

# Design beyond 'us vs them'

*How can developing  
world constraints inspire  
and drive design innovation  
at a global scale?*

*Case study: Neonatal  
Resuscitation Device*



Auckland University of Technology

Master of Art & Design 2012

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## Abstract

Design has a social agenda. It is clear that we have the responsibility to help those who are in need, but it is also vital to redefine what meaningful prosperity is for us. Most of the designers dedicate their time and energy to developing products and systems solely for the wealthy 10% of the world's population. Nothing less than a paradigm shift is required for design to include the other 90%. What we need more than ever is design inspired by commonality not by difference. There is no reason why designers cannot design for the underserved population while tending the needs of our own communities. Design can create opportunities for bridging markets and creating unexpected partnerships that will result in shared investments, capital, and benefits.

According to the World Health Organization, nearly one million babies die each year due to birth difficulties. With proper training and equipment, many of newborn fatalities due to breathing complications could be avoided. Neonatal resuscitation is commenced to assist the newborn's first breath. However, because of the lack of proper training, expensive equipment and under staffing, hospitals and communities in developing countries struggle to perform effective resuscitation. Meanwhile, in developed countries, home birth scenarios require midwives to be fully prepared with standard resuscitation equipment. There is a demand for a low-cost, highly portable and reliable resuscitation device globally.

This research project applied user-centred design principles to enhance the experience and effectiveness of neonatal resuscitation for inexperienced rescuers in both the developing and developed world context. The practice acts as a tool to explore the notion of using Third World constraints as innovation drivers for the whole World.

Designing for the Third world often means a ruthless pursue of affordability, accessibility and reliability. Products and systems must be low cost, low maintenance, intuitive to use and highly reliable to meet users' needs. These constraints forces designers to think outside the box and often lead to highly creative solutions, which largely impact people's health and well-being.



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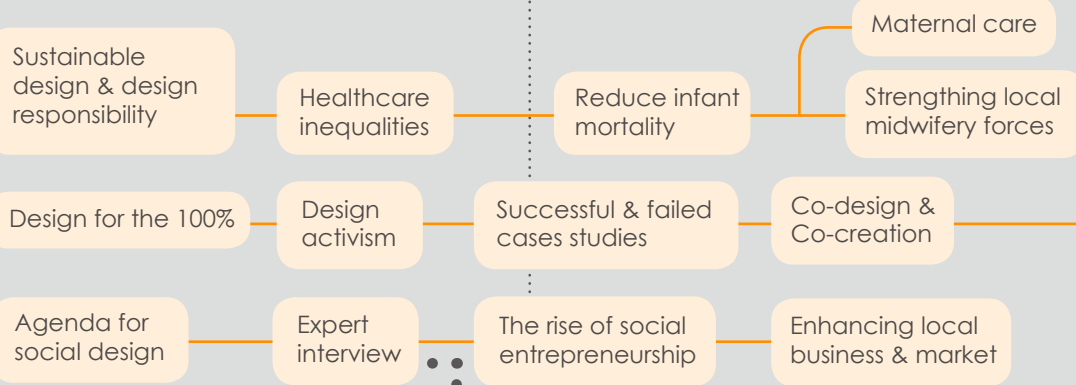
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Theory

Developing world constrains as innovation drivers for global challenges



Impact over function

A brave new business model

Personal journey & reflection

Exploration phase reflection

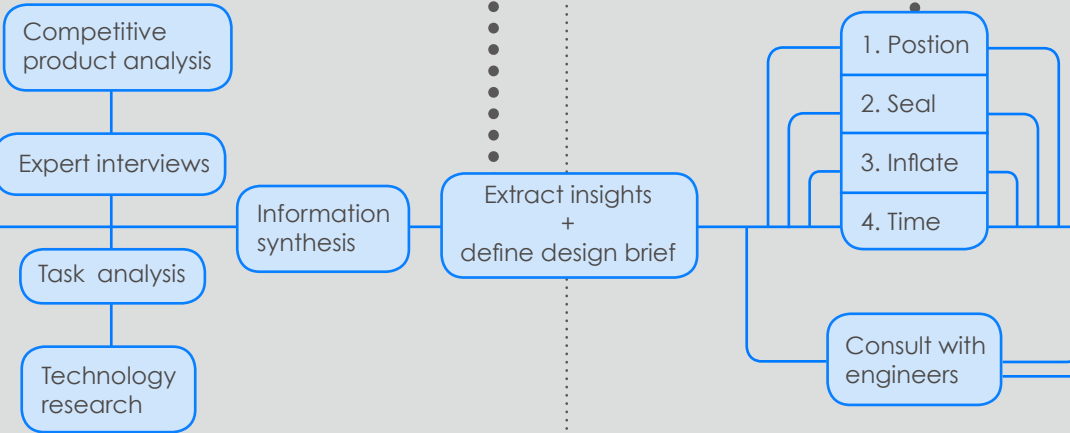
Concept phase reflection

Development phase reflection

Process reflection + Personal learning

Practice

Design and validate a low-cost, highly intuitive neonatal resuscitator to empower inexperienced rescuers



User feedback

Form exploration

Valve design

Suction v.s Inflation

Manufacture design

Scientific validation

Design refinement

Field test

Project map

# + Introduction

Sustainability can be defined as a balance between ecological stability, social equity and economic viability. Nowadays, sustainable design often address the ecological factors of products and systems while leaving the social and economic factors unregarded.

Healthcare inequality in developing countries is directly linked to the unsustainable social and economic development (Wilkinson, 2009). This results in a high child mortality rate. In fact, one of the Millennium Development Goals published by the United Nations is to reduce by two-thirds the mortality rate among children under five by 2015 (Bruntland Report, 1987).

Birth asphyxia is one of the main causes of high child mortality rate in developing countries. It occurs when the newborn is deprived of an adequate supply of oxygen. Worldwide approximately 1 in 10 newborns have breathing difficulties at birth and require some assistance in order to breathe. 60% births happened at home and is often attended by a female relative or unskilled traditional midwife. In most cases, mouth-to-mouth resuscitation is carried out if needed. This can lead to cross-contamination (Coffey, 2011).

Neonatal resuscitator is a simple and essential medical device designed to assist the suffocating newborns to take their first breath (Picture on the right shows how neonatal resuscitation is executed in a modern hospital environment). However, due to the lack of knowledge and experience; traditional midwives often failed to achieve adequate ventilation or in some cases over-inflate newborn's lung causing fatal damage and complications. Such simple life-saving device should be intuitive to use and further empower the rescuers to commence effective neonatal resuscitation (Path, 2008). Educating and training these inexperienced birth attendants is also critical for sustaining the accuracy and effectiveness of neonatal resuscitation. In the developed countries, more and more parents prefer birth at home. Midwives often have to gear up and carry numerous resuscitation equipment with them in order to be fully prepared for home birth scenarios.

This project explores how developing world constraints can be utilised to develop highly innovative interventions for both environment and benefit different groups of users by creating unexpected partnership and opportunities.

### Mission Statement

Using user-centred approach to design and validate a low-cost, highly reliable resuscitation device which will be used in developing world context while tending to the needs of communities in developed nations.

### Project Objectives

- 1. To demonstrate that design can bring health and well-being while enabling users to help and grow themselves.
- 2. To use developing world settings and constraints as innovation drivers for the developed world.

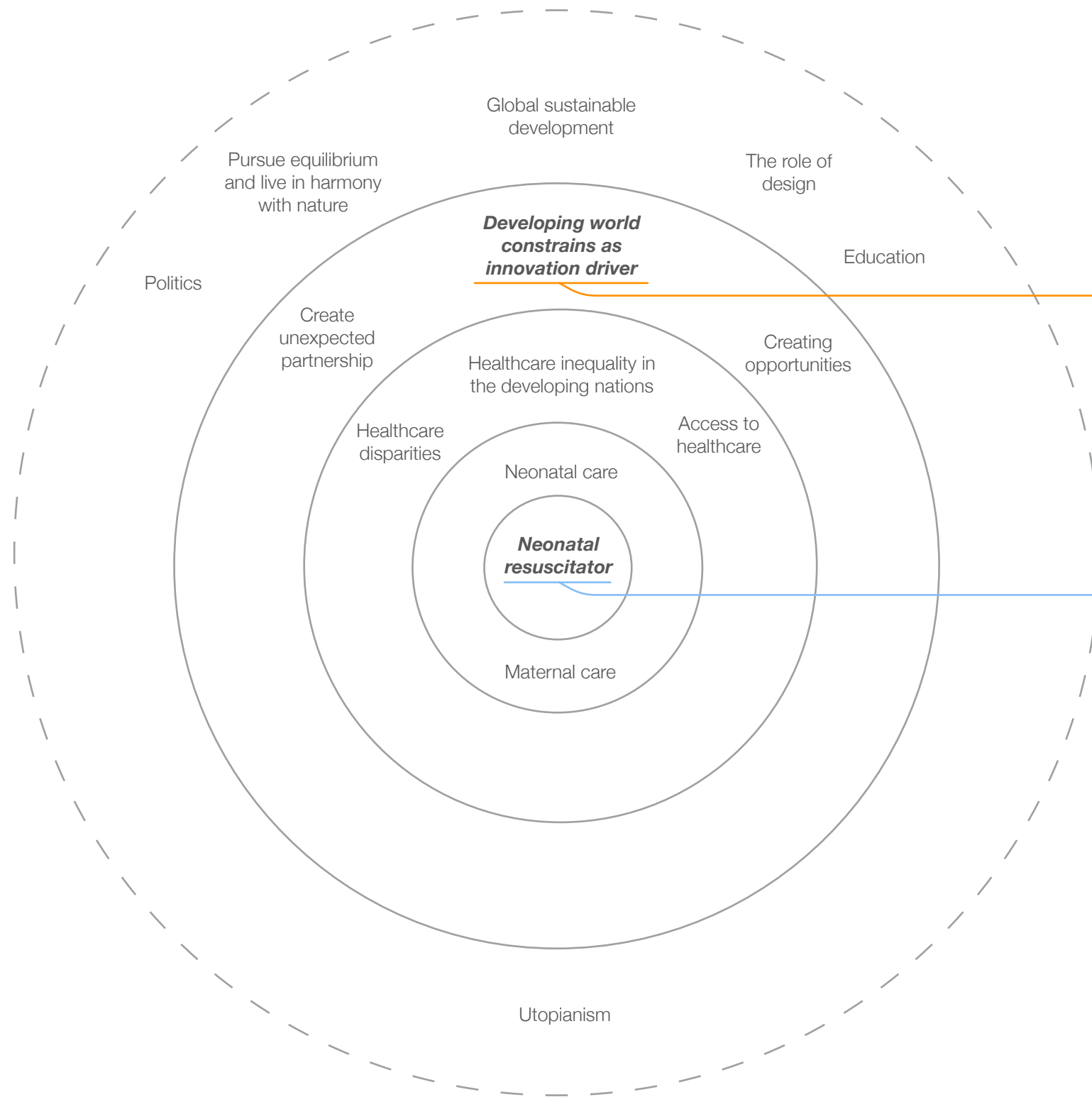
### Personal Objectives

- 1. To gain a deeper understanding of designing to include the other 90%.
- 2. To understand what my role is as a designer and how I can contribute to carry out a more responsible and sustainable future.
- 3. To reflect on the what I learned from the past 5 years and clarify my core design values.
- 4. To develop and demonstrate efficient time management skills.

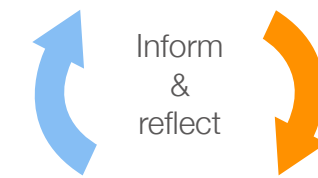


**1** in 10 babies require resuscitation at birth.





Embrace and utilise developing world constraints as innovation driver for the developed world.



Design and validate a low-cost, highly intuitive neonatal resuscitation device for varies home birth scenarios.

## + Nature of project

The nature of this research project is highly complex and multidimensional. A series of prototyping and user testing were carried out to validate the neonatal resuscitator design. The outcome interrogated the research question, 'How can developing world constraints inspire and drive design innovation at a global scale?' and the role of design in bridging markets and creating positive social and economic impact.



# + Methodology & Frameworks

## Research paradigms

- **Positivism & Interpretivism** - The nature of this research project is multidimensional. In order to design and validate a functional resuscitation device while explore the wider context of using developing world constraints as innovation drivers, multiple research philosophies are required.

Positivism, a philosophy based on scientific observation (Gray, 2009), was chosen to tackle the empirical aspect of this research project, this involved designing and validating the humidification system and technology. This deductive approach focuses on quantitative measures and went through four sequential stages: proposing a theory, hypothesis testing, observation recording, and evaluating data. The results then determine if the proposed theory needs further modification (Collins, 2010).

Interpretivism refers to understanding “the world as it is experienced and made meaningful by human beings” (Collins, 2010). The exploration and understanding of the broader social context of this research paper falls under this philosophy. Interpretivism uses inductive approach and relies on qualitative data (O'Brien, 2001). A combination of deductive and inductive research approaches were used in order to gain an in-depth understanding of the research topic and extract key insights to drive the creative design process.

## Experimental & Action research

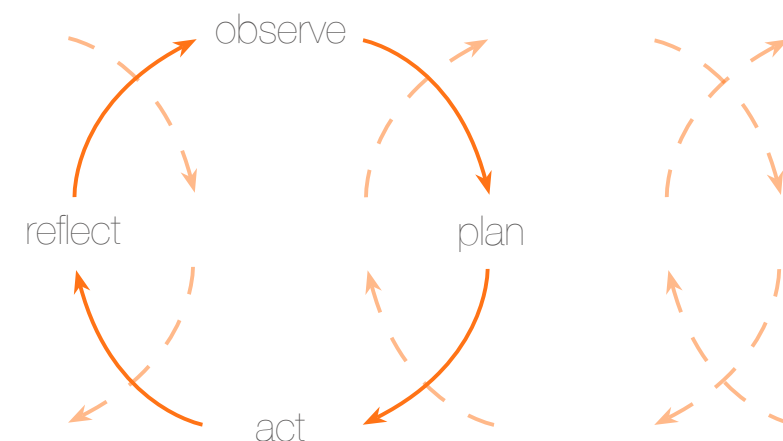
To ensure a successful outcome two major methodologies were applied - experimental and action research.

Experimental research (also known as, true experimentation) involves manipulating one or more variables while observing and measuring changes to the other variables (Experiment-Resources.com, 2008). The aim of this strategy was to understand the relationship between different variables (i.e. air pressure vs. material structure) in a neonatal resuscitation device.

Action research bridges the gap between research and practice. It is primarily involved with identifying issues or opportunities for change through research and actually making an impact through practice (Somekh, 1995). Not only

did this strategy help me understand the value of Third World constraints from the exploration phase but also allowed me to make a difference by designing intervention/s which potentially may improve the well-being of all users and stakeholders.

Action research is a cylindrical or spiral mode of action, which begins with planning how to implement intervention/s (supported by comprehensive research). The plan is then carried out, observed and reflected. The reflection is then fed into the next cycle (Kemmis, 1983).



## Research methods

- **Literature review** - A well-structured body of text that summarises the theoretical and methodological contribution of the research topic. The review act as a secondary source for the researcher to understand the current study and accomplishment (Collins, 2010). Synthesizing information from books, journal articles or dissertations then critically analyse and identifying any information gap for further interrogation is the core purpose of a literature review (Manalo & Trafford, 2004).

