Towards Eco-Organology and Paper Flute Design to Disrupt the Plastic Recorder Industry

Ching-Jie, Kang[1], Made Mantle Hood[2]*
Institute of Creative Industries Design, National Cheng Kung University
email: cj.artecent.k@gmail.com[1], made.hood@gmail.com[2]*

*Corresponding author: made.hood@gmail.com

Published online: 21 December 2023

Cite this article (APA): Kang, C. J., & Hood, M. M. (2023). Towards eco-organology and paper flute design to disrupt the plastic recorder industry. *Malaysian Journal of Music, 12* (2), 35-60. doi: https://doi.org/10.37134//mjm.vol12.2.3.2023

Abstract

In this article, the concept of "distributed capitalism" (Rifkin, 2011) is used to shift power among administrators, performers and audiences to problematise the homogeneity of unsustainable instrument materials. This shift involves adopting a participatory approach where musicians as key stakeholders get to choose their materials and self-construct their instruments. Instruments, society and ecosystems have intersecting and overlapping relationships that should be studied interdependently through eco-organology (Guy, 2009; Titon, 2013; Allen, 2013; Dawe, 2016), especially when mainstream culture consumption plays a crucial role in the struggle between sustainable materials for instruments and the ecosystem. As an example, mainstream production companies such as Yamaha, Aulos and Fender have standardised the industry and cornered the market for consumers in a top-down consumption model. Educators, artists, and retailers promote the consumption of mainstream instruments, further reinforcing their power of discourse in the materials field. Contesting standardisation, eco-organology involves the study of network relations between tangible materials and aesthetics from the viewpoint of culture and society. As an alternative material, this research project shared paper flutes with elementary school students and conducted over 20 workshops in Southern Taiwan where musicians of all ages self-constructed paper flutes. Paper is readily accessible, recyclable and allows end-users to follow an instruction manual, cut a template out and fold it into a playable flute. End-users participated in material selection, instrument construction and many became critically informed about current environmental issues with the plastic recorder industry. We argue that eco-organology helps decentralise mainstream instruments by educating end-users about eco-friendly materials.

Keywords: distributed capitalism, eco-organology, participatory design, plastic recorder, standardisation

Introduction

In broad terms, eco-organology is emerging as an interdisciplinary study involving the interdependent areas of musical instruments, ecosystems, and societies (Guy, 2009; Titon, 2013; Allen, 2013; Dawe, 2016). Interdependent, none of the three are excluded from decision-making for the design and manufacturing process. All have the potential to adversely affect sustainable materials and musical aesthetics in a mutual way. For these reasons, the principal eco-organology research objectives are to study network relations between tangible materials and aesthetics from the viewpoint of culture and society. Rather than a linear relationship between music and ecosystems, eco-organology is not only concerned with the selection of sustainable materials, but more importantly, identifying and critiquing the power structures, principal stakeholders, and multiple agendas of those who choose instrument-making materials and are involved in the decision-making process.

Throughout history, musicians from various cultures have been using a variety of materials to make musical instruments, such as gourds and spiderwebs for African balafon, bamboo for Balinese and Chinese flutes, as well as tree trunks hollowed out by termites for aboriginal Australian didgeridoos.

However, the mindset of "orthodox", "authentic", "proprietary" and "ideal" materials was largely constructed through westernisation, modernisation, and industrialisation. As a result, mass produced instruments tend to embrace a homogeneity of musical instrument materials. The monopolisation of instruments and materials not only consolidates the myth and belief of specific materials for instruments but also contributes to the overuse of some materials. For instance, African blackwood used for high-end oboes and clarinets as well as violin fingerboards, as well as Brazilian rosewood for high-quality guitars are facing a shortage[1] (Yamaha, n.d.; Jef, 2017).

Manufacturers are not the only stakeholders who have standardised musical instruments such as recorder. Musicians who have adapted to current instruments, students who learn with those musicians and teaching materials, as well as publication houses who distribute teaching materials, are also stakeholders who standardise the instrument. The informants, Sandy and Chan, both music educators, have mentioned that it will be easier and more efficient to teach the recorder instead of other instruments because teaching materials are mostly focused on the recorder, and this plastic instrument is easier to teach and learn (personal communication, November 10, 2022; personal communication, November 21, 2022).

First, this article introduces theoretical concepts on ecology and ecomusicology to frame the relevance of paper flute design in the disruption of the plastic recorder industry. Second, the article examines the current situation of plastic recorder use in Taiwan. Third, a prototype flute was subjected to a usability test involving 60 participants. This data was used to redesign and improve the prototype for the next phase of this study involving a blind test, semi-structured interviews, and elementary school workshops. The results of this study show that differing from conventional instruments produced following consumerism and modernism models, the paper flute was based on critical thinking in instrument design, material selection and accessibility. As an ethnomusicology study, we employ the generic term 'flute' to refer to a paper aerophone, because "recorder" connotes the Western European block flute (blockflöte) and English flute. "Flute" as a more inclusive term may refer to Balinese suling, Irish tin whistle, or Turkish Ney as well as a self-constructed paper aerophone. The paper flute allows people to participate in the design, self-construction, and material selection process of the instrument in an economically affordable and technically accessible way.

Ecology and Ecomusicology

Discourse on sustainable musical instrument design relates to ecology and ecomusicology. In the modern era, the urgency and importance of environmental preservation dates to the 1960s. The first large-scale eco-movement was organised during that time, to resist mainstream values of industrialisation and "techno-progressivism" (Whiteley, 2016, p. 100). During the 1970s, a significant change to the environmental movement occurred with the rise of the "environmental decade" which culminated in a complete change in public attitude and policy (Coglianese, 2001).

As a result of this dramatic change towards a strengthening eco-movement, eco-protection ideology has become the *zeitgeist* for this current era of the Anthropocene. However, ecological awareness towards the design and manufacture of sustainable instruments among musicians and instrument players is much less obvious (Guy, 2009). Studies on sustainability strategies employed by heritage orchestras in Southeast Asia (Hood, 2014) and the ecology of soundscapes influenced by diatonicisation and musical invasives (Hood, 2013) have begun to explore intersections between music and the eco-movement. However, a green trademark on musical instruments has not yet become a marketing priority in advertising through online catalogues of instrument companies or brick and mortar stores as well as exhibitions.

Related to the "green economy", ecomusicology has seen significant growth in interest among scholars such as Guy (2009), Devine (2015), Allen and Dawe (2016), as well as Boyle and Waterman (2016). Scholars' ideas address varying aspects between changing attitudes and beliefs about the current state of the environment reflected in music and the performing arts. They critique environmental problems in the musical world. Under the umbrella of ecocriticism (Eisley, 1969; Bateson, 1979), tangible and intangible cultures involving musical instruments, performances and musical activities are entry points that lead researchers to see human beings inextricably linked to, and not separate from, the environment.

Current Directions of Ecomusicology edited by Allen and Dawe (2016), has comprehensively discussed the definition of ecomusicology from different scholars' perspectives. Allen (2013) defines eco-musicology as, "the study of music, culture and nature"; Titon (2013) explains eco-musicology as, "the study of music, culture, sound and nature in a period of environmental crises". As Allen and Dawe suggest, the prefix of ecomusicology is better understood as "eco-critical" referring to ecological criticism, rather than "ecological". Given these definitions, the current study employs the perspective critiquing power structures in the unsustainable usage of plastic in the manufacture of musical instruments, specifically the ubiquitously distributed plastic recorder.

Eco-organology stands on the foundations of ecomusicology and organology to critique ecological issues and problematise industrialised processes in the music

ISSN 2600-9366, eISSN 2600-9331

instrument supply chain by offering green design for musical instruments. Ecomusicology is often eco-critically discussed through the intersecting areas of music (sound), culture (society) and nature (environment) (Guy, 2009; Titon, 2013; Allen, 2013). Similar to acoustemology (Feld, 1996), scholars explore the environment and how humans react to music under environmental crisis.

