype?** Please rate on a scale from 1 to 5 where 1=Very Poor and 5=Highly Enjoyable. Explain your rating.
2. **Functionality: Are you satisfied with the way the device functions and responds?** Please rate on a scale from 1 to 5 where 1=Very Dissatisfied and 5=Very Satisfied. Explain your rating.
3. **Size: What do you think about the size of this prototype?** Please rate on a scale from 1 to 5 where 1=Very Dissatisfied and 5=Very Satisfied. Explain your rating.
4. **Weight: What do you think about the weight of this prototype?** Please rate on a scale from 1 to 5 where 1=Very Dissatisfied and 5=Very Satisfied. Explain your rating.
5. How do you feel about the flat playing surface versus a concaved one?
6. What do you like the most about this device?
7. What do you like the least about this device?
8. What other features do you think should be included?
9. Would you be interested in owning a device like this, and if so, how much would you be willing to pay for such a device (in TT Dollars)?

Participants ranged in age from 15 to 63 years of age, with four being female and six being male. Two of the males had more than 25 years steelpan playing experience while the other participants had an average of 8 years steelpan playing experience. For questions 1 to 4 (rating scale questions), the summarised results are shown in Table 2. All mean scores were above 4 with narrow standard deviations indicating that participants on average found the roll-up steelpan prototype to be an enjoyable experience and they were mostly satisfied with the functionality provided. Participants were also mostly satisfied with the size and weight of the prototype.

Table 2: Results of Questions 1 to 4

Question (Rated on a scale from 1-5)	**Mean**	**SD**
Q1. Experience: What was your overall experience playing the prototype?	4.1	0.74
Q2. Functionality: Are you satisfied with the way the device functions and responds?	4	0.67
Q3. Size: What do you think about the size of this prototype?	4.2	0.92
Q4. Weight: What do you think about the weight of this prototype?	4.8	0.42

For Q1, participants stated that prototype was easy to play, especially with the velocity sensitive notes. They also commented on the good layout and reach of the notes and the attractive appearance. One participant did not like the sound of the stick hitting on the note surface, as it was "loud and distracting". Another participant stated that the inner notes on the 3rd octave (innermost ring of notes) could be a bit larger.

For Q2, participants suggested that the prototype needs improvement in the rolling response, and the audio level through the speakers are not loud enough. They also expressed a desire to play chords, but due to the limited implementation of the current prototype, this was not possible.

For Q3, participants commented that the diameter of the roll-up digital steelpan was good but the notes on the third octave needed to be a bit wider. One participant stated that the size of all the notes could increase a little more.

For Q4, participants commented that the light weight of the prototype was good, suggesting that other iterations of the product could be made even lighter.

Q5 tried to determine the preference of participants for playing on a flat surface versus a concaved surface of the traditional steelpan. Responses indicated that the flat surface had advantages where the hands can move faster across the flat surface as compared to the concave surface. Participants mentioned that it is easier and comfortable to strike notes on the flat surface, explaining that in the concave surface of the traditional steel pan, a lot of wrist movement and re-positioning of the player's body is involved. However, two participants commented that they preferred a concave surface because they are accustomed to playing on such a surface.

Q6 enquired about what participants liked most about the device. All responses were positive with participants mentioning the size of the device (good weight, capability to fold up compactly, portability, and ease of storage). They also mentioned that the device is similar to a traditional steel pan, but it is easier to play, and it could be used as a practice pad that can be carried with them. There is the added advantage where corrosion of the metal in the traditional steel pan would not be an issue in the roll-up digital steelpan.

Q7 investigated what participants disliked about the device. The most mentioned dislike was that the device was unable to play chords, which is an important element in playing the steelpan. Other participants mentioned a preference for the control panel being at the top of the device. The sound quality was another dislike as it was often distorted or muffled. The noise distortion occurred when the processor became overloading at times during testing. Two participants indicated their dislike for the size of the inner notes and the shape of the outer notes stating that the eye must be able to easily differentiate between the notes. Another dislike was the sound of the stick hitting the pad that proved to be distracting. Users also expressed their dislikes in the rolling capabilities as it was not as clean or responsive as a traditional steel pan. A

participant disliked the audio volume as it was too low in his/her opinion, and another participant complained about a lag in the audio output.