In this research project, a literature review has been used to understand and examine the philosophy of Design Activism & Design for social change. Victor Papanek, Alastair Fuad-Luke and Emily Pilloton are experts and writers that provides in-depth insight and wisdom regarding empowerment design and social responsibility of design.

- **Expert interviews** - A series of semi-structured interviews with experienced and knowledgeable researchers / practitioners were undertaken to gain key insight on a specific research topic. Dialogues with skillful midwives, nurses and pediatricians really unravel the current issues and concerns with neonatal resuscitation in both developing and developed world scenarios.

- **Character profiles** - is about bringing typical customers or users to life by listing out their background and experiences (IDEO, 2002). Based on literature review, expert interviews and onsite observation, three generalised character profiles were generated to provide a clear understanding of users' behaviours, life styles and values. These profiles direct and drove the design process throughout the project.

- **Competitive product survey** - Identifying direct and indirect competition and comparing product characteristics are the focuses of this survey. Functionality, usability and emotionality of different designs are compared and evaluated. This is a useful method to recognise existing resuscitation technology, establish functionality requirements and understand user expectations (IDEO, 2002). The survey also revealed potential market gaps and unpacked the unmet need of current users.

- **Cognitive task analysis** - is about documenting every tasks, actions, objects and performers involved in a process. Cognitive task analysis adds in the observation of performers' sensory input, decision point of within each tasks and actions. By observing and noting down each stage of resuscitation procedure, in-depth insights are gained through understanding users' perceptions, attentions and needs. Opportunities for product / system improvement rises throughout the analysis.

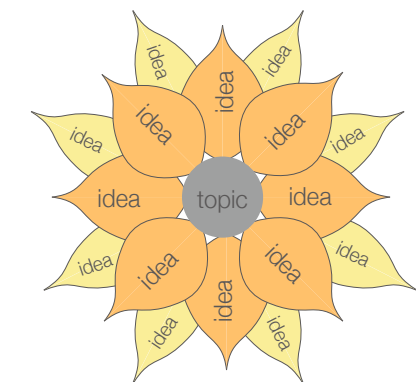
## Design methods

- **Mindmapping** - This method is used to recall existing knowledge on a subject. A diagram is utilised to represent ideas, tasks, or other information linked to and arranged around a central key word or idea.

Mind maps are used to generate visualised ideas and classify them (De Bono, 2006). In order to organise the gathered information regarding Third world constraints and resuscitation devices a word diagram is generated.

- **Lotus blossom** - This method is developed by Yasuo Mattsumura for the purpose of generating multiplicity of ideas.

It is a highly visual way to create and organise a large variety of alternative concepts around the proposed topics. Ideas bloom from the central topic like the unfolding of lotus petals when it blossom. A group of students, designers, and potential users were gathered to carry out this method. It is an extremely effective way to trigger ideas and encourage constructive discussions.



- **Concept ideation** - translates potential ideas generated by lotus blossom into sketches and drawings. This method helped support and facilitate design process and continued to stimulate the flow of concept generation.

An A4 sketch book was used to convert thoughts/ideas into 2D illustrations. It is a pragmatic tool for communicating ideals with potential users and note down feedbacks and enquiries for further development.

- **3D prototyping** - This technique is used vigorously throughout the design process. It usually operates in two levels. The initial stage was quick-and-dirty followed by refined and detailed modeling. Rough prototypes of the resuscitator allows users interaction and evaluation which leads to concept refinement.

- **CAD** - Solidworks is the main program used for resolving the finalised concept. This tool should be used during concept detailing phase rather than concept ideation phase. Inappropriate usage of this method may conflict with the creativity flow of design process by narrowing possible solutions and form too early. CAD is useful for producing accurate mold for prototyping (i.e face mask and pressure relief valve).



## Frameworks

- **Inclusive Design** - The origin of this concept emerged from 'barrier-free' and 'universal' design. It is built on the early principles of designing to include the disabled for accessing the built environment (Coleman, 2007). The definition of this highly complex framework continuous to evolve and extend. Inclusive design has been expanding its shelter to embrace different races, education, income, culture etc... This overarching theme relies on a comprehensive understanding of responsibilities, of those who design and developed the material world in relationship, to those who live in it (Coleman, 2007).

*"We believe that applying an inclusive design approach is good for business as well as for customers. We are proud of our reputation for developing products which can be used by all our customers, regardless of age or ability" (BT Inclusive Design Toolkit)*

Design to include the marginalised population has been my interest of study since my honours year. In 2011, I explored the relationship between design and social impact in the developing world through the case study of developing a humidification system for a low-cost, highly reliable infant incubator.

This year, I attempted to explore the underlying relationship between developing and developed world while using inclusive design as a tool to create exceptional partnerships and foster collaborative relationships.

- **Participatory Design** - Design with, rather than design for, the target users is a more socially responsible way to develop appropriate technologies, products, or infrastructures for a specific context or scenarios (Berger, 2009).

It is our role as a designer to actively engage with users and encourage them to contribute during this co-design process. The fundamental premise of participatory design is to acknowledge that people have the right to take part in the design process (Berger, 2009). The diagram on the right shows that the overlapping area of professional and public realm in the notion of collaborative innovation. This is where participatory design methods is utilised to increase the resilience and desirability of the outcome.

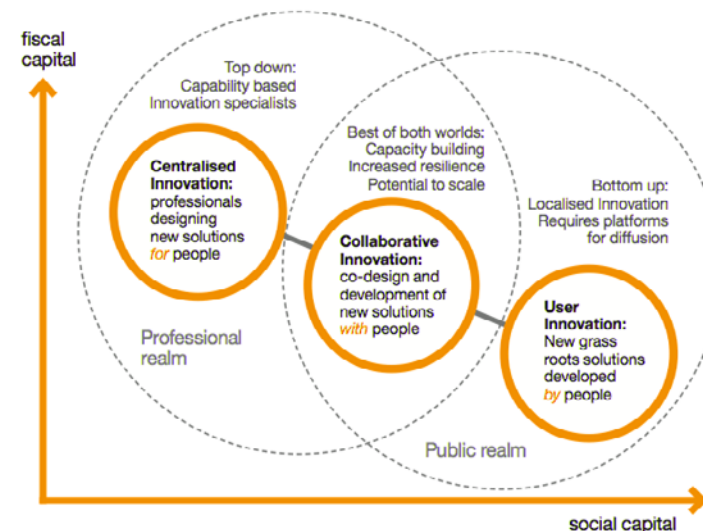
I had facilitated feedback sessions to involve midwives (both experienced and inexperienced) and pediatricians into the design process of neonatal resuscitation device.

*Simplicity is the ultimate sophistication"*

*-Leonardo Da Vinci*

- **Minimalism** - Minimalist design is about simplicity and purity in form, features, or concepts. Capturing the essence of 'doing more with less', Companies such as Muji and Apple advocates minimalism as their product design style. By eliminating unnecessary elements of a design, the object itself projects honesty and clarity (Bertoni, 2004).

Nowadays, healthcare products are usually highly engineered with complex features and forms. The practical aspect of this project aimed to tackle medical product design in a minimal and humanistic way. Neonatal resuscitator is a simple yet complex life-saving device. It is simple in terms of its functions but complex in terms of minimising human error and maximising comfort and usability.





# 1.0 Exploration phase

- 1.1 Literature review
- 1.2 Expert interviews
- 1.3 Character profiles
- 1.4 Competitive product survey
- 1.5 Cognitive task analysis
- 1.6 Key insights
- 1.7 Design brief



# 1.1 Literature review

## Designing for the 100%

Most of the world's designers dedicate their time and energy on developing artifacts and infrastructures solely for the wealthy 10% of the world's population. Nothing less than a paradigm shift is required for design to include the other 90% (Copper-Hewitt, 2007). The dotted area represents opportunities for bridging markets and creating unexpected partnerships that will result in shared investments, capital, and benefits (Pilloton, 2009). Designing at a global scale means embracing the difference between people, culture, environment etc...The challenge is to design for everyone and create a win-win situation.

What we need more than ever is inspiration through unity not difference. In order to create greater impacts we must go beyond the mentality of 'us vs. them'. Design thinking should not only support the growth and economic empowerment of the developing world but also tending the needs of our own communities. Pilloton (2009) stressed that her organization recognize that their work for the under-served population is not charity. They understand that these people are an integral part of the global future. By designing feasible, life-improving interventions, they believe is the humanitarian way to catalyse economy and breeds prosperity (Pilloton, 2009).



fig 1.1 - 'Don't ignore me', Unicef ad tells the story of 1.5 million underprivileged children in China.

## Embracing constraints

In order to think outside the box you need to make the box first. Before solving a problem, one has to thoroughly understand the core of the problem and everything that relates to it. But without setting constraints and specifications the process of problem solving can be difficult and exhausting.

Extreme constraints push designers to seek new ways of utilising inexpensive material and manufacture process. These

limitations or restrictions can lead to radical innovation of tackling severe problems. For example, 'Designing a laptop for kids in the developing world. It cannot cost more than \$150. But the parts along cost more than that.' or 'There is a high percentage of elders taking wrong medicine by mistake. They simply cannot read the labels. What can be done?'

Izhar Gafni, a bike enthusiast, designed a cardboard bike that cost \$9 to \$12 US dollar to manufacture. He quoted "When we were told it's impossible, than we know it's the right way to be done." (Berger, 2009). He pursued a seemingly impossible goal but the result is astonishing and rewarding.

Constraints sometimes can make designers' life difficult but on the other hand, too much freedom can be the worst constraints because without boundaries designers tend to get lost and lose site of purposes and goals.

Design that does "more with less" is needed more than ever in today's world. So where is the more in "more with less"? The more is "more of the organization." Actually, all of it (the entire pipeline actually). When considering how to do less, one must optimize the whole – consider the entire value stream. Look for waste, root it out (Berger, 2009). Doing so will typically require/ result in improving quality and lowering waste.

We can learn how to embrace constraints from Mother nature. Through millions of years of trials and errors, nature had designed and developed solutions dealing with survival constraints. Designers can be inspired by and mimic nature's way of making things more efficient and sustainable. This is Biomimicry. Benyus (Ask Nature, 2008) suggests that at the beginning of a project designers should ask themselves, "What in the nature world is already doing what I'm trying to do?". The chances are several solutions already existed.

## Design activism

Design activism has emerged in recent years as a term to denote creative practices that invoke social, political and environmental agency. Typically, it distances itself from commercial or mainstream public policy-driven approaches. Instead, it embraces marginal, non-profit or politically engaged design theories, articulations and actions (Fuad-Luke, 2009).

Design activists are often motivated by a strong sense of altruism and morality, aimed to create positive social and environmental changes for the greater good (Fuad-Luke, 2009).

## Birth asphyxia

Every year, 940,000 die of intrapartum-related neonatal deaths (also known as "birth asphyxia"), 99% in developing countries without medical assistance, according to the World Health Organization (WHO). Birth asphyxia is one of the primary cause of early neonatal mortality. It is a global challenge.

Asphyxia means lack of oxygen. Birth asphyxia is a medical condition when newborns' brain or other organs are deprived of adequate supply of oxygen and failed to establish regular breathing (Lawn, 2007).

Some causes of birth asphyxia may include:

- Too little oxygen in the mother's blood before or during birth.
- Very long or difficult delivery.
- Problems with the umbilical cord during delivery.
- A serious infection in the mother or baby.
- High or low blood pressure in the mother.
- Baby's airway is not formed properly.
- Baby's airway is blocked.
- The baby's blood cells cannot carry enough oxygen.

Once the baby is diagnosed with birth asphyxia, neonatal resuscitation should be carried out immediately with a bag-valve-mask or equivalent device. Newborns often respond quickly to adequate ventilation. Few of them require chest compression or pharmaceutical administration (Casalaz, 1998).

## Neonatal resuscitation in low-resource settings

Neonatal resuscitation is a relatively simple procedure, however, due to a lack of knowledge and training newborn and maternal care, most of the developing countries failed to establish a system to address the emergency need of newborns. If some of the rural settings, neonatal resuscitation is literally non-existence or inappropriately practiced. With appropriate interventions these problems can be solved. However, barriers such as conflict between traditional and modern medicine, lack of human resource and infrastructures, need to be well considered in order to create a long-lasting, positive impact in these resource-limited areas (Coffey, 2007).

Physical distance and financial constraints were two major reasons that prevented communities from accessing trained midwives. Traditional birth attendants/midwives and home delivery were highly preferable. These healthcare providers are often the only healthcare resource in these communities (Titaley, 2010). It is crucial to educate and strengthen these traditional midwives in order to achieve adequate prenatal (during labour) and postnatal (after birth) care in remote areas.

Studies reported that users in low-resource settings have a clear preference for the bag and mask device over the tube and mask device, due to its ease of use (Path, 2008). A few users prefer the tube and mask device because of it's simplicity and protability. Both device are considered difficult to clean and maintain in low-resource settings. The complex inner components of the device is difficult to access for cleaning.

A well-known program called Helping Babies Breathe (HBB) aimed to improve birth rates and decrease neonatal mortality rate in developing countries. It is an initiative of the American Academy of Pediatrics (AAP) in collaboration with the World Health Organization (WHO), US Agency for International Development (USAID), Saving Newborn Lives, the National Institute of Child Health and Development, and a number of other global health organisations (Korioth, 2010).

They advocate the importance of seizing the 'golden minute' after birth. The first 60 second after birth can mean life or death for the newborn. They developed a series of comprehensive training solutions and implementation guide which were adopted in many developing countries and had profound impacts (Korioth, 2010).



fig 1.2 - Helping Babies Breathe programme in South-Africa



## 1.2 Expert interviews

### Semi-structured interview questions

- > Is oxygen source necessary during neonatal resuscitation?
- > When is chest compression required?
- > What are the key factors for effective resuscitation?
- > What are the core issues of neonatal resuscitation in rural settings?
- > What are the existing strategies to deal with such burden?
- > What are the common mistakes during resuscitation?
- > Are there any cultural barriers to implementing medical training programs?
- > How is the equipment maintained?
- > In your opinion, is single-use or multi-use inflation bag more suitable for low-income settings?
- > How can current equipment be improved?



fig 1.3 - Normal v.s over-distended alveoli

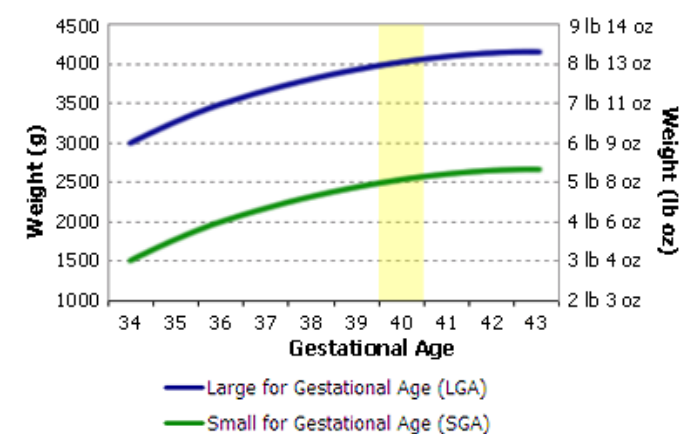


fig 1.4 - Birth weight and gestational age



### Midwives

Diane Hirst  
RGON RM, BHSc (Midwifery)  
Post Grad Dip (Health Prof Ed.)