Therefore, this organological study on ecology issues focuses on two construction materials: plastic, a material commonly equated to a pollutant; and paper, commonly recognised as a sustainable "green material". However, in broad terms, eco-organology is concerned with the ethical and political issues in the boundary of a given tangible environment. Although musical instrument makers often insist on using natural materials to create their masterpieces, many are unethical or unsustainable. For example, the supply of python skin for making an *erhu* (二胡; Chinese two-string bowed fiddle) involves environmental issues; cat and dog skin for making a Japanese *shamisen* involves ethical issues; ivory for making piano's white keys prior to plastic involved endangered animals.

Similarly, ABS plastic resin recorders are an extension of the ubiquitous use and abuse of the natural environment. Plastic recorders do not biodegrade. That said, there is complexity woven into their manufacture and distribution as one of the most prevalent instruments in education systems around the world. Mass produced by companies such as Aulos for decades, this resin-based instrument is as common as a plastic straw.

Taiwan's Recorder-scape

Although one of the most ubiquitous musical instruments in the world, plastic recorders are insulated from change largely because of government education policies protect and consolidate the use of plastic recorders in the compulsory education system. The "recorder-scape" of Taiwan illustrates how the plastic recorder has become firmly entrenched in music education. The recorder is widely represented in the literature that covers the history of the recorder in Taiwan (Xu, 1989; Wu, 1990; Wu, 2004; Lin, 2005; Tseng, 2006) but also depicted in the anecdotes shared by informants who participated in this study.

According to Tseng, in 1969, the KHS company began to introduce plastic recorders from Yamaha, in Japan to Taiwan. Father Alphonse Soren started to promote Karl Orff Schulwerk along with the recorder which further popularised the instrument. In 1971, Luming Publication House in Taiwan started to translate the teaching materials from other countries and produced soprano and alto recorders. These results attracted the attention of Professor Ou-Kang from the National Taiwan Normal University; thus, he recommended the Ministry of Education employ the recorder as a mandatory teaching tool (Tseng, 2006, p. 62). In 1980, a "Recorder Mentoring Project" was founded by Rong-Gui, Wu (officer of the National Taiwan Symphony Orchestra), to train schoolteachers to be able to teach recorders in school (Tseng, 2006 p. 64). Afterward in 1984, the Ministry of Education fixed the recorder as a mandatory instrument. Hence, the recorder began to be regarded as the most important instrument in the Taiwan compulsory education system (Tseng, 2006, p. 65).

Recorder education issues are not only the concern of academia. A YouTube channel “志祺七七 X 圖文不符”, interviewed several experts in recorder instrument and music education in Taiwan. In this video, Prof. Shun-Wen, Wu of the National Taiwan Normal University’s Department of Music, mentioned that the accessible playing technique of the recorder is one of the important factors that make the recorder a common teaching tool in compulsory music education in Taiwan. The initial motive for employing recorders in Taiwan's education system was to give more people the opportunity to learn music because piano and violin required more musical and economic investment. Therefore around 1983, to make recorders economically affordable, some local manufacturers in Taiwan started to develop plastic recorders. In 1993, the Ministry of Education mandatorily fixed recorder education as required content for compulsory music education, a regulation that lasted until 2001. Although this regulation was cancelled, most music teachers still uphold the recorder as an easy means to teach and learn music. Moreover, the teaching materials provided by most publishers are still readily available for recorders helping the plastic recorder maintain its dominance (志祺七七 X 圖文不符, 2023).

However, the technical accessibility and economic affordability of recorders also negatively impact the instrument as articulated by several participants in this study. In the opinion of a music major named Anna who specialises in the instrument, recorders are too ubiquitous because almost every Taiwanese has learned or purchased at least one plastic recorder during their studies. It can be purchased almost anywhere from online retailers, stationery stores or grocery stores. This situation makes recorders hierarchically different from other prestige musical instruments. Moreover, the recorder is one of the easiest wind instruments on which to make a sound. It is employed by the education system as an “elementary tool”. Sandy, a recorder player and music teacher in elementary and secondary school who also participated in this study, has a similar opinion to Anna. Sandy says, “plastic recorders are cheap and affordable” (personal communication, November 10, 2022). She complains that students often lose their recorders, and she collects a lot of derelict recorders in her music class every term.

Plastic recorders are commonly depicted in daily conversations in Taiwan’s recorder-scape as disposable items. Informants provided several solutions to this problem. Former recorder ensemble members Chen and Julia suggested collecting the recorders from students and handing them down to younger students or recycling them. Yuan who experienced compulsory music education growing up recommended manufacturing plastic recorders with recyclable materials or giving them to family members. Summer, a 10-year-old student accompanied by his father Ting remarked that he was also aware of the ecological issues of plastic and said, “We should stop using plastic recorders altogether” (personal communication, November 29, 2022).

One crucial difference between plastic recorders and plastic straws is people usually do not throw away the former. In a narrow sense, abandoned plastic recorders do not directly pollute the environment. However, in a broader sense, as long as the demand exists, the Taiwan factories will maintain production of plastic recorders by the millions. The “plastic recorder as an invisible but well-distributed rubbish”, maintains the running of mould-injection machines in factories such as Yamaha and

Aulos. However, those informants who value the plastic recorder say it is not only a musical tool, but also embodies their wonderful childhood memories. Although Julia, Chen and Anna do not play plastic recorders anymore, keeping them preserves memories as an invaluable treasure. From this alternative perspective, plastic recorders not only embody instrumental value but also offer comfort to those who attach importance to it. As Sandy suggests, "playing a recorder releases stress" (personal communication, November 10, 2022), an argument that musical activities socially bridge people to a larger sense of comradery and even humanity in an effort to counter techno-progressivism.

In Taiwan and other countries, plastic still maintains a dominant presence and recorders are widespread in its music education soundscape. As mentioned above, this organological study addresses ecology issues by focusing on two construction materials: plastic, a material commonly equated to a pollutant; and paper, typically recognised as a sustainable "green material". However, we do not attempt to refuse the use of plastic products by criticizing its unsustainability, because the "greenness" of a material is often socially and technologically dependent. For instance, the initial objective of Thulin's invented plastic bags was to prevent deforestation caused by the low durability of paper bags (Foster, 2019). As Taiwan musicians and educators, Sandy and Chan both defend the value of plastic recorders and do not regard them as dispensable items. As long as people play plastic recorders, and extend or recycle their use, they feel plastic recorders will not be harmful to the environment. Julia and Chen both have similar ideas to Sandy and Chan. Their experiences not only present the view of former junior recorder performers but also represent the views of recorder enthusiasts who see the plastic recorder as a meaningful and invaluable instrument.

But the question remains about how to find an alternative to the plastic recorder. Employing the use of paper as an alternative material and a participatory design may have unforeseen benefits.

Designing the Paper Flute: An Alternative to Plastic Recorder

Throughout the musical instrument industry, there are several examples that demonstrate the ecological concern about instrument design.[2] Prior to 1494, instrument builders had constructed pipe organs featuring paper pipes (Bucur, 2019, p. 307). However, probably due to its low durability, nowadays, paper is not commonly used for making musical instruments, although it is an accessible material. Informants such as Julia and Chen, question the low durability of the paper flute because it will probably be unsustainable, just like the paper bags in Thulin's era. However, the "long-life" plastic recorder that is virtually absent in the recycling system and second-hand market, although physically durable, loses its value as an instrument and is distributed in everyone's house as a kind of "invisible rubbish". Moreover, as we upcycled abandoned book covers, desk calendars, and paper bags to make all paper flutes in this study, we encourage end-users to use leftover paper products.

Research questions in this study centre on how to use a participatory design in the construction and assembly of musical instruments for end-users. The simplicity over complexity approach called KISS (Keep It Simple, Stupid) (Interaction Design Foundation, n.d.) is one of the main objectives that will inform the design of this paper flute. For convenience, the template was designed with only straight lines, thus, it was easy to trim by end-users.