Q8 asked participants about what other features should be included in the device. Participants asked for sounds of other steelpan types (low c tenor, double seconds, bass etc) and sounds of other musical instruments (piano, drums, etc), together with a recording and playback facility. They also suggested separating the control panel from the body of the chassis so it can be attached or detached for ease of transport. An audio jack should be included for external connections and a stand should be included that can adjust the playing surface in height and tilt. One participant stated that a convex bump in the centre of each note would be useful (as in the traditional steelpan). Two participants were satisfied with the prototype as presented.

Question 9 asked users about their interest in owning a roll-up digital steelpan and the price range that they would pay for such a device. All users indicated their interest in owning the device once it is further developed and all the issues addressed. Three participants (30%) indicated they would pay in the TT$500-$1000 (USD$74-$148) range, five participants (50%) indicated they would pay within the TT$1000-$1500 (US$148-$222) range and two participants (20%) indicated they would pay more than TT$1500 (more than USD$222). They added that they knew the price for a traditional steelpan, E-Pan and PHI, and something cheaper would appeal to them.

6. Discussion and Conclusions

A working prototype for a low-cost roll-up digital steelpan was developed and successfully tested. In the testing phase, participant responses indicated that there is potential for further development of the idea to overcome current limitations. The prototype device was appealing to all participants as evidenced by their ratings and comments. All participants indicated interest in owning a roll-up digital steelpan once it is fully functional and the cost is kept low and affordable.

Participants suggested many areas for improvement which will be addressed in further prototypes of the device. These include incorporating other ranges and types of steelpan sounds into the device, incorporating sounds of other musical instruments, adding a recording and playback feature, and designing a portable stand for the device. Additionally, the electronic hardware performance can be drastically improved. Given that a generic Arduino Due microcontroller was used to prototype the device, it was not suitable for handling the real-time processing needed for low latency and polyphonic (multiple simultaneous) note production for chords. Developing a custom Printed Circuit Board (PCB) will lead to a more compact device with a better response and eventual economies of scale. Though the sample of participants was limited to ten experienced steelpan players, the indicative results are encouraging and points to the need for further design iterations and more extensive testing with a larger sample of users. Further testing would look at different audiences for the device including professional musicians, students and tourists.

In conclusion, a low-cost roll-up digital steelpan instrument was designed, built and tested as a first iteration. The concept showed promise as a viable product once costs could be kept low while including the important features requested by users. With further design iterations and prototyping, the limitations of the current design would be overcome, and a market ready product can be produced to meet the needs of steelpan players and enthusiasts around the world.

References

[1] L. Turchet. Smart Musical Instruments: vision, design principles, and future directions. *IEEE Access*, 7, (2018) 8944-8963.
[2] S. Cupid, 2006. *Electronic synthesized steelpan drum*. U.S. Patent No. 7,030,305. Washington, DC: U.S. Patent and Trademark Office.
[3] B. R. Copeland, M. Byron, E. Philip, K. Maynard, 2011. *Apparatus for percussive harmonic musical synthesis utilizing MIDI technology*. U.S. Patent No. 8,063,296. Washington, DC: U.S. Patent and Trademark Office.
[4] U. J. Hansen, T. D Rossing. The Caribbean Steelpan, and some offsprings. *Forum Acusticum*, (2005).
[5] A. R. Tindale, A. Kapur, G. Tzanetakis, P. Driessen, A. Schloss, 2005. A comparison of sensor strategies for capturing percussive gestures. In *Proceedings of the 2005 conference on New interfaces for musical expression*. National University of Singapore.
[6] C. Medeiros, M. Wanderley. A comprehensive review of sensors and instrumentation methods in devices for musical expression. *Sensors*, 14 no. 8, (2014) 13556-13591.
[7] A. R. Jensenius, R. Koehly, M. M. Wanderley, 2005. Building low-cost music controllers. In *International Symposium on Computer Music Modeling and Retrieval* (pp. 123-129). Springer, Berlin, Heidelberg.
[8] Design Council, 2007. *Eleven lessons: Managing design in eleven global companies*. United Kingdom Design Council.
[9] Design Council, 2019. *Design Council's framework for innovation*. Retrieved from: https://www.designcouncil.org.uk/