Diane spent six years in the middle east as a midwife, helping Arabic women give birth. She also worked in Northshore Hospital as a midwife advisor and then went on to become a midwifery lecturer in Auckland University of Technology. Her aim is to help every woman have a fulfilling childbirth experience that makes her feel powerful - in whatever way that is meaningful to the woman and her family.

"You never know what's coming!" said Diane, as she elaborate her dreadful experience in the middle east. It is important to have a clear understanding of mother's condition and medical history before attending birth and the challenge is to prepare for the worst. Ongoing training programs and availability of equipment are essential to maximise maternal and neonatal care. It is heartbreaking that sometimes Diane's effort of caring goes to waste, especially when local midwives or community health workers ignored her warnings regarding the importance of postnatal care. Even though a baby may survive after proper neonatal resuscitation, continuous care is required to ensure the well-being of the baby.

Oxygen administration used to be an important part of neonatal resuscitation, however, recent studies reported that too much oxygen can be a hazard causing brain damage to the baby; therefore, it is no longer recommended. Room air contains 21% oxygen which is enough for resuscitating the newborn. Diane reminded me that oxygen is a drug, when used inappropriately, causes fatal damage.

Diane also pointed out that the key to effective neonatal resuscitation is adequate ventilation while preventing lung overdistension (see figure 1.3). To achieve adequate ventilation one must open the airway by positioning the baby's head in a neutral position. The current practice involve rolling up a piece of towel and place it under baby's shoulder to maintain the position.

With abundant home birth experience in both rural Saudi Arabia and New Zealand, Diane invokes everyone including parents and family members to learn the basics of resuscitation in case of emergencies (when skilled professionals is unavailable).



### Paediatrician

Dr. Shuman Mitik  
MD 1980 Belgrade  
Spec Paed 1987 Belgrade

Dr. Mitik raises issues regarding different sizes and weight of newborns. At full term, the average baby will be about 51 cm long and will weigh approximately 2.7 to 4 kg depending on the gestational age (see figure 1.4). This means baby's lung capacity (16~24ml) varies according to its birth weight.

The current neonatal bag-mask device has no control over the air volume. The amount of air delivered to the newborn is influenced by the operators' hand size, techniques and mask leakage. The existing silicon mask often require special techniques or even two-people operation to achieve an airtight seal (mouth and nose) while delivering adequate ventilation. The standard bag-mask device is 250ml while newborn require only maximum of 30ml of air. Dr. Mitik explained the reason the bag is designed to be this volume is for achieving enough pressure for the air to flow through the mouth and nose to the lungs and eventually alveoli. It is an effective tool for manual ventilation but carries the risks of under and over inflation.

### Neonatologist

Dr. Lindsay Mildenhall  
MB ChB 1986 Auckland; DCH 1989 Otago  
Dip Obst 1989 Auckland; FRACP 1994

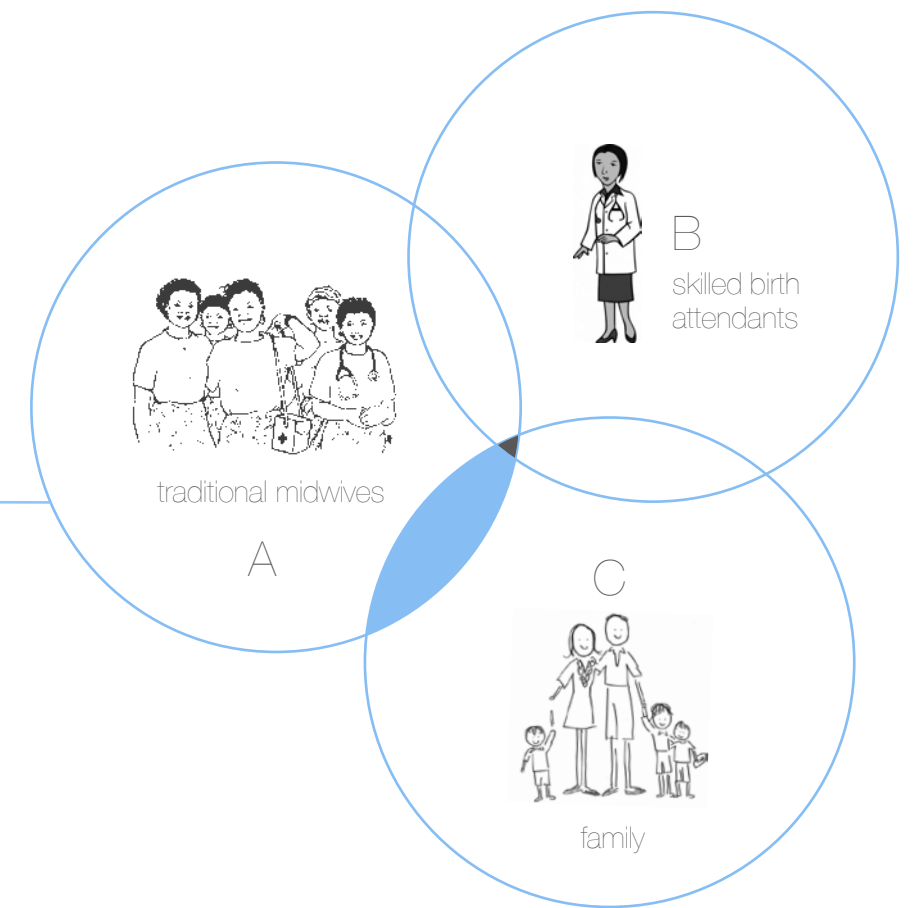
Dr. Mildenhall mentioned the importance of introducing PEEP (peek expiratory end pressure) valve to the existing manual resuscitation device. He explained that PEEP keep the lungs of ventilated infants partially expanded at the end of expiration, thereby preventing their complete deflation and minimising lung damage. There are existing PEEP valve design for bag-mask device, however, most users find it difficult and confusing to work with.

"Neonatal resuscitation is extremely energy-consuming. If you don't feel tired during the procedure than that means you are not putting enough effort into it and probably not doing it correctly." said Dr Mildenhall. This shows doctors have the perception of effective neonatal resuscitation being intensive and exhausting.





## 1.4 Character Profiles



### Target A (primary user)

Village midwives / traditional birth attendants (TBA), community health workers (CHW) in low-resource settings.

**Education:** They have Informal training that is used to help with before, during, and after pregnancy care of villagers. This information is transferred from generation to generation.

**Duties:** In most cases, village midwives are the only health care provider. The community perceived the role of both village midwives and traditional birth attendants as essential for providing maternal and health care services.

**Working Conditions:** The village has no electricity, and they have no access to a telephone. The primary health facility is about 7 km from the village. This health facility has 3 doctors, 2 lady health visitors, 6 auxiliary nurse midwives, 3 microscopists, and 2 pharmacists.

### Target users B (primary user)

Skilled birth attendants / trained midwives in resourceful settings.

**Education :** Fully trained and licensed health care professionals with abundant knowledge and experience regarding child birth and neonatal resuscitation.

**Duties :** To provides basic and emergency health care services to women and their newborns during pregnancy, childbirth and the postpartum period.

**Working Conditions :** Modern hospital or home birth scenarios with sterilised equipment, adequate electricity and human resource. Most home birth cases require midwives to carry resuscitation equipments from home to home.

### Target users C (secondary/tertiary user)

Family members/care givers in low-resource and resourceful settings.

**Education :** They have minimum or decent knowledge of commencing adult CPR but have almost no knowledge or experience of managing child birth and executing neonatal resuscitation.

**Duties :** Giving emotional support to the mother during child birth. In some cases, where there is a lack of human resource, family members/relatives may assist the midwife during and after pregnancy.

**Typical Working Conditions :** Varies from poor sterilised condition with no electricity to standard modern hospital scenarios.



# 1.5 Competitive product survey

A product matrix is drawn to present where the indirect and direct competitive products are positioned in the market place. A market gap was clear. None of the resuscitation device on the market meets the low-cost, low-risk criteria.

A lot of design efforts goes into the development of high-tech auto resuscitators which are more reliable and relatively high cost. Low cost devices such as the pocket mask and tube-mask resuscitator are inherently flawed. They can cause harm to the newborn if not used correctly (Path, 2008).

Most resuscitation devices require proper training to maximise effectiveness and minimise potential risks.

- fig. 1.5 - 'The Next Step' Neonatal Resuscitator
- fig. 1.6 - Hand Held Automatic Transport Resuscitator
- fig. 1.7 - Neopuff (Fisher & Paykel Healthcare)
- fig. 1.8 - Automatic Oxygen Powered resuscitator.
- fig. 1.9 - Pediatric Silicone Resuscitators
- fig. 1.10 - Topstar bag and mask
- fig. 1.11 - Pneumatic emergency transport manual resuscitator
- fig. 1.12 - Ambu Oval Plus Silicone Resuscitator
- fig. 1.13 - Manual pump resuscitator
- fig. 1.14 - Pocket mask
- fig. 1.15 - Tekno tube and mask
- fig. 1.16 - CPR face shield



ideal concept



fig. 1.5



fig. 1.7



fig. 1.6



fig. 1.8

High-cost

fig. 1.9



Fig. 1.10



fig. 1.11



High-risk

Low-risk



fig. 1.12

market gap



fig. 1.13



fig. 1.15



fig. 1.14



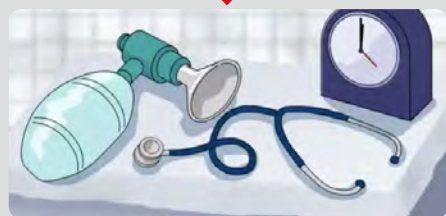
fig. 1.16

Low-cost



# 1.6 Cognitive task analysis

## Preparation



A flat surface with a warm cloth is required to place and dry the baby. A clean resuscitator, stethoscope, and a working clock must be present anytime during birth. The birth attendants thoroughly washes both hands and put on a glove.

## Assess & Position



## Seal



## Inflate



## Assess



After assessing, If the heart rate is below 60 beats per minute then the baby needs immediate resuscitation. First, Position the face to a neutral position, parallel to the surface. Second, seal the baby's mouth and nose with the mask using the 'OK' hand position. Inflate baby's lung by slowly deflating the bag while counting, "squeeze, two, three". Repeat this five times then check for crying and assess baby's heart rate.

## Monitor with mother

If the heart rate is above 100 beats per minute and the baby is crying vigorously then it is safe to give the baby to the mother. Both mother and newborn will be monitored.



## Single-person



## Two-person

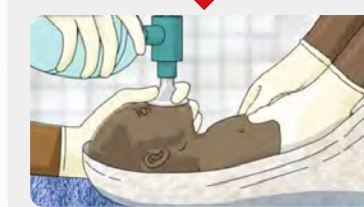
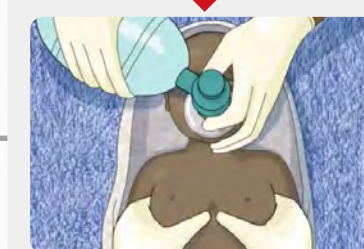
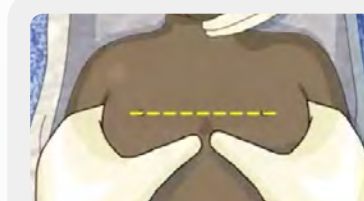


## Jaw thrust

If there's no signs of crying and the heart rate does not increase, jaw thrust is applied to achieve adequate ventilation. This technique can be achieved by one or two people. Single-person jaw thrust require the rescuer to position the fingers over baby's jaw, lift it forward and hold in place. Using the other hand and place the mask over the baby's mouth and nose and give 5 inflation breaths.

## Chest compression

This is only commenced after the a series of inflation breaths and the heart rate is still below 60 beats per minute. It is a rare condition. Before starting this procedure, the rescuer has to make sure the baby's chest is rising from inflation breaths. The rescuer then places both thumbs just below the imaginary line joining the nipples and compress the chest by 1/3 quickly and firmly. 3 chest compressions are given to one breath. This procedure is continued until the baby's heart rate increases.



## Monitor with mother



15

30

45

60

sec

\* Images in the research method are retrieved from <http://vimeo.com/medicalaidfilms/channels>



## 1.7 Key insights

### Accessibility

**Home births** - Worldwide 60% of all births happened at home and are attended by unskilled traditional midwives or female relatives. Bridging the gap of home births will directly increase the chance of rescuing newborns who need neonatal resuscitation.

### Functionality and Safety

1. Resuscitating with room air (21% oxygen) is just as effective as using 100% oxygen. Dealing with high concentrated oxygen is complicated which require knowledge and experiences.
2. An airtight seal between baby's face and the mask is required to execute proper resuscitation. Rescuers must select the appropriate mask size for adequate sealing.
3. Does not provide PEEP/CPAP (unless a PEEP valve has been fitted).
4. It is difficult to provide consistent inflation pressures.
5. It is difficult to deliver a sustained inflation longer than 2 - 3 seconds.
6. Unless an in-line pressure manometer is inserted, the operator does not know how much pressure is being delivered: it could easily be in excess of 40 cmH2O.
7. The operator can inadvertently deliver large volumes of gas to the infant which may cause a pneumothorax or damage the lungs of a preterm infant.

8. When ventilating a newborn infant, clinicians should aim for approximately 4 – 6 mL/kg per breath (e.g. a term infant weighing 4kg requires 16 – 24 mL with each inflation).

9. A 240 mL self inflating bag (e.g. Laerdal "preterm" bag) is therefore more than adequate for ventilating any sized newborn infant.

### Usability

1. Airway position - During the process of resuscitation rescuers constantly reposition the head of the baby to get an unobstructed airway position in order to maximise the effectiveness of the ventilation.
2. Single rescuer - Inexperienced single rescuer using a bag-valve-mask commonly find difficulty in maintaining both an airtight seal between them, mask and the face and an unobstructed airway with only one hand.
3. Timing - Rescuer should count 'breath, 2, 3' to deliver 1 puff of air every 3 second. Five breaths of sustained initial inflation should be delivered to the baby (each breath should last for 5 seconds).
4. Communication - A large number of traditional midwives or birth attendants are illiterate; therefore, instructions with words becomes a communication barrier.
5. Maintenance - In a limited-resource context high-quality sterilisation of a used medical device is often not an option.

## 1.8 Design brief

### Target Users

**Primary rescuer** - Traditional midwives who had some or no neonatal resuscitation training are the main target user. They are usually middle aged women with inadequate knowledge and equipment to execute proper neonatal resuscitation.

**Secondary rescuer** - In some cases, mothers or other family members can provide extra support for midwives during neonatal resuscitation (ie. Keeping the infant warm and hold the mask while midwife commence chest compression).

**Patient** - Infant born between 37 and 40 weeks ( weigh between 2.5 to 4 kg) suffering from birth asyphxia.

### Product Market

**Potential market size** - 60 million nonfacility births, most do not have access to resuscitation.

**Price range** - Between US\$ 5 ~ \$ 10.

**Competitive products & services** - Bag-Valve-Mask device, Tube-Valve-Mask device and Mouth-to-Mouth device (including a face shield) are the three main types of the competitive ventilation devices.

### Product Attributes & Specifications

**Purpose** - To assist birth attendants on performing effective neonatal resuscitation in a limited-resource context.

**Performances** - The device must achieve constant positive pressure ventilation to inflate infants' lungs. A one way valve must be included to allow infants to exhale. The device must be designed for illiterate

**Features** - A face mask is required to form an airtight seal around the nose and mouth of the infant. Part of the device should provide neck support for infants.