There are two terms used in this study. The first is "prototype paper flute" (see Figure 1 and 2) which refers to the instrument first created in 2018 prior to being examined by 60 participants in the usability test. Paper with a weight and thickness of approximately 250 GSM[3] has been selected through several pre-data collection phases of this project to make paper flute prototypes. The 250 GSM paper is thick enough to increase the durability of the paper flute and, based on our test, can be used for a total of eight hours. As is the case with all wind instrument classes for children, end-users were recommended to clean the mouthpiece before playing by using tissue or hygienic towelette. Coated paper is recommended but not necessary. The prototype paper flute has been recognised by a public agency, Figure 3 shows the poster of the "Paper Flute Workshop" designed and advertised by the Southern Taiwan Maker Centre, Ministry of Labour, Taiwan, Figure 4 shows the paper flute was performed in a forum hosted by the Ministry of Labour.

The second term "redesigned paper flute" refers to instrument improvements on the prototype based on the results of the usability test. The redesigned paper flute is in the key of F5, featuring seven holes in the front, like the sopranino recorder. The thumb hole is not considered due to the complexity of constructing the rolled-layered paper bore structure, yet the higher octave range similar to the regular sopranino recorder is still playable, as discussed later in the article by informants in the blind test. While not a diatonic F major flute, it is capable of a range of F5-Bb6 and can accommodate chromatic notes by using fork fingering (The link to the YouTube video is on page 52).

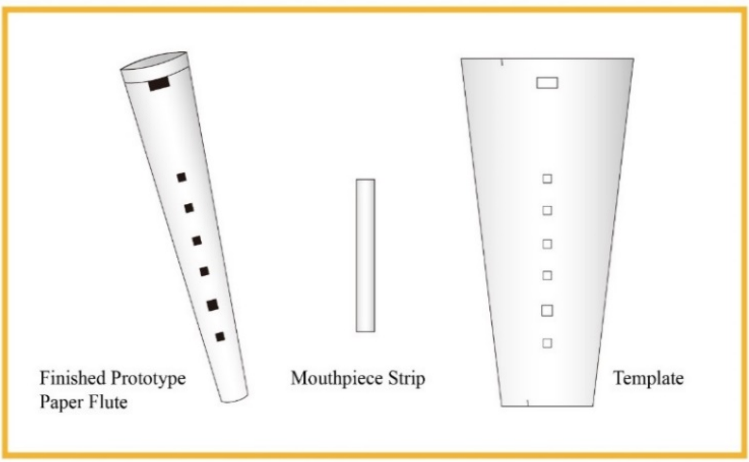


Figure 1. Trapezoid-shaped prototype paper flute design diagram.

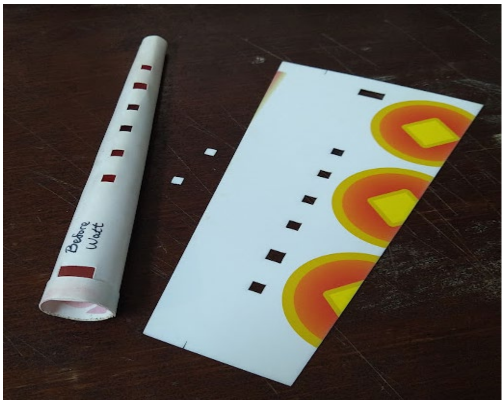


Figure 2. Trapezoid-shaped prototype paper flute design diagram. Photo by the author

Figure 3. The poster of "Paper Flute Workshop" designed and advertised by Southern Taiwan Maker Centre, Ministry of Labour, Taiwan. Screenshot from Facebook.

Figure 4. The seated performer (left) plays the paper flute at the 2nd International Forum on Vocational Training and Maker Movement, hosted by the Ministry of Labour, Taiwan, in 2019. Photo by Mr. Chen Jia Hong.

Usability Test for Evaluating Prototype and Redesigning Paper Flute

In order to increase the engagement rate and assess the functionality of the paper flute a usability test was employed. There were 40 participants evenly categorised by age and gender. These participants had no specific training in handicrafts. To increase objectivity, an additional 20 participants who were familiar with handicrafts were invited to partake in the usability test. These participants were design students, relics conservatory students, crafts teachers, and craftsmen. The following table shows the categories of 60 participants:

Table 1

The participants for the usability test for prototype paper flute assessment.

Usability Test Participants for Prototype Paper Flute				
No.	Categories	Gender	Age	No. of People
1	Untrained Participants	Female	11-15	5
2		Male	11-15	5
3		Female	16-20	5
4		Male	16-20	5
5		Female	21-40	5
6		Male	21-40	5
7		Female	41-60	5
8		Male	41-60	5
9	Trained Participants			20
Total				60

In this usability test, all 60 participants made the prototype paper flute with an instruction manual and tutorial video. The process of participants constructing the paper flute (draw, cut, roll, seal, fold, play and adjust), and sounding it was observed and recorded for further analysis. Feedback forms were also filled up by participants after prototype paper flute making completion. Interviews were not included in this usability testing session due to the considerable number of participants and time limit. There were five (5) categorical observations made on the prototype paper flute making process which include template drawing, template cutting, bore rolling and sealing, labium folding and windway making and playing and adjusting. The following are the categorical observations made on modification and adjustments that were applied to the redesigned paper flute:

ISSN 2600-9366, eISSN 2600-9331

Template Drawing

Physically, pitch is affected by dimension and is proportional to the total size of the musical instrument. For acoustical accuracy, non-integer numbers were employed for the template drawing instructions for the prototype paper flute; however, as some participants suggested, it would be more convenient to utilise integer numbers.

The principal consideration of redesigning the paper flute was making it convenient and easily assembled. Therefore, a small-scale dimensional adjustment and a higher fault tolerance were considered. For example, the width of the template corresponds to the diameter of the bore. The bore diameter can affect the sound; therefore, it was more important to address how much the template was rolled, rather than how wide. Thus, the width of the template can be an integer number. With the consideration of tone quality, wavelength and hand feeling, the redesigned paper flute template will no longer use a trapezoid shape. A rectangle shape 10cm wide and 21cm long will replace the trapezoid prototype shape.

In order to create a wavelength of F5, with a diameter of 2cm, the redesigned paper flute had to be 21cm long in geometry (See Figure 5). The other consideration was that 21cm is the width of an A4 paper, which means the template was easier to measure and cut. The size of the windway is 1cm*1cm correlated to the size of the window, which is 1cm*0.5cm. All the tone holes are 0.5 cm*0.5 cm, with intervals of 1cm, 1.5cm and 2cm. The dotted line seen in Figure 5 functions as the limit for rolling. It is positioned at the bottom and top edge of the template, with a 3cm distance from the left edge. Figure 5 shows the redesigned paper flute template, including the mouthpiece part.

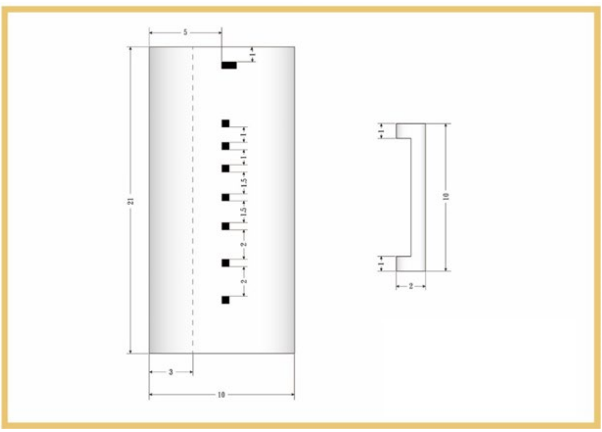


Figure 5. The template of the redesigned paper flute.

Template Cutting

Observing participants undertake the cutting process during the usability test was unexpectedly convenient for the participants, even for the children. A utility knife and a cutting mat were suggested for use. Scissors were not recommended to cut the tone holes and window because they may accidentally fold the template. Inherited from the prototype paper flute, the template design excluded any curved lines and the tone holes are square, thus it is easier to cut than a circle.

Bore Rolling and Sealing

According to usability test feedback, the process of making the prototype conical bore was the most challenging for participants. A conical bore is more difficult to roll than a cylindrical bore. For a small instrument, the length difference between both bores is relatively small. After a mock-up test, we found the difference between the prototype (conical) and redesigned (cylindrical) paper flute was the sound quality and the playing feel, issues not about the usability, but rather adaptation and not about quality, but rather aesthetics.

Labium Folding and Windway Making

To build a windway on a prototype paper flute, the participants were required to fold a shallow concave at the mouthpiece area. The full process was complex as shown in Figure 6:

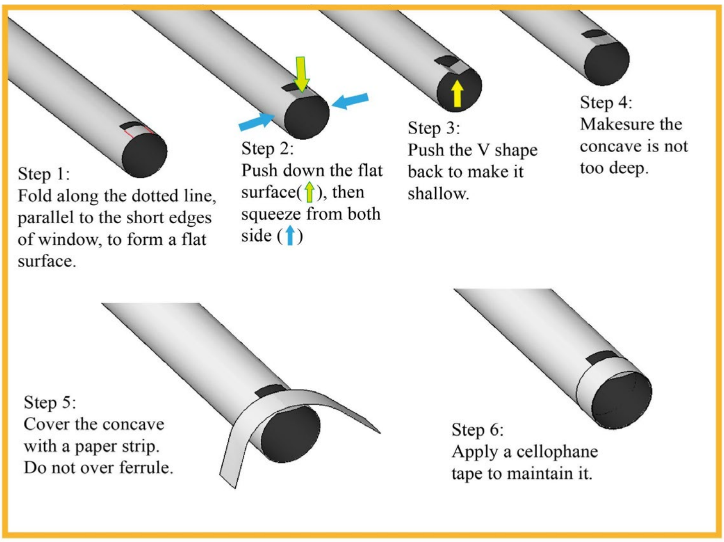


Figure 6. The prototype paper flute windway making process. Design by the author.

The usability test participants often failed to make a well-concave because they over-ferruled the bore and pressed the shallow concave into a deep V shape.

To overcome this windway design flaw, the redesigned paper flute employed a new design to overcome the problem. The strip was inserted into the bore. The elasticity of the paper strip maintained its own position to form the mouthpiece windway (Figure 7).

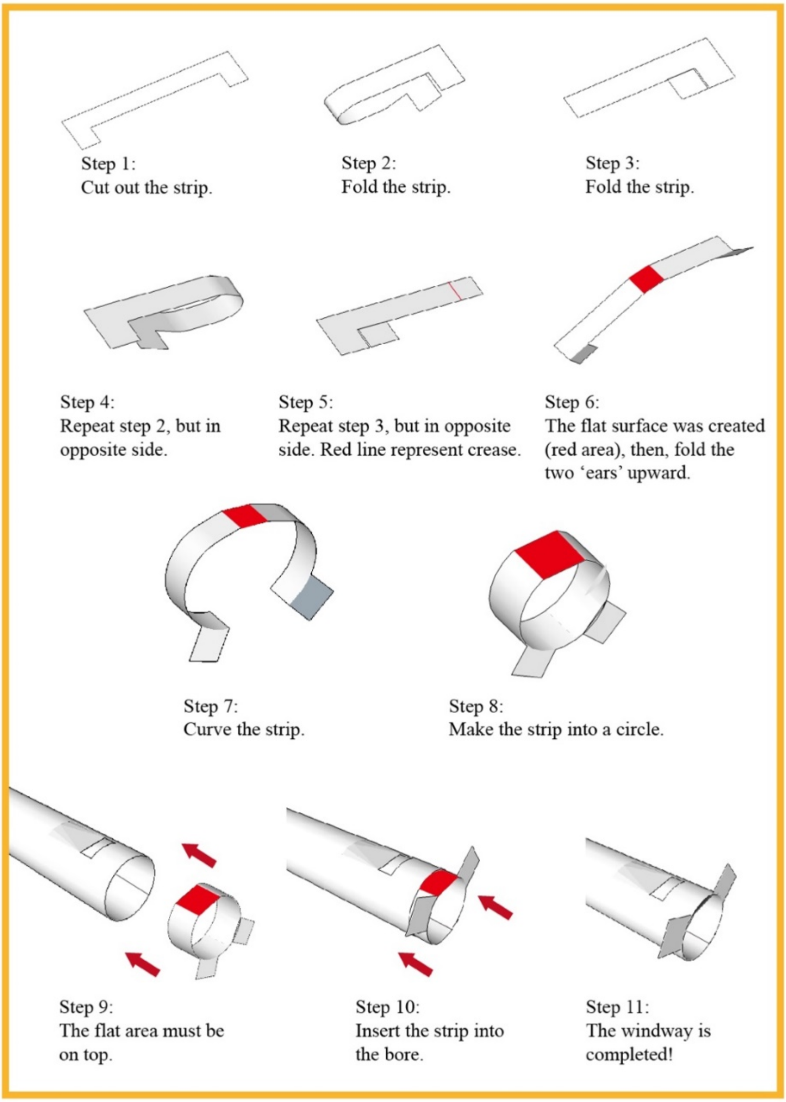


Figure 7. Redesigned paper flute windway construction process. Design by the author.

Observing human behaviour interactions with material properties was an important part of the redesign. Through observation, it became clear participants were not able to easily manipulate and adjust, but not over-ferrule the material for the prototype paper strip. The new redesign decreases human manipulation, prioritizing the elasticity of paper strips.

This windway-forming method changed the windway itself to a lower position. Therefore, it was necessary to fold the labium into form. The folded labium is then geometrically lower than the wall of the bore (Figure 8).

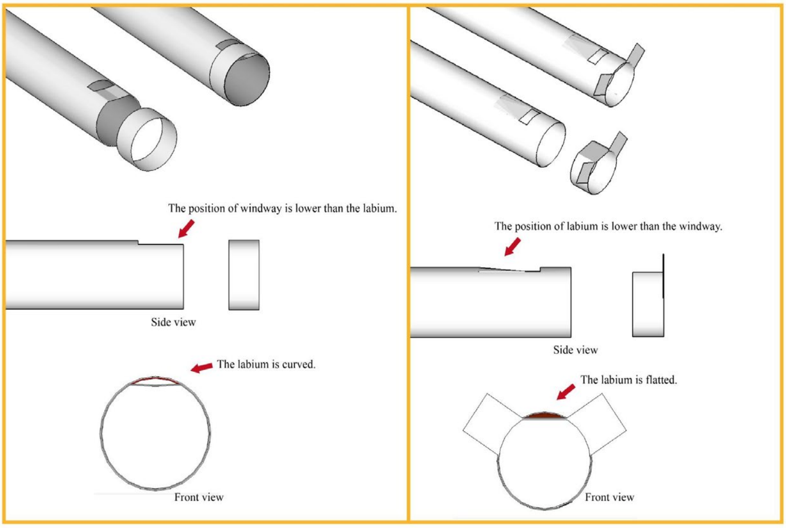


Figure 8. Prototype (left) and redesigned paper flute (right) labium structure. Design by author.

Playing and Adjusting

The usability test provided data to improve the playing and adjustment of the redesigned paper flute. Its making process became easier and had a lower error rate, and even the playability became higher. It was suggested to adjust the mouthpiece to make the redesigned paper flute conform more ergonomically to end-users because different individuals have a variety of playing behaviours such as the speed and volume of exhalation, angle of holding the flute as well as embouchure.