**Maintenance** - The device must be easy to maintain.

**Aesthetics** - The form of the product should suggest to the user how it should be used. It must appear safe, friendly and clean.

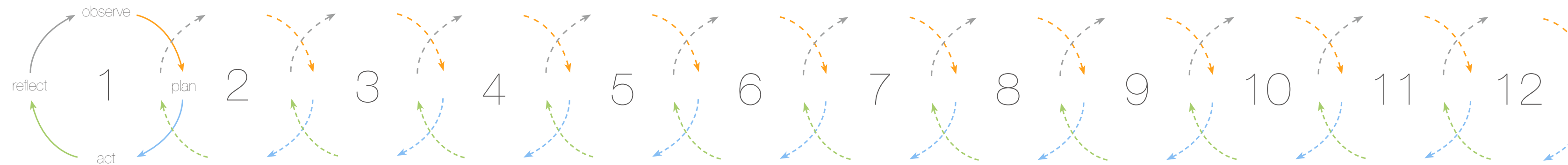




## 2.0 Concept phase

- 2.1 Supervision cycles
- 2.2 Mind-mapping
- 2.3 Lotus blossom
- 2.4 Inspiration (mood board)
- 2.5 Design for emergency
- 2.6 Concept ideation
- 2.7 Prototyping
  - 2.7.1 Position
  - 2.7.2 Seal
  - 2.7.3 Inflate
  - 2.7.4 Time
- 2.8 Concept direction
- 2.9 User feedback

## 2.1 Supervision cycles

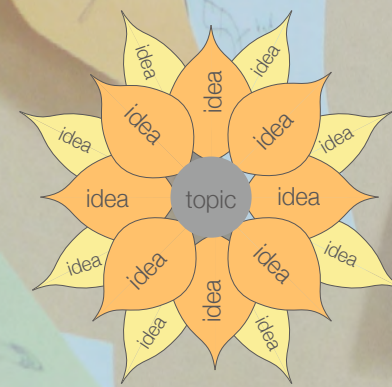
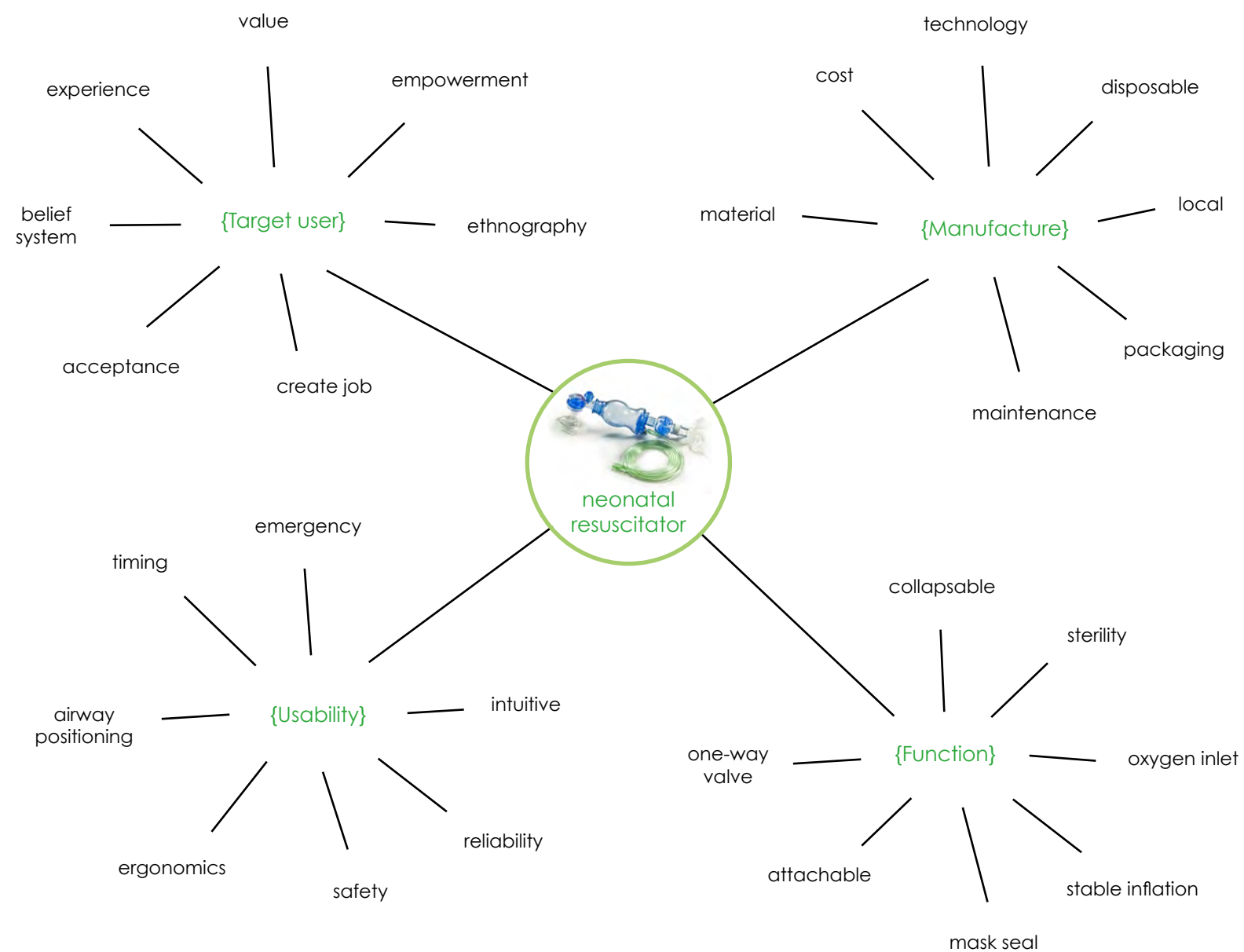


Meetings with supervisors and classmates were scheduled for every two weeks. Twelve meetings through out the project represents twelve action research cycles. Each meeting provides constructive discussion and reflection for the next cycle of research. The reflection were summarised and informed the plan of action for next stage.



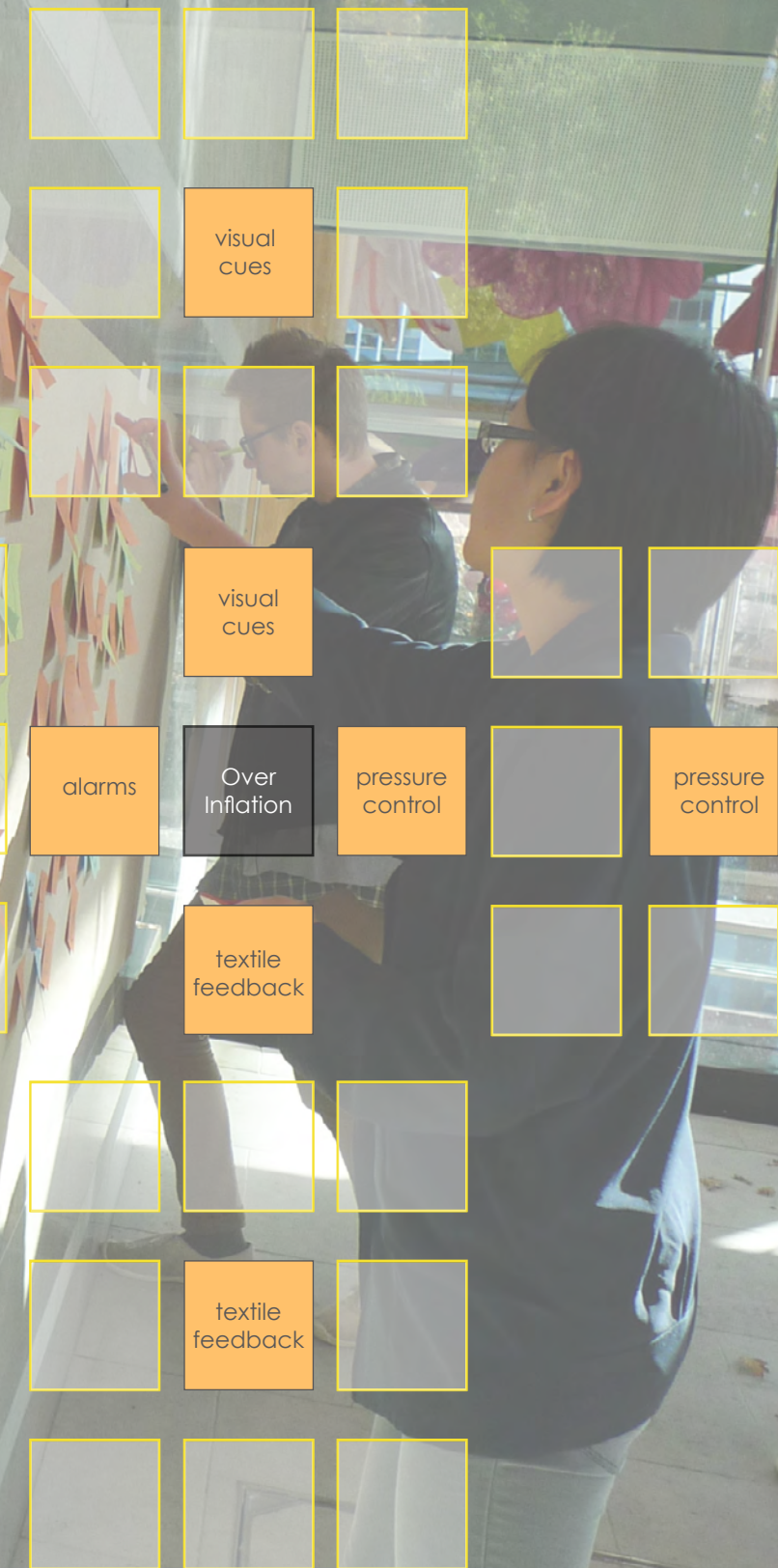
## 2.2 Mind-mapping

By generating ideas in a radial, graphical, non-linear manner, mind maps encourage a brainstorming approach to planning and organizational tasks. Though the branches of a mind map represent hierarchical tree structures, their radial arrangement disrupts the prioritizing of concepts typically associated with hierarchies presented with more linear visual cues. Using this point of reference in brainstorming encourages users to itemise and connect concepts without a tendency to begin within a particular conceptual framework. (Buzan, 2003)



## 2.3 Lotus blossom

A group of postgraduate students were gathered to carry out this event. A lotus blossom matrix was laid out for guiding and organising this design method. Four central topics including, airway positioning, over-inflation, mask seal and timing of the resuscitation process are proposed for idea exploration and discussion.







## 2.4 Inspiration

My inspiration came from minimalist design, emergency equipment, medical product design and nature. Innovation often came from discovering unexpected relationship between objects or systems. Mother nature is always a good source of inspiration. Nature has its way of solving problems in the most simple and elegant way.

- fig. 2.1 - bellows
- fig. 2.2 - spirit level
- fig. 2.3 - insulin pump
- fig. 2.4 - pacifier
- fig. 2.5 - water purification pump
- fig. 2.6 - collapsible razor
- fig. 2.7 - teapot hourglass
- fig. 2.8 - rescue stick
- fig. 2.9 - close-up of octopus suction cups



fig. 2.10 - Nursing kit

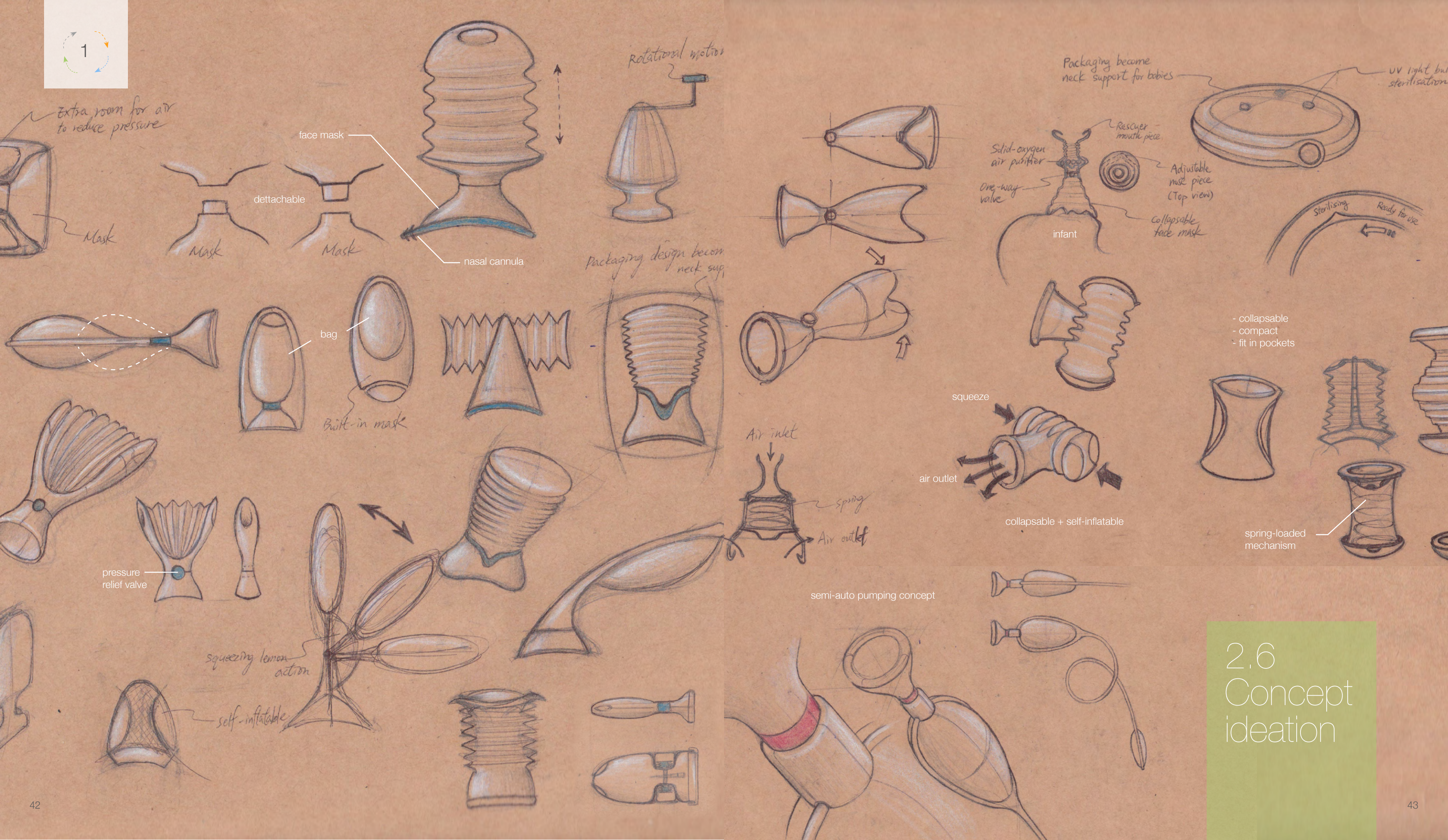


fig. 2.11 - First aid kit

## 2.5 Design for emergency

Under a stressful, emergency situation, it is common that inexperienced rescuers may panic and put both themselves and the rescuee in higher risks. Poorly designed emergency equipment causes extreme user frustration which lead to poor judgement and mistakes. Emergency device must provide guidance and feedback to allow the rescuers & rescuees to follow and act accordingly. The first aid kit designs on the left are examples of well-designed emergency equipment. They both provide clear information and guidance. Neonatal resuscitation is considered as an emergency situation during child birth. Rescuers must act fast and accurate. It is essential that the resuscitator design does not hinder the procedure and enables rescuers to perform safely and effectively.