In terms of the accessibility of instrument construction technique and knowledge, the design of the paper flute retains flexibility for end-users to explore the interaction flow between themselves and the instrument. This is in contrast to the commodified and ready-made musical instruments in the plastic recorder market where consumers can only select instruments to find the most suitable one. Instead, the design of the paper flute encourages end-users to make an instrument that conforms to themselves.

Distributed Capitalism and the Paper Flute Redesign

The redesigned paper flute discussed above offers end-users an opportunity to participate in the construction and material selection process under the idea of distributed capitalism. Based on the idea of distributed capitalism and the KISS principle, the conceptual considerations when designing the paper flute are acceptable acoustic properties, simple structure, accessibility, usability, and impact.

With these criteria, the rate of involvement in the self-making paper flute process was a significant and considerable determinant. Designing a self-made paper flute is a process that involves negotiating the quality of the instrument and the degree to which end-users participate in construction. Said differently, how much work does

Malaysian Journal of Music Vol. 12, Issue 2 (35-60)
ISSN 2600-9366, eISSN 2600-9331

one need to do to make a paper flute? The challenges of designing the paper flute appeared when the end-users who were non-professionals were invited to construct the flutes. Paper flute making must consider the ability of its end-users, but the joy of engagement could not be sacrificed too much, i.e., the making process could not be too easy.

In a related test, the redesigned paper flute was subjected to evaluation for its accessibility, level of engagement and most importantly the time it took to assemble. Our enthusiastic 10-year-old musician named Summer and his father, Ting were joined by Amy (15 years old) and Rick (10 years old), a sister and brother pair accompanied by their mother named Yong. The following table shows the time they took for every stage of the redesigned paper flute making process:

Table 2

Time required for four informants to complete the redesigned paper flute.

Redesigned Paper Flute	Time taken (minutes)			
Making Processes	Ting	Summer	Amy	Rick
- Template Drawing	13	24	12	9
- Template Cutting	6	18	9	7
- Bore Rolling	7	9	6	4
- Mouthpiece Making	6	6	3	4
	32	57	30	24

Although Summer took the longest time (57 minutes), he completed and played the redesigned paper flute successfully. Summer and his father, Ting, felt surprised by the similarity between the paper flute and the standard plastic recorder and were excited to play it. They made several attempts and finally produced a satisfying sound by reducing the amount of air exhaled. Even Ting managed to play some simple melodies on the flute.

Rick showed his ability and confidence when making the redesigned paper flute in just 24 minutes. When Amy occasionally glanced over to her brother Rick to check whether her procedure was correct or not, Rick would patiently assist her. Both were able to draw a precise template and cut it out in a short amount of time (see Figures 9 and 10).

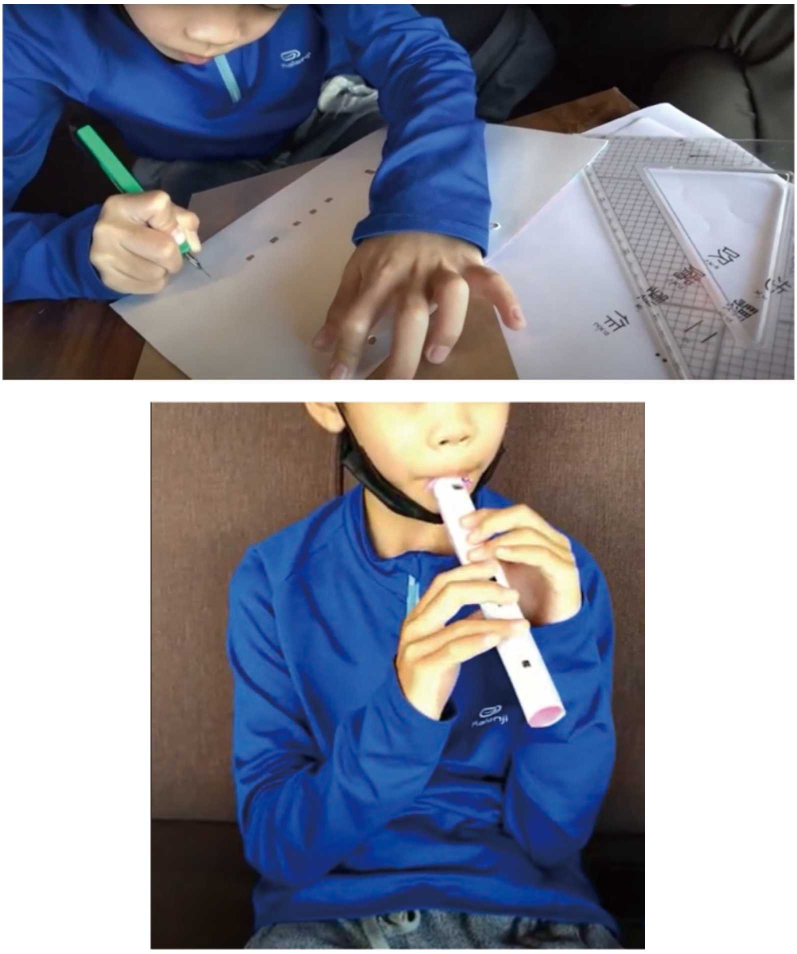


Figure 9 and 10. Rick cutting the template and playing the redesigned paper flute template after windway and mouthpiece adjustment. Photo by the author.

After Rick's template was trimmed, he showed his enthusiasm to help Amy. Rick made the bore successfully and could play some simple melodies such as "Mary had a Little Lamb" and "Hänschen klein".[4]

Blind Test: An Evaluation of Acoustics and Aesthetics

This stage of the research project to disrupt the plastic recorder industry using eco-organology invited 13 informants for a blind test and interview. All informants have experience with the plastic recorder and represent a broad spectrum of musicians including educators, performers, students, amateurs and parents. The following table shows their information:

Malaysian Journal of Music Vol. 12, Issue 2 (35-60)
ISSN 2600-9366, eISSN 2600-9331

Table 3

Informants who participated in the blind test.

	Informant(s)	Background Information
1	Julia	Former members of a recorder ensemble in elementary school.
2	Chen	
3	Nica	University students with experience in compulsory recorder music education.
4	Yuan	
5	Anna	Contemporary music student who majors in recorder.
6	Sandy	Recorder and music teacher in elementary and secondary school.
7	Chan	Professional recorder performer and lecturer at a university.
8	Wen	Parent of diploma students of the recorder.
9	Ting and Summer	Parent and children who engage in compulsory recorder music education.
10	Yong, Amy and Rick	

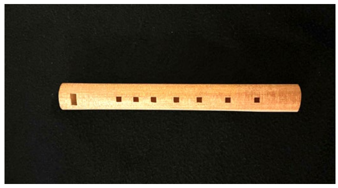
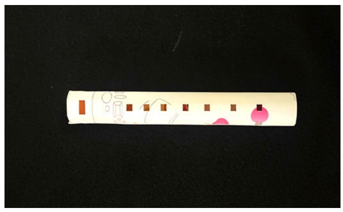
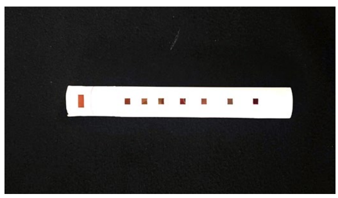
Several studies have proved the reliability and validity of the blind test in the acoustical judgment of musical instruments, and further analyse the phenomenon of canonizing instruments in terms of materials and history (Cho, 2014, 2017; Oleg, n.d.; Widholm et al, 2001). These studies served as a model for the blind test for paper flutes. The following QR code links to a short sample video of a blind test. In this video, a major scale in F is played in ascending order and descending order by redesigned paper flute and plastic recorder (similar to blind testing the informants).

https://youtu.be/JpvJolIajaU

The following blind tests with informants were conducted by the first author and involved six types of fipple flutes constructed from various materials. The table below shows the pictures and descriptions of these flutes:

Table 4

Variety of fipple flutes used for interviews and blind tests.

Fipple Flute	Description	
Wooden Flute	The construction process of this flute is similar to the redesigned paper flute. A piece of veneer was employed for making this wooden flute.	
Metal Flute	The construction process of this flute is similar to the redesigned paper flute. A yellow brass sheet was employed for making this metal flute.	
Polypropylene (PP) Flute	The construction process of this flute is similar to the redesigned paper flute. A polypropylene sheet was employed for making this PP flute.	
Redesigned Paper Flute	A cylindrical fipple flute made of paper in F.	
Plastic Recorder	A regular Yamaha plastic sopranino recorder in F.	
Bronze Recorder	A bronze casted sopranino recorder in F.	

Every blind test was administered for a duration of approximately 20 minutes in a 100 square feet room that served as the acoustic environment. Each informant sat opposite the first author at a moderate distance from a desk. They turned around when he played the fipple flutes for the blind test.

The results of the blind test indicate that the sound of the redesigned paper flute and Yamaha plastic recorder are virtually indistinguishable. While three participants were more familiar with recorder, six out of nine participants could not distinguish the redesigned paper flute and plastic recorder including Nica, Yuan, Anna, Sandy, Chan, and Dong.

In terms of preference, eight out of 11 informants acknowledged the quality of sound for the redesigned paper flute. The following table are the informants and their comments about the redesigned paper flute:

Table 5

Comments on redesigned paper flutes by the informants.

No.	Informants	Comments on redesigned paper flute
1	Julia	It has a well-tuned pitch, and the timbre is mellow and rich. It is probably a wooden flute.
2	Chen	This is Chen’s favourite flute. The timbre is richer than the others (wooden and metal flutes), and the sound is more stable.
3	Nica	It is a “real” plastic recorder. It is too common, so no impression of it in the first test.
4	Yuan	It sounds “natural”, like a bamboo flute, or at least the materials contained fewer plastic elements.
5	Anna	It is a standard Sopranino recorder, but the pitch is not so accurate.
6	Sandy	It is well-tuned, but the volume is small and limited. It sounds like a controllable flute, probably made of plastic rated 8/10.
7	Chan	It is a bronze recorder. The lower note is out of tune.
8	Wen	The sound is better than the plastic recorder.
9	Yong	It has a mellower timbre than the plastic recorder.
10	Amy	It has a mellower timbre than the plastic recorder.
11	Rick	It has a mellower timbre than the plastic recorder.

In these interviews, informants listened to the sound of the redesigned paper flute during the blind test. The sound quality was pleasant but also surprising to them. Therefore, they are confident with the paper flute as a mediator with the potential to trigger end-users’ ecological awareness of the plastic recorder industry. For instance, Chen and Yuan both regarded the resources of recycled and regular paper with suspicion but had changed opinions on the issue of paper material after they examined and experienced the redesigned paper flute. The paper flute inspires informants to look at the contrasting arguments against plastic recorders and consider their sustainability issues, and the worldwide-scaled education trend that defines plastic recorders as a necessary and mainstreamed teaching tool in a mandatory way.

In the blind tests, most informants found the sound quality of the redesigned paper flute was sonically appealing and musically acceptable. For some informants, the sound quality was aesthetically more pleasing than the plastic recorder. For this reason, we argue that acoustically and aesthetically, the redesigned paper flute has the potential to disrupt the dominance of the recorder industry and serve as an alternative to the plastic sopranino recorder.

Applying the Paper Flute to a Group of Elementary School Students

The following section is an observational record of the construction process of the redesigned paper flutes by 12 elementary school students (four females and eight males, all between nine- and ten- years old). The interactions between these students were observed and analysed. Therefore, the time spent on each making process was not recorded. Every individual mentioned was given an alias. We highlight in this stage of the research a "horizontal knowledge flow" created between the designer, end-user and paper flute. As outlined below, the design of the paper flute reserves a degree of flexibility for end-users to contemplate alternative ways of making connections between themselves and the instrument. This participatory design element helps motivate musicians to make an instrument that reflects their input and ideas.

During this study several students demonstrated talent in mathematics, music, drawing, cutting, and sealing. As a result, these individual talents helped bring the class together and make group progress. For instance, Willy drew a precise template in a short time and then started to help and teach other students to complete the templates. As other students explained to the first author, Willy excelled in mathematics, so he could assess and measure the template very precisely. Other students had learned this basic measurement skill in their regular mathematics class, but some students still had not mastered it and could not efficiently read the decimal places with accuracy. However, after Willy taught them one by one to count the scales on the ruler, they understood the measuring method and were able to read the scale and draw the template by themselves.

Willy also considered the ergonomics of the redesigned paper flute. He discussed with his fellow student Kenny that the last finger hole will probably not allow their pinkie finger to cover it because the finger holes are in a straight line. Excited to face a challenge, Willy began measuring to determine a better position for the last finger hole. Willy physically bent the template to put his fingers around it, marking the suitable position. Then, he drew the same finger hole but in a new position. He realised the relationship between the horizontal and vertical axis and understood that the finger hole can only be horizontally offset to maintain the pitch. The following figure shows Willy finding the best position for the last finger hole and his template (see Figure 11 and 12):

ISSN 2600-9366, eISSN 2600-9331

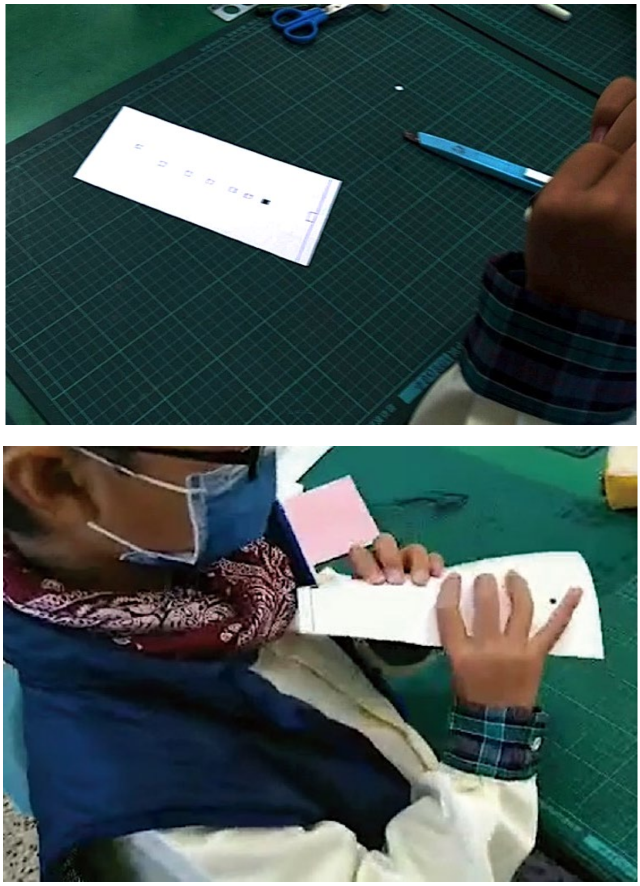


Figure 11 and 12. Willy redesigned, sketched, and trimmed the template finding a suitable position for last finger hole. Photo by the author.

Willy and Kenny agreed that the distance between the finger holes was too wide. Willy took out his alto recorder and measured the distance between finger holes. He found that his alto recorder required a larger distance than the redesigned paper flute. After Willy measured the alto recorder, he felt the finger hole distance on the redesigned paper flute was not actually an obstacle for playing and feels confident playing it.

In addition, Willy quickly realised the absence of a thumb hole on the paper flute may be a disadvantage. Although the first author explained to him that this design allows people to play an octave higher without a thumb hole, Willy believed that he could control the pitch better by using a thumb hole. Thus, he compared the redesigned paper flute with his alto recorder and found the relative thumb hole position for the first and second finger holes, and finally, he added a thumb hole to his flute.