## 2.6 Concept ideation





## 2.7 Prototyping

A structured prototyping plan was necessary to ensure a fruitful learning process. By dividing this phase into four sessions, I was able to thoroughly tackle each session. With clear objectives in each session, I measured my success and failure by referring to these objectives. However, these objectives may change depending on the user feedback.







## 2.7.1 Position

Moving the baby's head to a neutral position is vital. The airway in a newborn is very position sensitive. Both forwards and backwards tilt can block the airway. Similar to a plastic straw if the angle is too great it will kink. The conventional way of maintaining this position is placing a rolled-up towel under baby's shoulder.

A compact, portable mouth-to-mask concept is prototyped for testing. The device consist of 3 components: heart-rate indicator (A), face mask (B) and neck support (C).

Step 1 : Remove the heart-rate indicator.

Step 2 : place the heart-rate indicator on the chest of the baby (between the nipples). The triangle indicates the thumb location for chest compression.

Step 3 : Place the neck support in the optimal position. This creates an unobstructed airway position which maximise the effect of ventilation.

Step 4: Expand the collapsible face mask (with built-in one-way valve) and form an airtight seal on baby's mouth and nose.

Step 5: blow into the collapsible mask and look for chest rise.

Mouth-to mask concept is ideal for inexperienced rescuer due to its ease of use. Achieving an airtight mask seal is much easier with two hands. The rescuer is at the head end of the baby and is therefore well positioned to assess chest expansion during inflation. The heart-rate indicator gives immediate feedback of infant status to the rescuer. The neck support resolves the trouble of constantly repositioning the infant's head.

However, issues regarding over-inflation and oxygen intake still need to be addressed. A simple flow-rate indicator on the face mask may be effective to warn the rescuer not to blow excessively.

The disadvantage of this concept is that the verbal communication between the rescuer, the mother and other healthcare providers is restricted which further delay the resuscitation process.

I also explored different ways of informing and maintaining the neutral position such as the implication of spirit level (fig. 2.12) as a visual feedback or inflatable support (fig. 2.13) like the life jacket.

step 1



step 2



step 3



step 4



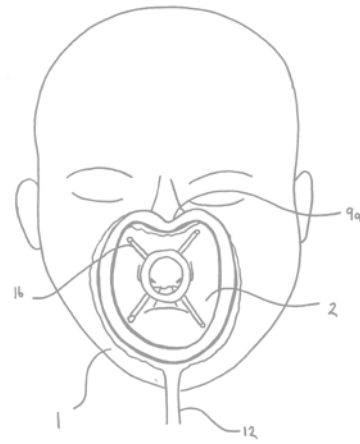
step 5



fig. 2.12 - Spirit level



fig. 2.13 - Life jacket

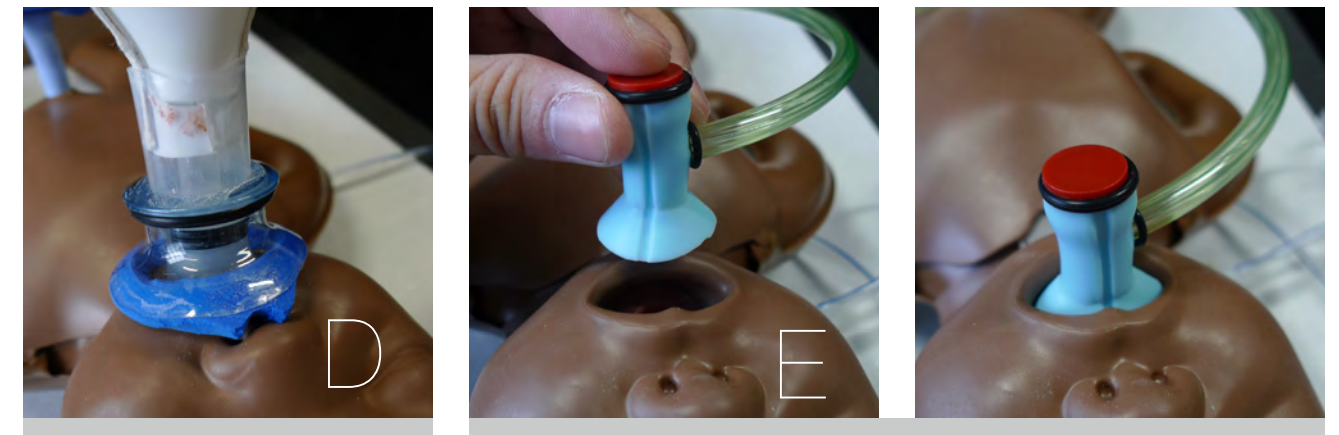


## 2.7.2 Seal

The face mask is the interface between the infant and the resuscitation device. It is crucial that the mask require only a minimal amount of pressure to achieve an airtight seal. Masks for infants usually come in two sizes - large and small. During the process of resuscitation, the mask is taken on and off the infant's face quite frequently; therefore, the design of the mask must be intuitive for easy positioning and sealing. As part of the ideation phase, I explored objects/products that are designed for sealing and holding.



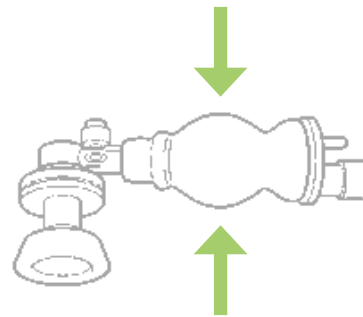
Inspired by the design of the pacifier, mask a, b, c are built to explore the idea of an extruded structure which keeps the mouth open for adequate ventilation.



This mask features a padding, which seals the mouth and blocks the nostrils during neonatal resuscitation.

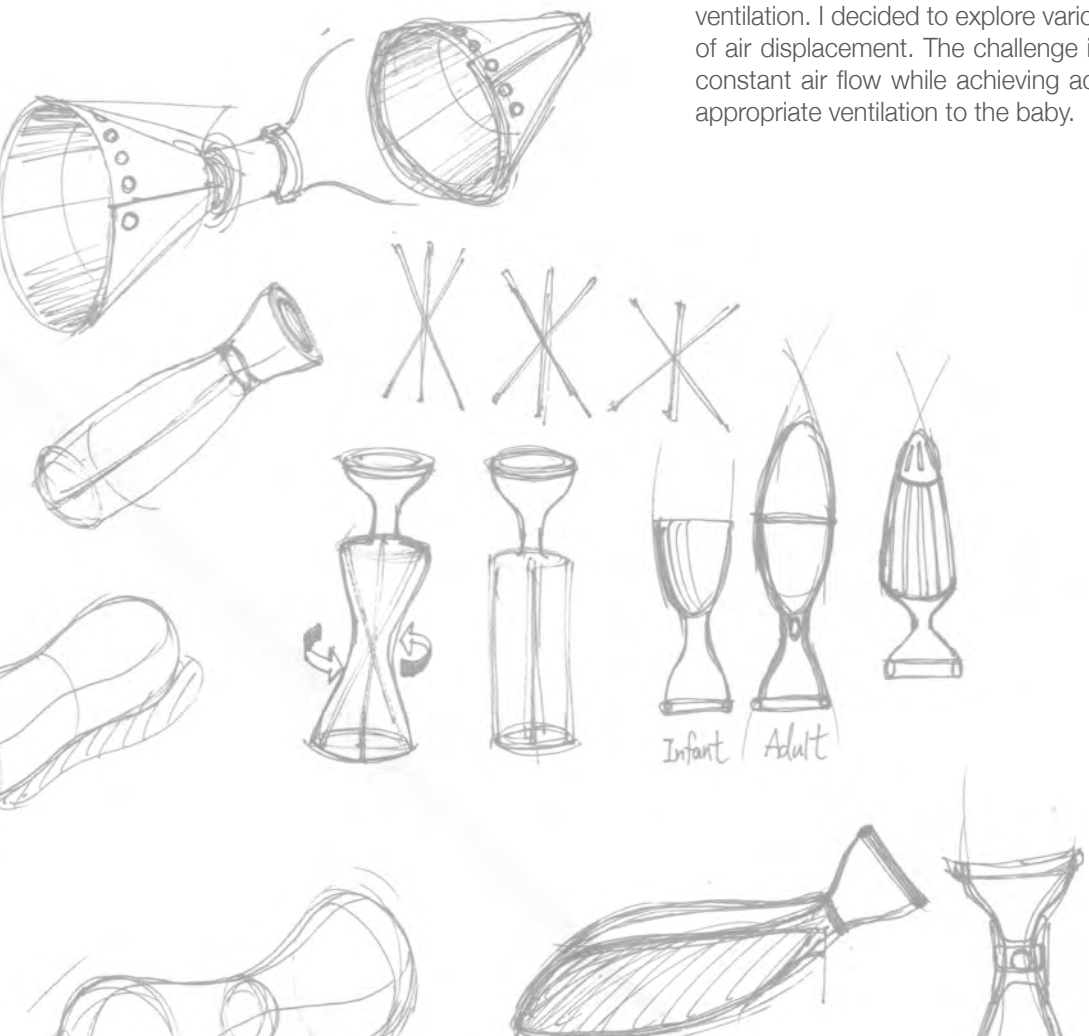
This concept mimics the function of the mouthpiece used for scuba diving. The seal is created inside the mouth between the infant's gum and the lips.





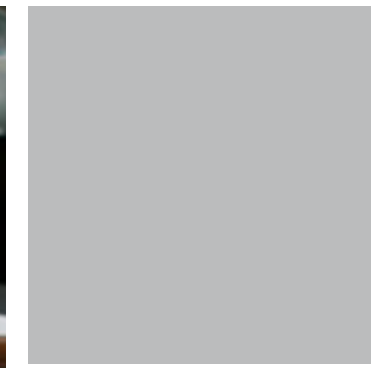
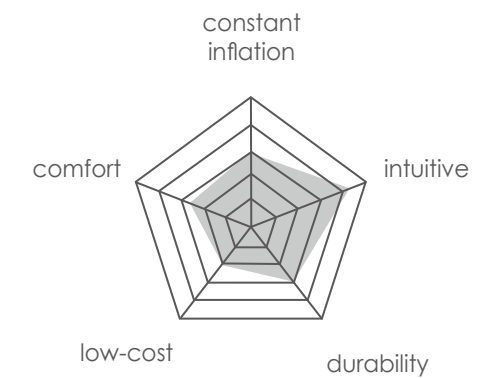
### 2.7.3 Inflate

Adequate ventilation is the key to successful resuscitation. It is equally important to not over or under inflate baby's lung. Manual device such as bag-valve-mask device can achieve adequate ventilation but is poorly designed to control the volume and pressure of the ventilation. I decided to explore various methods of air displacement. The challenge is to provide constant air flow while achieving adequate and appropriate ventilation to the baby.



### Concept A

A series of experimentation with collapsible structures was carried out to explore the idea of a compact, self-inflating bag and mask device.





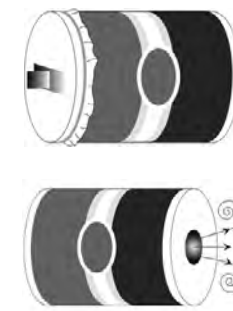
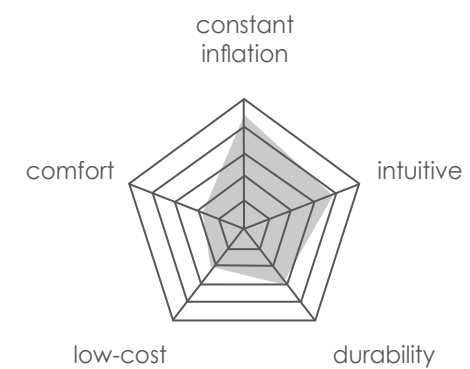


## Concept B

Inspired by the design of the air pump and syringe, this concept adopted the three-finger pumping action. This construction allows the rescuer to deliver positive air pressure at a constant rate, despite the hand size of the rescuer. Unlike the self-inflation bag this concept controls the amount of air flow and pressure.

As the rescuer push down the handle of the device a built-in, spring-loaded mechanism will force the handle to eject back up. The device is then ready for the next inflation.

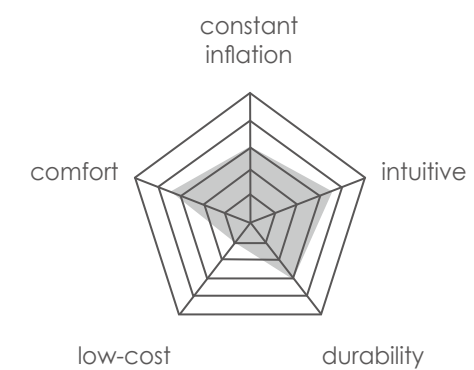
The height of this model causes minor discomfort to the resucer's wrist during resuscitation.



## Concept C

This concept is made up of a cylinder, an elastic surface, a pulling tag and a collapsible face mask.

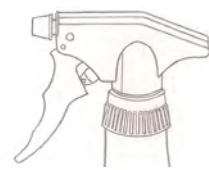
Mimicing the principle of an air cannon, this concept delivers a puff of air as the rescuer pull and release the tag. The pressure of the air is determined by how far the tag has been pulled. The further the pull the greater the pressure.



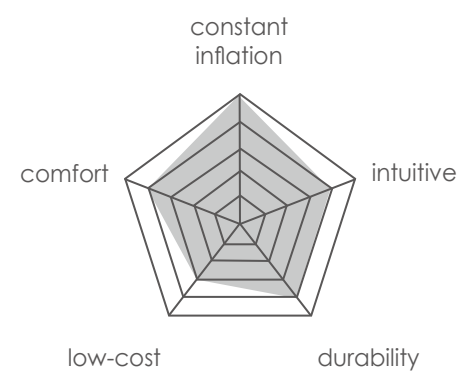




### Concept D

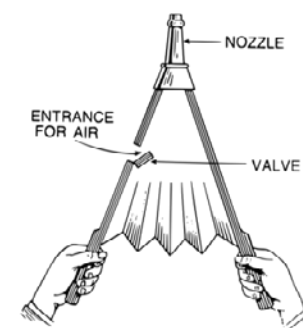
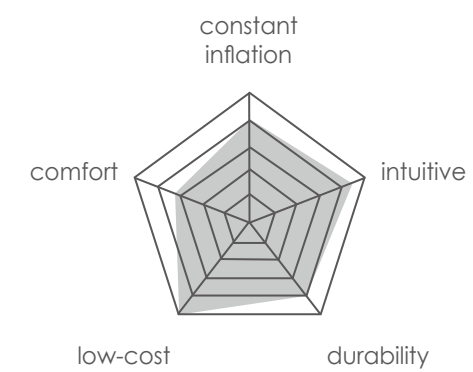


The spray can mechanism controls the water pressure by restricting the size of the outlet. Same principle is applied to this concept. Air pressure can be controlled and adjusted depending on the scenario. The air volume delivered to the baby is constant and safe.