Due to the efficiency of leading the class, and to ensure the students are safe when using a knife, they were required to consolidate assembly steps. The students were divided into Group A (four students who are afraid to use a knife), and Group B (eight students who are confident in using a knife). They sat together in two groups so the first author could ensure that they were safely when using the sharp knife. Meanwhile, he invited Group A to observe the template-cutting process of Group B. After Group B completed the trimming process, three students from Group A became confident and said that they would attempt to cut by themselves, only one of them was assisted by two students from Group B. Finally, they trimmed out the templates.

Only three students made the bore successfully the first time, and one student completed the bore the second time. Other students realised the difficulties of maintaining and sealing at the same time; thus, they asked for help. They stayed in a pair, one child held the paper rolled into shape the bore, and the other applied the tape to seal it. After the first author demonstrated the making process of the mouthpiece, the students made it successfully and started to make some sounds on their flutes. Figure 13 and 14 shows Emily and Aaron playing their flute:


Figure 13 and 14. Aaron and Emily playing the redesigned paper flute. Photo by the author

After some adjustments, ten students were able to successfully sound the flutes. Only Jacqueline and Patrick asked for the first author's help. He taught them to make a new mouthpiece. After some adjustment, they could also play some notes, and began to explore songs and music with the paper flute made by them. One thing we found interesting was kids were more careful using paper flutes because they realise that paper-made items are more delicate and not as strong as plastic items. While some students horse around with their plastic recorders pretending they are swords or other weapons in mock battles, and they use their paper flutes are treated much more delicately.

Making paper flutes is a learning-through-playing process for children. Informants like Julia, Chen, Yuan, Anna, Sandy, Chan, Ting, Amy, and Rick were quite confident that the redesigned paper flute would be suitable for children and as a teaching tool for learning music and acoustics. Through applying the redesigned paper flute to a class of 12 elementary students, we observed children like Willy and Kenny, were not only concerned with the paper flute itself, but were able to correlate its implications with the regular plastic recorder. They did this by comparing the structure of both instruments and thereby engaging with organological issues they might not have considered otherwise. Moreover, they were not only accepted the idea of the paper flute on its own terms, but they also examined its structure in an ergonomic way. They then redesigned a new individually adapted paper flute. At this moment, a horizontal knowledge flow was created between the designer, end-user, and paper flute. As mentioned previously, the design of the paper flute retains flexibility for end-users to explore the interaction flow between themselves and the instrument and encourages end-users to make an instrument that conforms to their creative ideas.

Most importantly, this group activity highlighted the value of cooperation and mutual aid in instrument making while constructing the redesigned paper flute. Children are often excited to voluntarily help each other to complete to share knowledge, exchange ideas and assess problems. Therefore, we argue the redesigned paper flute achieves an eco-organological objective that strikes a balance between usability and playability while targeting the challenge of environmental awareness by avoiding ready-made plastic instruments in favour of pedagogically engaging self-constructed instruments that are fun and playful.

Conclusion

Paper flutes and eco-organology as applied to the "recorder-scape", attempt to disrupt the current hyper-market driven plastic recorder industry in Taiwan. However, this disruption is only a minor first step at raising awareness and inspiring much needed debate on the contrasting arguments for and against plastic recorders, as well as to consider sustainability issues. Through reviewing existing literature and conducting interviews with informants, the plastic recorder was scrutinised as a ubiquitous item due to the power structures and commercial reasons behind the compulsory education system in Taiwan.

Informants' responses in this study show a paper flute as a mediator has the potential to trigger end-users' ecological awareness of the plastic recorder industry. For instance, Chen and Yuan both had opposing opinions on the issue of paper material after they examined and experienced the redesigned paper flute and recycled and regular paper resources were regarded with suspicion. In addition, the low-status people give plastic recorders is one of the factors affecting its waste, and loss of value as a musical instrument. As musicians and educators, Sandy, and Chan both defend the values of the plastic recorder, and do not regard it as a dispensable item. They hold the view that as long as people play recorders, and extend its life, plastic recorders will not be harmful to the environment. Julia and Chen both hold similar views with Sandy and Chan. Their experiences not only present the view of former junior recorder performers, but also represent the views of recorder enthusiasts who see the plastic recorder as a meaningful and invaluable instrument.

On the one hand, an abandoned and forgotten plastic recorder does not pollute the environment so long as it does not get thrown away. On the other hand, if the demand exists, Yamaha and Aulos factories will continue production with mould-injection machines. What is clear is that the phenomenon of plastic recorders as a dispensable item still exists. Chen suggested collecting the recorders from students and reusing or using or recycle them. Yuan suggested manufacturing recorders with recyclable materials, and to donate our plastic recorder to family members. Summer who is only 10 years old was also aware of the ecological issues of plastic. He simply suggested to stop using plastic recorders altogether.

One of the reasons informants have confidence in paper flutes as an alternative to mass-produced plastic instruments, is the satisfactory performance of the redesigned paper flute. The results of blind tests show the indistinguishable sound of the redesigned paper flute compared to a plastic recorder. Nica, Chen, Anna, Ting, Dong, Yong, Amy, and Rick could not distinguish between the redesigned paper flute and other fipple flutes. In terms of musical aesthetics, Wen preferred the redesigned paper flute over plastic recorder, because the former has a "warmer and more tender" voice.

In terms of applicability, the redesigned paper flute as an engaging and assessable self-made instrument is readily available as a downloadable template for communities such as elementary schools. By introducing the redesigned paper flute to these communities in Taiwan, their awareness may be raised about environmental issues occurring in the plastic recorder industry. Understanding the diversity of musical instrument materials against standardised instruments, and the possibility of self-constructing paper flutes rather than buying a factory-made recorder, helps consumers realise the mutual and interdependent relationship between industry, environment, society, its education system, and alternative instruments designed with eco-organology in mind.

Endnotes

[1] Yamaha and Fender both face material shortage issues. However, according to the "Yamaha Supplier CSR Code of Conduct" and "Yamaha Group Timber Procurement Policy", Yamaha strikes the balance between instrument purposes and environmental concern by investing in African Blackwood in Tanzania and signing an agreement with the Okhotsk General Sub Prefectural Bureau and the town of Engaru, Monbetsu-gun, Hokkaido. Yamaha maintains the supply chain of timbers and avoids the reduction of specific timbers. However, the way Yamaha practices the idea of sustainability is just a temporary solution because they still insist on the use of specific woods, rather than a variety of choices. An official Fender statement proclaims they are transitioning most of their Mexico-made products away from rosewood to pau ferro for their SRV signature Stratocaster and transitioning to ebony for their American Elite series. However, they are still using Rosewood as their main fretboard material due to the "historical accuracy" argument.

[2] The ecological construction process of a tradition-inspired djembe percussion instruments was studied by Chen, Kuang-Jih (Chen, 2016). He advocates using multi-plank instead of lathe-turning one-piece logwood to replicate the Mandinka djembe drum, particularly his four principles of making djembe: reducing waste, using multi-materials, timbre heterogeneity, using recovered wood when possible. Chang, Chia-Yin (Chang, 2012) focuses on the environmentally friendly *huqin* instruments (胡琴; a family of Chinese bowed fiddles) of Hong Kong Chinese Orchestra (HKCO). HKCO and other makers developed synthetic leather *huqin* because of the inadequate supply of python, and unethically, even some makers tried dog, fish, or other animal skin.

[3] GSM (grams per square metre) is the paper weight and thickness unit.

[4] "Hänschen klein" (Little Hans) is a German folk song composed by Franz Wiedemann in 1899. For the Sinophone the melody is well recognised as *xiaomifeng* (little bee).

References

Allen, A. S. (2013). Ecomusicology. In C.H. Garrett (Eds.), *The Grove Dictionary of American Music* (pp. 80-81). Oxford University Press.

Allen, A. S. & Dawe, K. (2016). Ecomusicologies. In A.S. Allen & K. Dawe (Eds *Current directions in ecomusicology: Music, culture, nature* (pp. 1-15). Routledge.

Bateson, G. (1979). *Mind and nature: A necessary unity*. Dutton.

Boyle, W. A. & Waterman, E. (2016). The ecology of musical performance: Towards a robust methodology. In A.S. Allen & K. Dawe (Eds.), *Current directions in ecomusicology: Music, culture, nature* (pp. 25-39). Routledge.

Bucur, V. (2019). *Handbook of materials for wind musical instruments.* Springer.

Chang, C. Y. (2012). 胡琴類樂器改革的探究-以香港中樂團環保胡琴為例 [Research on the reform of huqin instruments: Taking the Hong Kong Chinese orchestra's environmentally friendly huqin as an example], [Master's thesis, Tainan National University of the Arts]. https://hdl.handle.net/11296/vbs8t3

Chen, K. J. (2016). 環保概念多板合成Djembe之設計與製作 [Design and production of environmentally friendly concept multi-board synthetic Djembe], [Master's thesis, Tainan National University of the Arts]. https://hdl.handle.net/11296/98fw3s

Cho, A. (2014). Elite violinists fail to distinguish legendary violins from modern fiddles. *Science*. https://www.science.org/content/article/elite-violinists-fail-distinguish-legendary-violins-modern-fiddles

Cho, A. (2017). Million-dollar Strads fall to modern violins in blind 'sound check'. *Science*. https://www.science.org/content/article/million-dollar-strads-fall-modern-violins-blind-sound-check

Coglianese, C. (2001). Social movements, law, and society: The institutionalization of the environmental movement. *University of Pennsylvania Law Review, 150*(1), 85-118. http://dx.doi.org/10.2139/ssrn.297161

Dawe, K. (2016). Materials matter: Towards a political ecology of musical instrument making. In A.S. Allen & K. Dawe (Eds.), *Current directions in ecomusicology: Music, culture, nature* (pp. 109-121). Routledge.

Devine, K. (2015). Decomposed: A political ecology of music. *Popular Music, 34*(3), pp.367-389. https://www.jstor.org/stable/24736940

Eisley, L. (1969). *The unexpected universe*. Harcourt, Brace & World.

Feld, S. (1996). Waterfalls of song: An acoustemology of place resounding in Bosavi, Papua New Guinea. In S. Feld & K. H. Basso (Eds.), *Senses of place* (pp. 91-135). School for Advanced Research Press.

Foster, L. (2019, October 21). Plastic bags were invented to help save the planet. *Newsround. BBC*. https://www.bbc.co.uk/newsround/50094813

Guy, N. (2009). Flowing down Taiwan's Tamsui river: Towards an ecomusicology of the environmental imagination. *Ethnomusicology, 53*(2), 218-248. https://www.jstor.org/stable/25653067

Hood, M. M. (2013). Musical invasives: Ecology and the forces of diatonicization in Balinese music. In The 2nd Symposium of the ICTM Study Group on Performing Arts of Southeast Asia Proceedings (pp.235-239). Philippine Women's University.

Hood, M. M. (2014). Bamboo bridges: Vocality and human temporality in Balinese flute playing. *Musica Journal, 9,* 22-34. https://journals.upd.edu.ph/index.php/musika/article/download/5197/4668

Interaction Design Foundation (n.d.). Keep It Simple, Stupid (KISS). https://www.interaction-design.org/literature/topics/keep-it-simple-stupid

Jef. (2017, May 19). Fender officially stopping rosewood guitars and basses this summer! The

CITES regulation are now kicking in fast! *Gear News*. https://www.gearnews.com/fender-officially-stopping-rosewood-guitars-basses-summer/

Lin, S. F. (2005). 直笛音樂教育在臺灣之引進與發展 [The introduction and development of recorder music education in Taiwan]. *教師之友 [Journal of Professional Teachers]46*(4), 64-72.

Oleg. (n.d.). Welcome to our alto sax audio lab. *Oleg products*. https://olegproducts.com/alto-saxophone-audio-lab/

Rifkin, J. (2011). *The third industrial revolution: How lateral power is transforming energy, the economy, and the world.* Palgrave Macmillan.

Titon, J. T. (2013). The nature of ecomusicology. *Música e Cultura, 8*(1), 8-18. https://www.academia.edu/5517860/The_Nature_of_Ecomusicology_2013_

Widholm, G., Linortner, R., Kausel, W., & Bertsch, M.A. (2001). Silver, gold, platinum – and the sound of the flute. *Research Gate*. https://www.researchgate.net/publication/228488924_Silver_gold_platinum-and_the_sound_of_the_flute

Whiteley, N. (2016). *Design for society*. In W.-L. You, M.-Y. Yang, Y.-Y. Li, (Trans.). Lianjing Publishing Co., Ltd.

Yamaha. (n.d.). Sustainable resource use. *Yamaha*. https://www.yamaha.com/en/csr/environment/sustainable_resource_use/

志祺七七. (2023, January 7). 學校的音樂課，真的學得到東西嗎？是誰規定音樂課要學直笛的？《蛤Huh?》EP3｜志祺七七 [Do you really learn anything from music class at school? Who decided that music class should learn the recorder? “Huh?” EP3 | Shasha 77] [Video]. YouTube. Retrieved January 25, 2023, from https://www.youtube.com/watch?v=o59n1goiwEs&t=160s

Tseng, H. W. (2006). *論直笛移入台灣音樂教育體系後的發展與適應—以中壢地區三所國小之觀察為例* [The development and adaptation of recorder in Taiwan since moving into the music educational system: Observations of three elementary schools in Chung Li as examples], [Master's thesis, Taipei National University of the Arts]. https://hdl.handle.net/11296/tca646

Wu, M. C. (2004). *木笛一百問* [Questions about the recorder]. 小神笛出版社 [Xiao Shen Di Publisher].

Wu, R. G. (1990). 台灣省第一屆直笛比賽記實 [Records of the first recorder competition in Taiwan province]. *音樂教育月刊 [The Music Education] 17*, 26-35.

Xu, Y. Q. (1989). *中日音樂教學之比較研究* [A comparative study of music teaching in China and Japan]. Chuan Yin Music Publishers.

Biographies

Ching-Jie Kang (CJ Artecent) is the art director and musical instrument designer of Before Watt. He is currently enrolled in the Ph.D. program at National Cheng Kung University's Institute of Creative Industries Design in Taiwan. He earned a Master of Arts in Ethnomusicology from Tainan National University of the Arts. Prior to this, he served as a research and development engineer for a musical instrument company in Taiwan and as a music instructor at Amber Contemporary Music Academy in Malaysia. His artworks were exhibited and performed at the National Theatre and Concert Hall, the National Taiwan Museum, the

ISSN 2600-9366, eISSN 2600-9331

Taiwan International Festival of Arts, the Tainan International Music Festival, the Taiwan Contemporary Culture Lab, the Tainan City Traditional Orchestra, and the Ministry of Labour.

Made Mantle Hood is professor of ethnomusicology, Chair of the Graduate Institute of Ethnomusicology and Director of the Asia-Pacific Music Research Centre at the Tainan National University of the Arts, Taiwan. He serves as Chair (2021-2025) of the ICTM PASEA study group. His previous posts were at Universiti Putra Malaysia (2012–2018), Melbourne University, Australia (2011–2012) and Monash University, Australia (2005–2011). His current research interests include ontologies of sounded movement, endangered forms of vocalisation, tuning systems as well as music and social justice. He is currently the lead researcher in the Taiwan Ministry of Science and Technology-funded project, 'Decolonializing Indonesian and Philippine Indigenous Performing Arts' (2022–2024). He is the author of Triguna: A Hindu-Balinese philosophy for gamelan gong gede music (2010) and co-editor of Music: Ethics and the community (2015).