### Concept E

The purpose of a bellows is very similar to a resuscitator. It is a device for delivering pressurized air in a controlled quantity to a controlled location. Likewise, a resuscitator is designed to deliver positive air pressure with regulated air volume to the patient. Concept F functions like a bellows except that it has the ability to self-inflate. The folding structure of the plastic causes it to spring out as the user deflates the device.

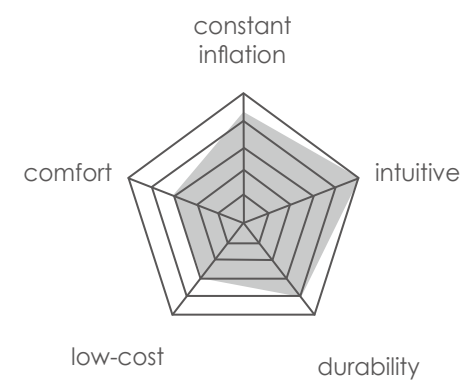






## Concept F

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The rescuer(s) may be inexperienced and under stress during an emergency, and therefore, it is important that the device is easy to use and provide some form of guidance or leadership during the resuscitation process.

An automated or semi-automated device may achieve accurate resuscitation but the rescuer is forced to rely on the technology and has no alternatives if the device failed. There is a fine line between empowerment and disempowerment.

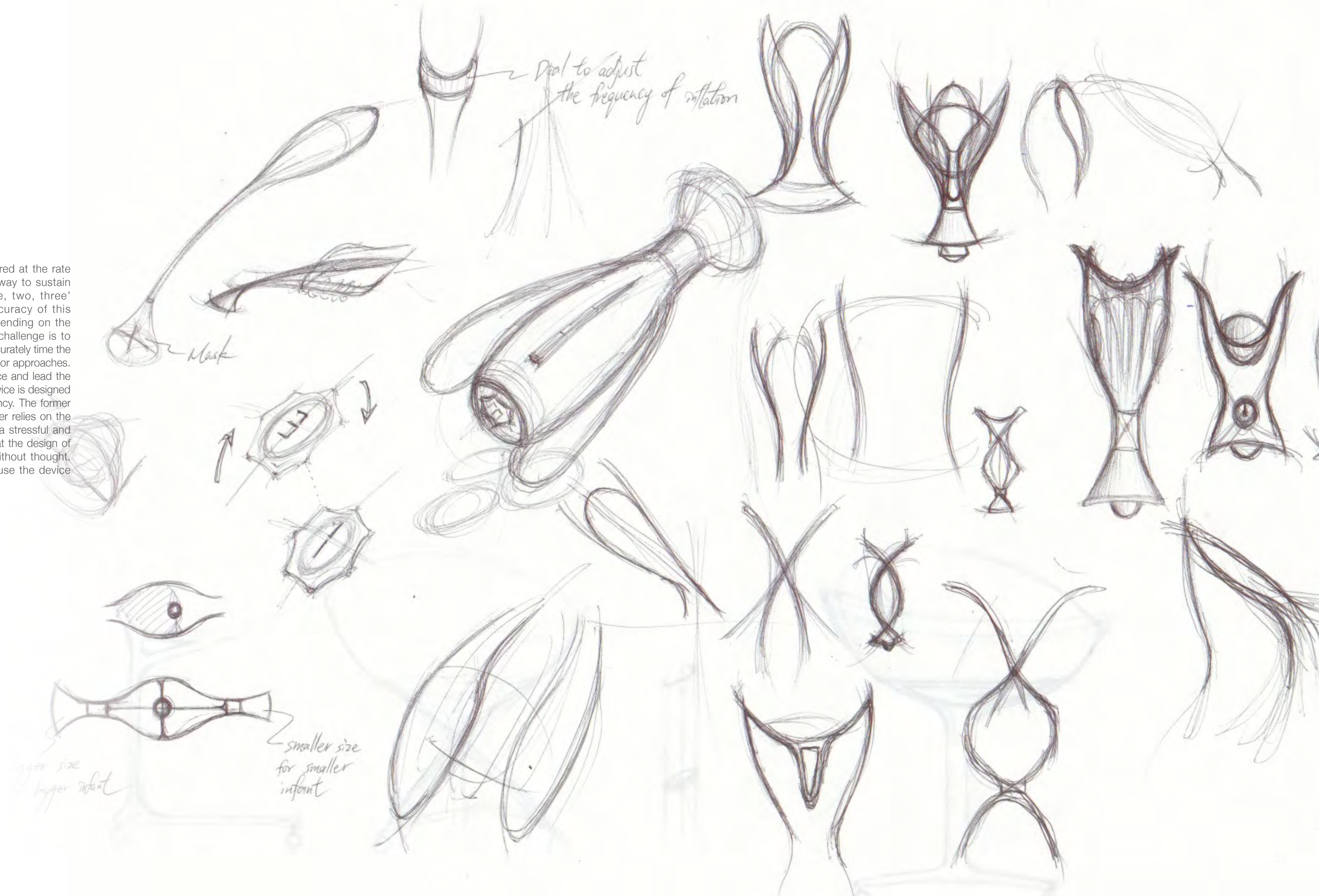


## 2.7.4 Time

# 5

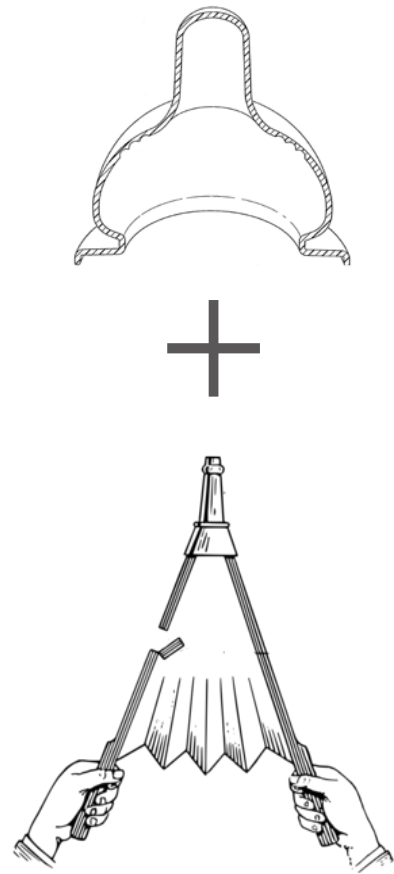
- second initial breaths

Inflation breath should be delivered at the rate of 40 breaths/min. A common way to sustain this rate is to count 'squeeze, two, three' continuously. However, the accuracy of this counting method may vary depending on the experience of the rescuer. The challenge is to allow inexperienced rescuer to accurately time the inflation breath. There are two major approaches. The device could provide guidance and lead the rescuer (i.e. metronome) or the device is designed to be operated with a set frequency. The former empowers the user while the latter relies on the technology. Nonetheless, under a stressful and intimidating situation, it is vital that the design of the device encourages action without thought. The rescuer should be able to use the device accurately with no confusion.





## 2.8 Concept direction

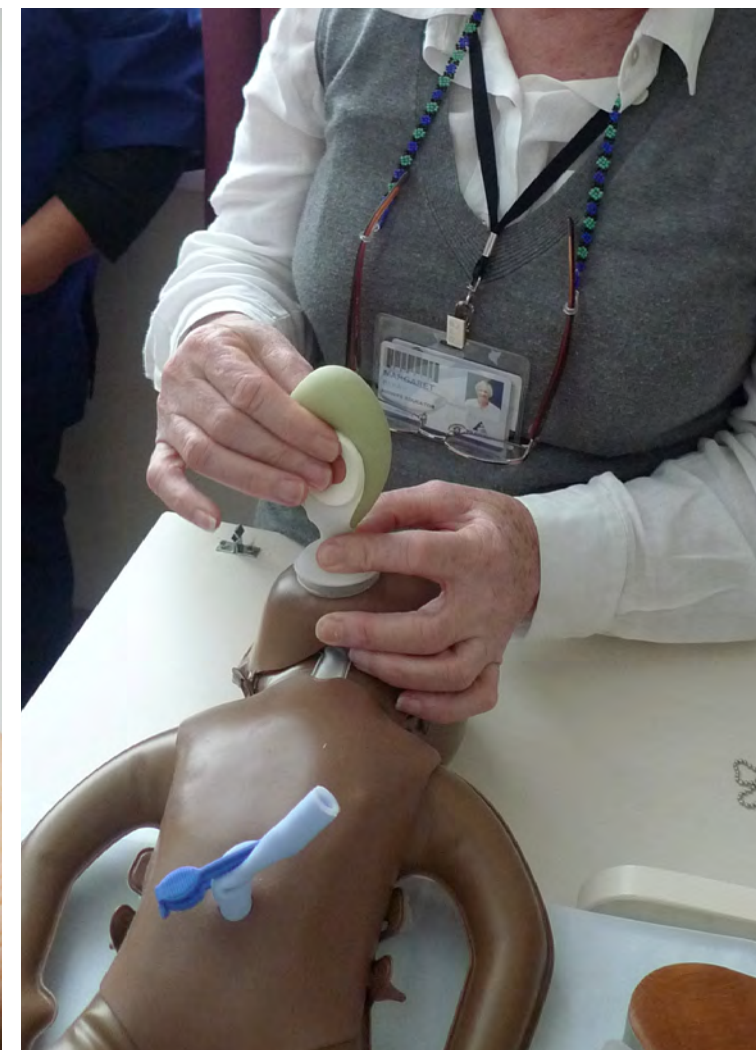


This concept is originally inspired by the bellows. The mask shaped like a pacifier, is designed for easy positioning and perfect sealing. The two handles on the side allow users to control the amount of air delivered to the baby. The rhythm is maintained by slowing down the reinflation speed of the bag and giving users tactile feedback.





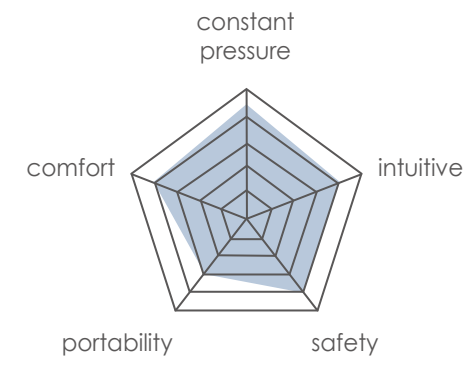
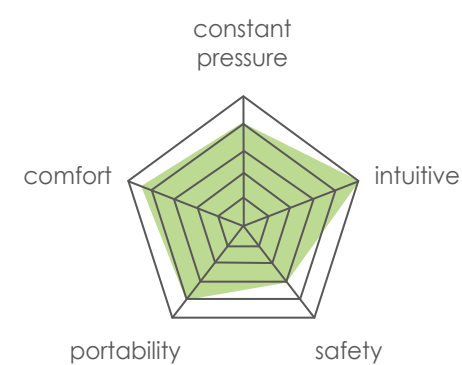
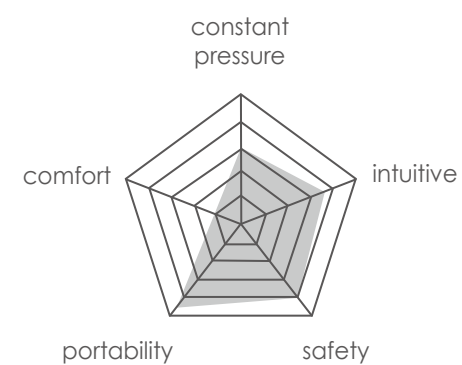
## 2.9 User feedback



Three prototypes are presented to potential target users for critical feedback. The participants include two paediatricians from Middlemore Hospital and Northshore Hospital, five highly trained midwives with home birth experiences (Two of them have had experience of delivering babies in low-resource settings i.e Saudi Arabia and Vanuatu), two midwife interns from Samoa and Tonga, and five inexperienced users from AUT product design faculty. The participants were asked to evaluate the functions, ease of use, comfort, feasibility and portability of the three resuscitator prototypes. This session was constructively utilised to gain feedbacks and suggestions for further development. With the users' input at this early ideation stage, a co-designing and co-creating process was carried out.

A few users especially the inexperienced users expressed difficulties with using one hand to maintain an airtight seal while delivering inflation breaths to the baby manikin. Prototype A's handle is too flexible and therefore, failed to provide structural rigidity while deflating the bag. Prototype B received plenty of positive feedbacks from various group of users and is the most preferred out of the three prototypes. Over half of the participants complimented about the comfort of the two flaps on the side of the mask. Prototype C is also well received. The form and texture of the silicon bulb projects a clean and safe image to users.

The main concerns were the size of the mask and the amount of air pressure delivered to the baby. All three models failed to cover the nose while allowing air to flow through. As the paediatrician and experienced midwives point out, babies breath through both their nose and mouth, but mainly their nose; therefore, it is critical to inflate the lungs through both nasal and mouth cavity in order to eradicate any potential blockage. The healthcare professionals did not advocate the one-hand operation technique. They believe two hands are required to achieve an effective seal and delivers adequate ventilation. Base on these comments and suggestions, the project proceeds to the development phase.





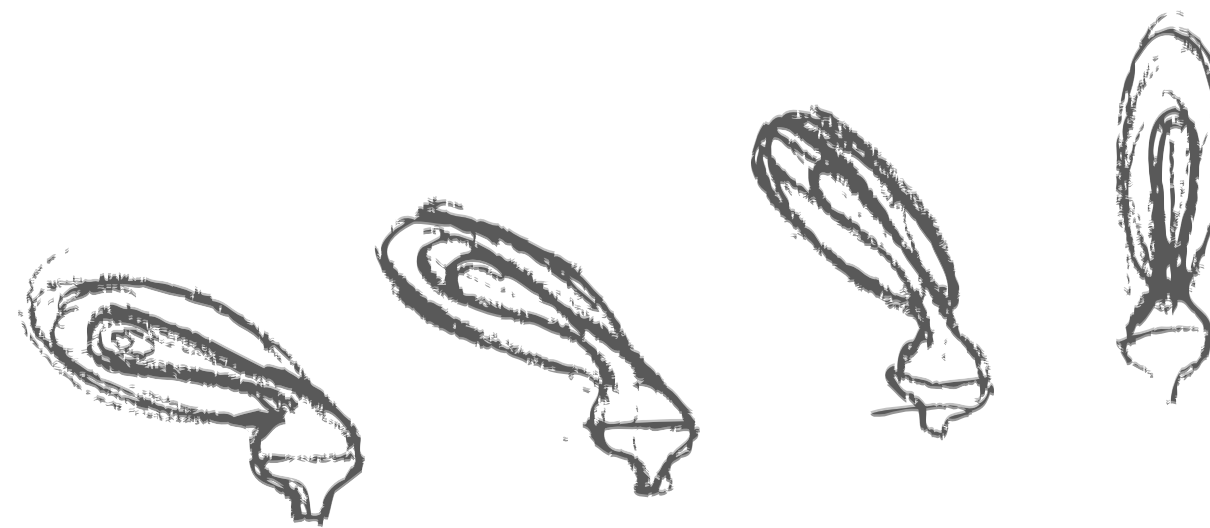
## 2.10

### Concept phase reflection

How to be a responsible citizen? What contribution can I bring to the society? These are questions my parents and teachers used to ask me when I was young. As I grew up, I realised something had to be done regarding social justice and inequality. Fortunately, what I learned and gained in university has profound environmental, social and economic implications. I am convinced that design thinking and process is an effective tool to reach out and influence people at a global scale. It has been a challenging yet fruitful journey for me.

Co-designing with experts and users really accelerates the design process. Bringing potential users into the concept ideation phase makes the object more valuable to the users and creates a deeper product-to-human relationship.

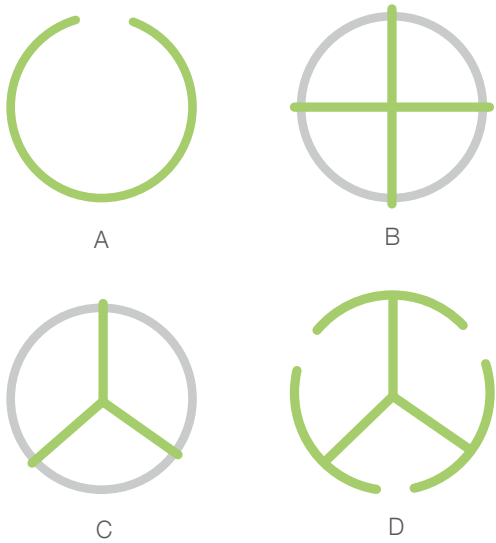
Referring back to my research question and theory, I realised that the core purpose of this project is about designing with a strong sense of responsibility and making connections with users through empathy. It is also about embracing and celebrating constraints while appreciating the design opportunities these limitations bring to the healthcare industry. Personally, I believe that healthcare system in the developed world needs to shift its focus from technology-driven to human-centred. At the same time, It is our responsibility to guide and empower the developing world to create a more sustainable healthcare system.



## 3.0 Development phase

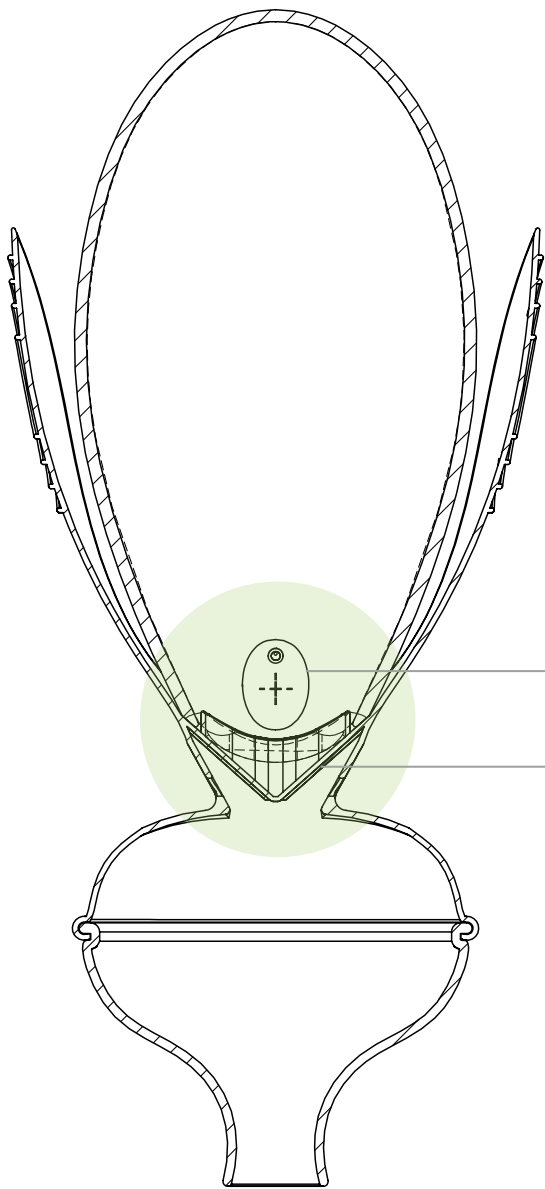
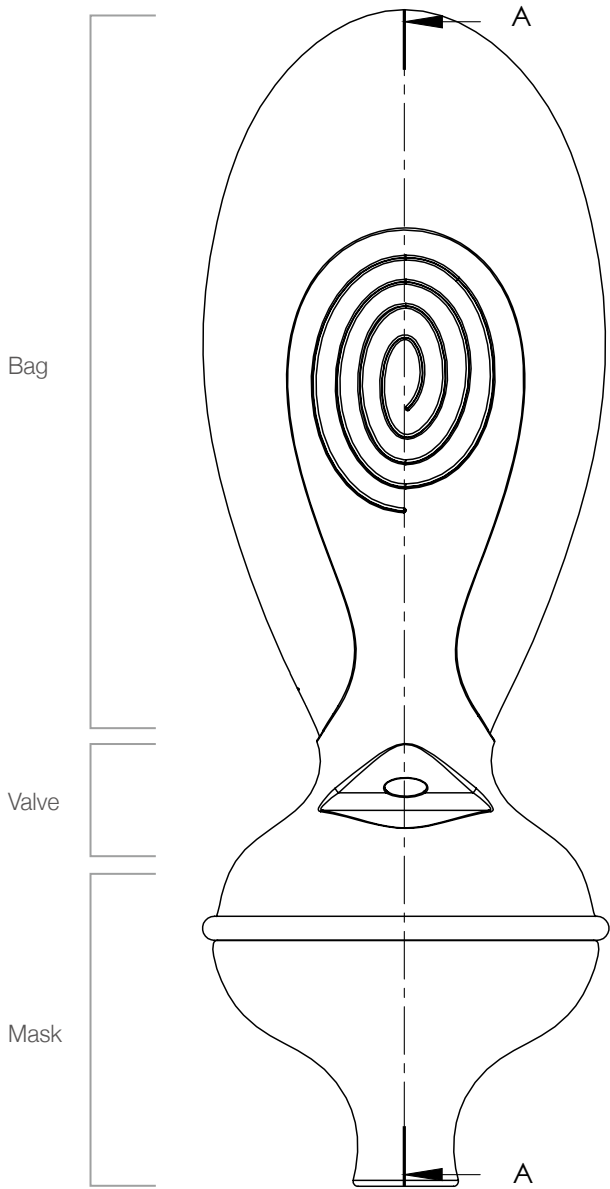
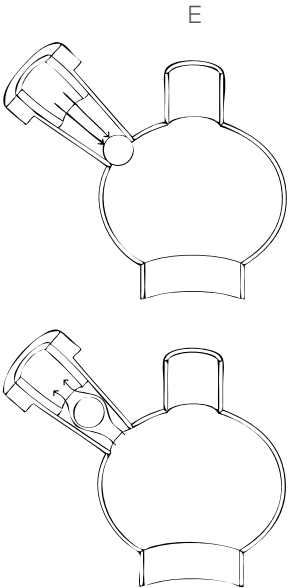
- 3.1 Valve design
- 3.2 Form & aesthetics
- 3.3 Ergonomics
- 3.4 Suction v.s inflation
- 3.5 Mask redesign
- 3.6 Packaging design
- 3.7 Manufacture design
- 3.8 Design evaluation





The line drawing above shows different types of valve design. Valve A is a one flap design. Valve B is a four flap valve which causes too much leakage. Valve C is a three flap valve that does not allow the valve to open widely. Valve D is an alternative three flap valve. The flaps on this design does not close all the way when the air flow stops. Valve E is design for releasing stagnate smoke when using a hookah. Resuscitator requires two valves, one for inlet air and one for patient exhaled air.

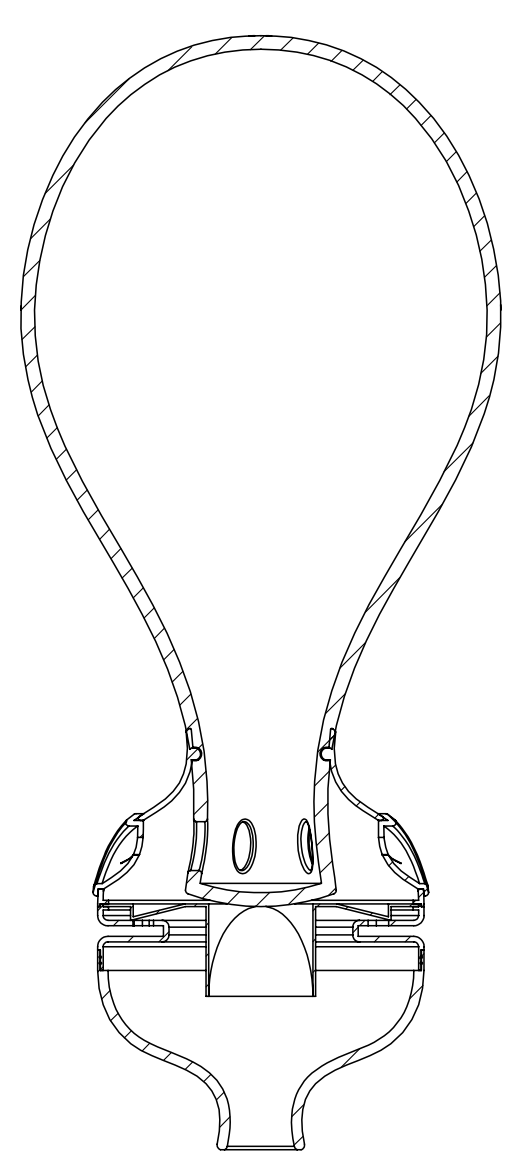
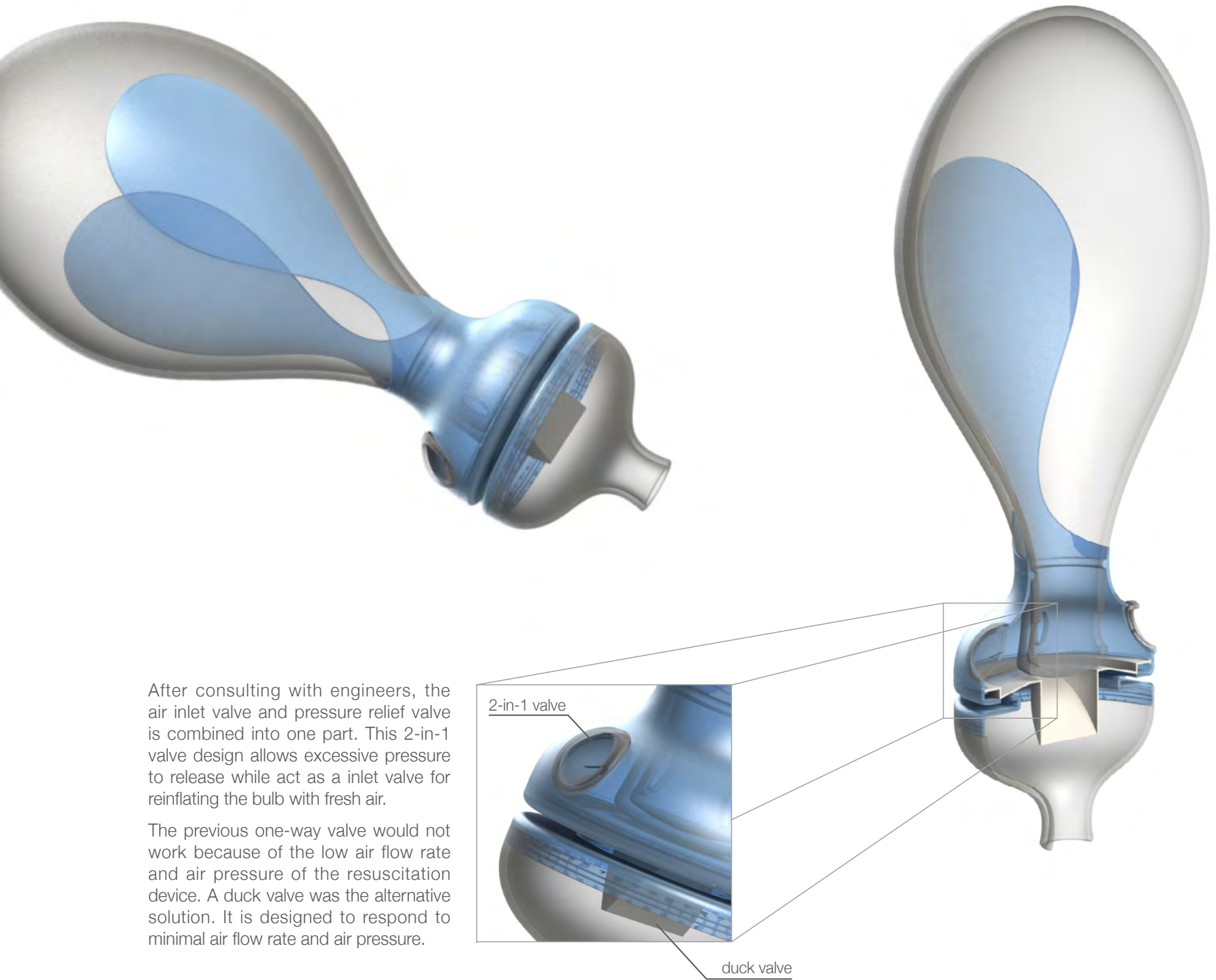
Valve cut out  
Reference



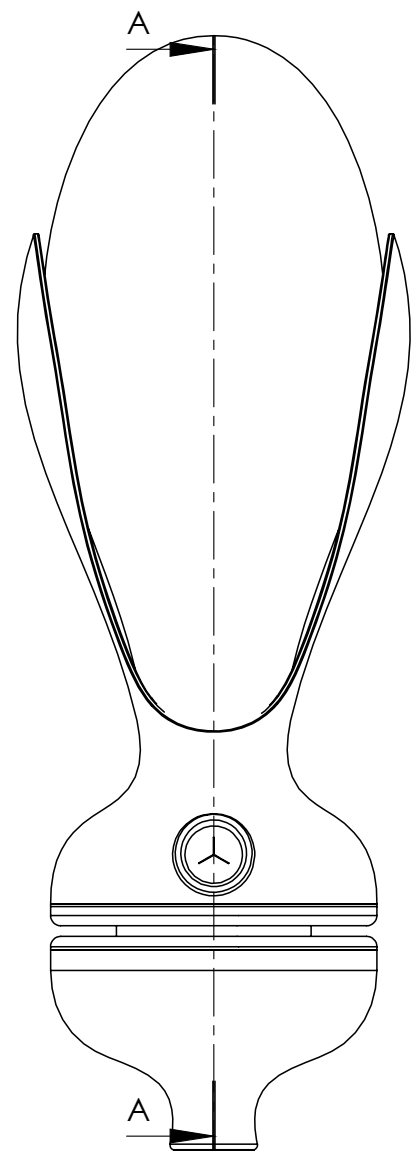
**Inlet valve**  
The purpose of this valve is to allow the self-inflating bag to reinflate after each inflation breaths. The valve should be sealed once the self-inflating bag is fully inflated. The size of the valve cut should allow a three-second reinflation in order to match the rhythm of inflation breaths.

**Outlet valve**  
A two flap valve is a one-way valve that allows the air in the bag to flow to the newborn and does not allow the exhaled air of the newborn to return to the bag. The exhaled air exit from the holes on the neck of the resuscitator.

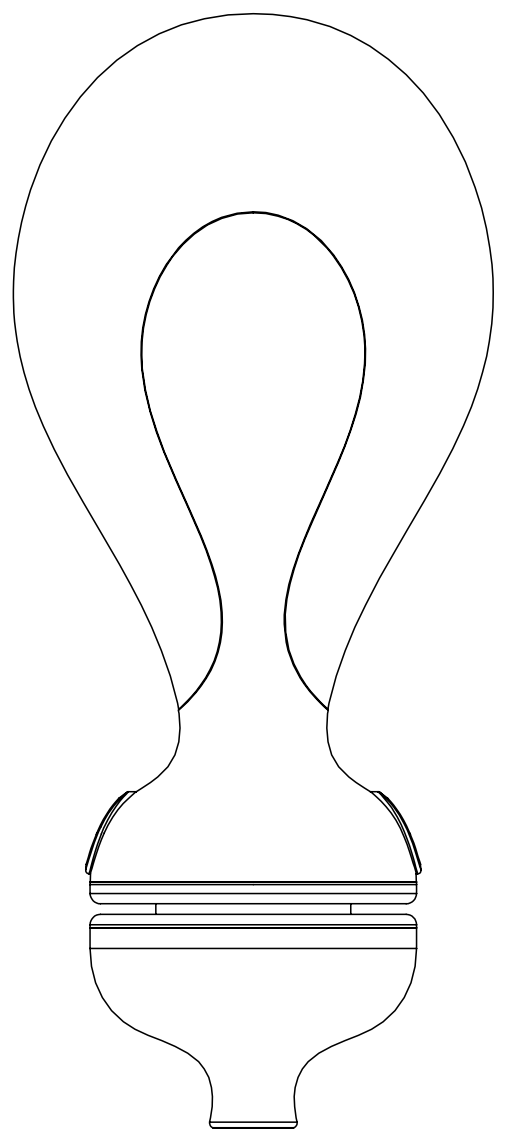




SECTION A-A

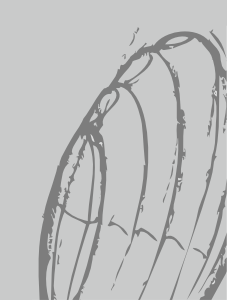


FRONT



SIDE





## 3.2 Form & Aesthetics

This was perhaps the most difficult phase of the design process. While minimalism is the main framework for designing the form of the device, it is vital to consider what is the appropriate form and aesthetics for communities in developing world settings.

It is important to understand target users' perceptions and expectations of medical equipment and thoroughly investigate their culture identity and values before assuming an appropriate aesthetic for the users. Without going through the industrialisation phase of the Western culture, communities in Third world countries have minimal experience or knowledge in perceiving the design language from the developed world. This results in alienation, uneasement and unwillingness to accept certain design solutions (Krippendorff, 2006).

Under the constraints of this research I acknowledged that it is inappropriate or even arrogant to assume a design language to be accepted by other cultures. Co-designing with the traditional midwives and local health workers is a more pragmatic way to establish forms and style that they can appreciate and connect with. A bellows is an object that most people/users can relate with blowing air. I intended to use its design language as a starting point for interrogating what is aesthetically appropriate and acceptable for different cultures.

An ongoing dialogue with the end users strengthened the integrity of the chosen concept. Meanwhile, I gathered inspirational images and objects to further develop an appropriate design language for the developed world. The form of a gourd and a bee matches the design element of the resuscitation device. The body, neck, and head of a bee respectively echos the bag, valve, and mask of the resuscitator.



3.1



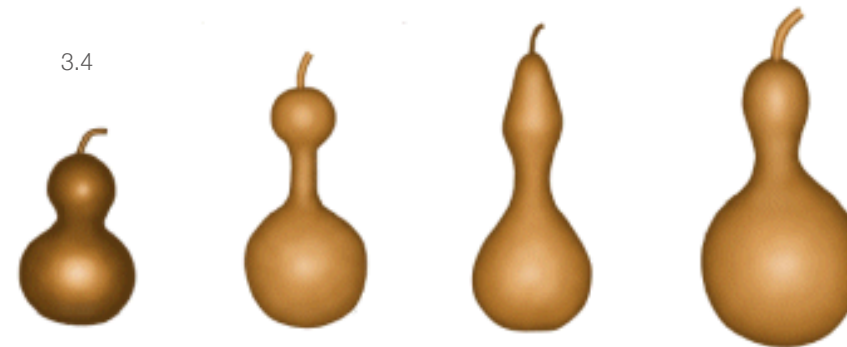
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3.3



3.7



3.4



3.5



3.6



3.8



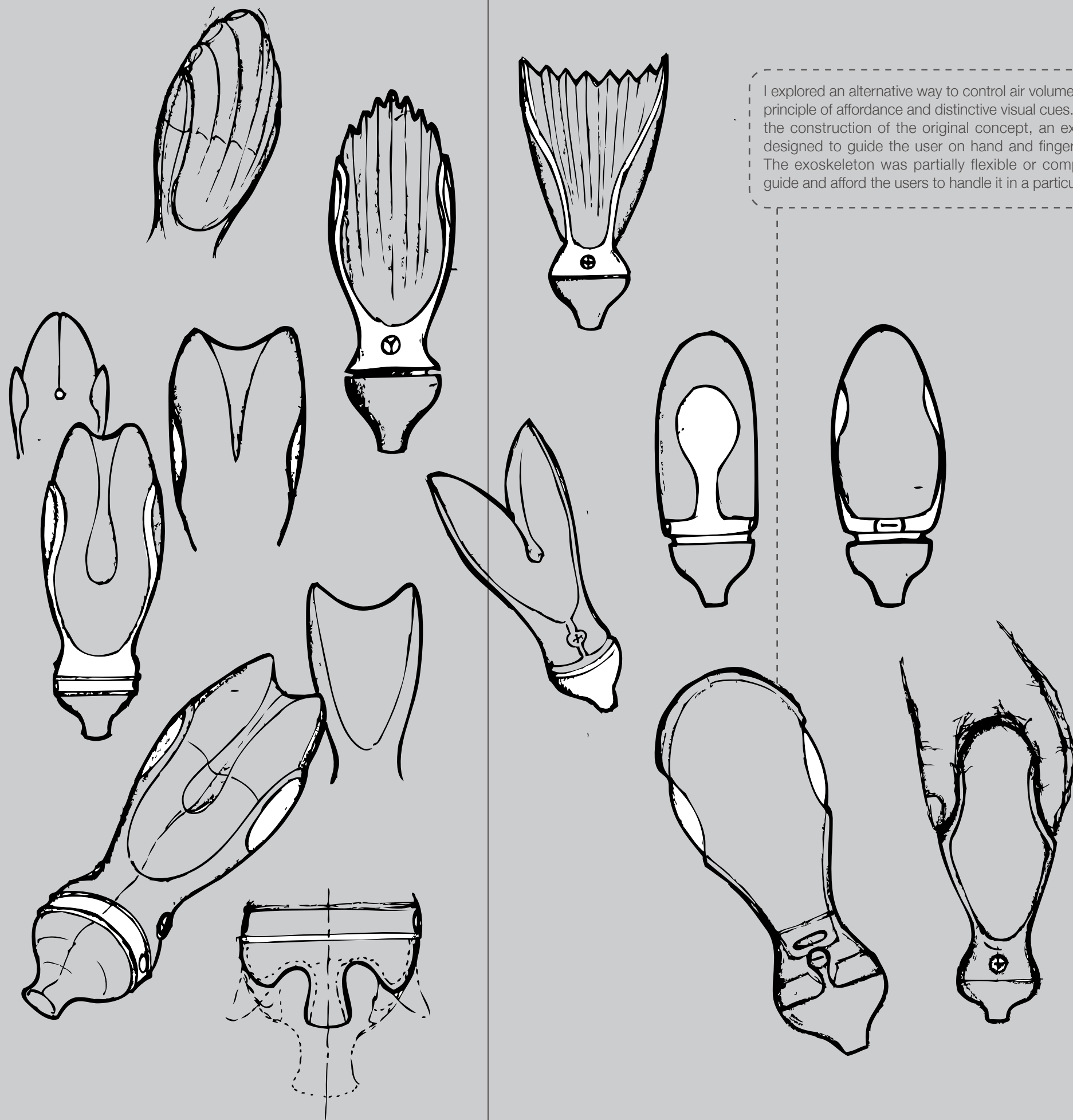
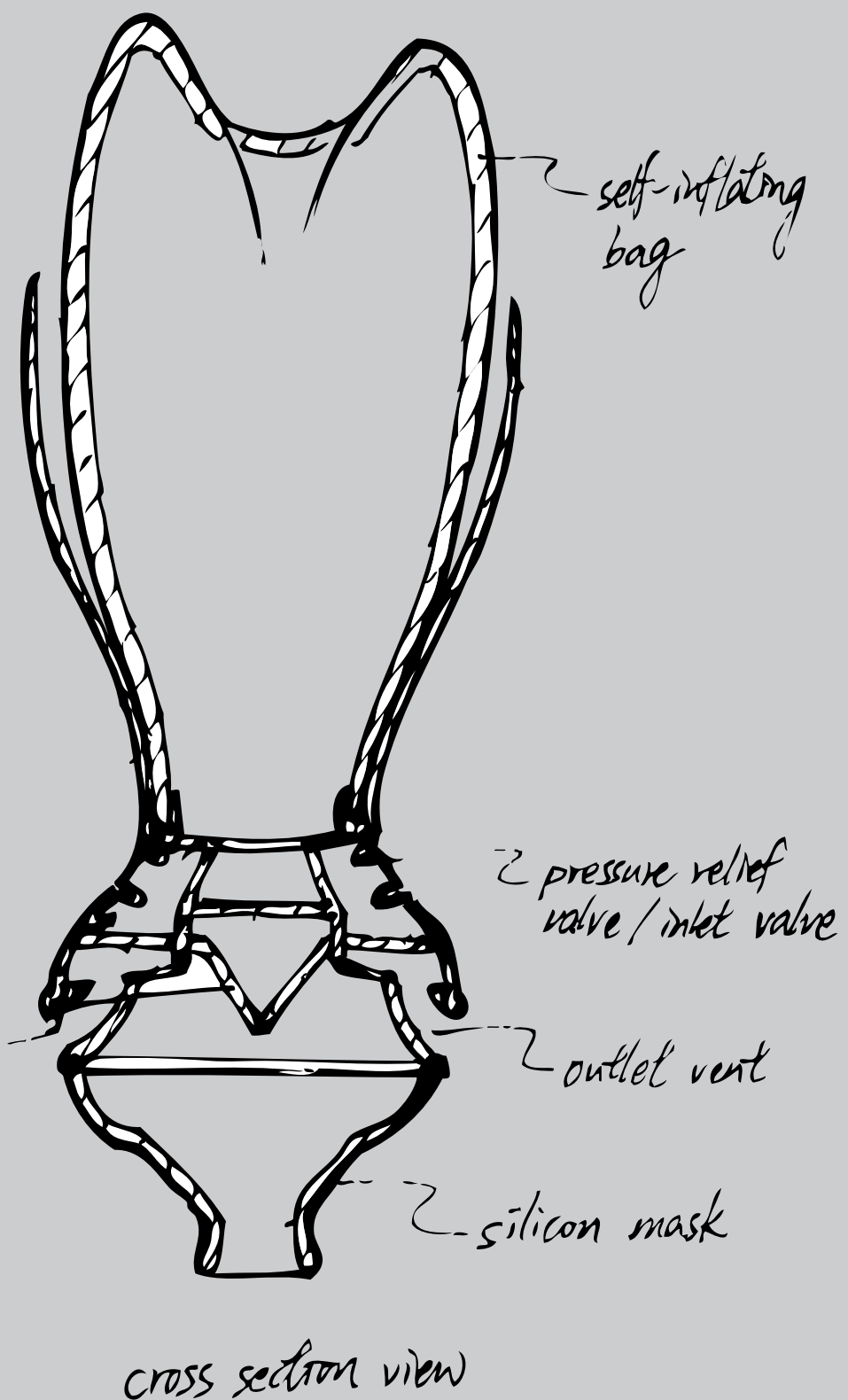
3.9



3.10



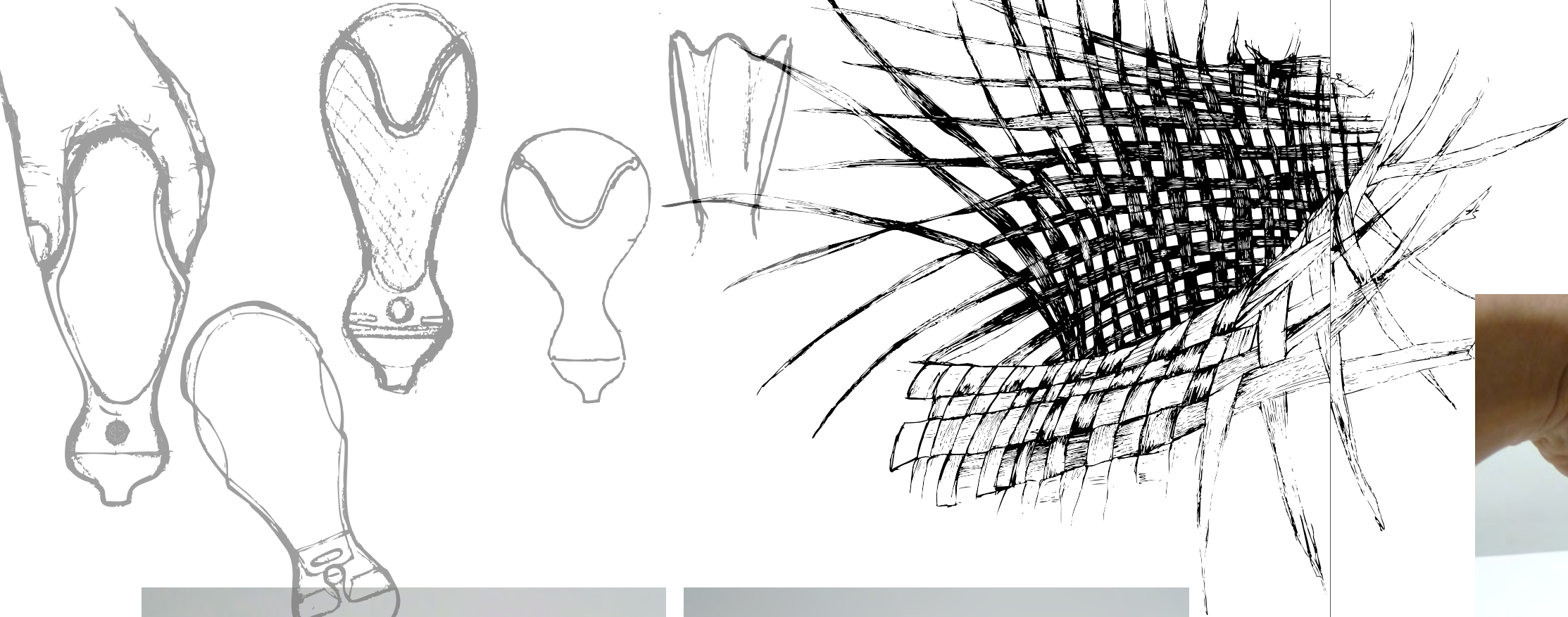
3.11



I explored an alternative way to control air volume by using the principle of affordance and distinctive visual cues. By reversing the construction of the original concept, an exoskeleton is designed to guide the user on hand and finger positioning. The exoskeleton was partially flexible or compressable to guide and afford the users to handle it in a particular way.





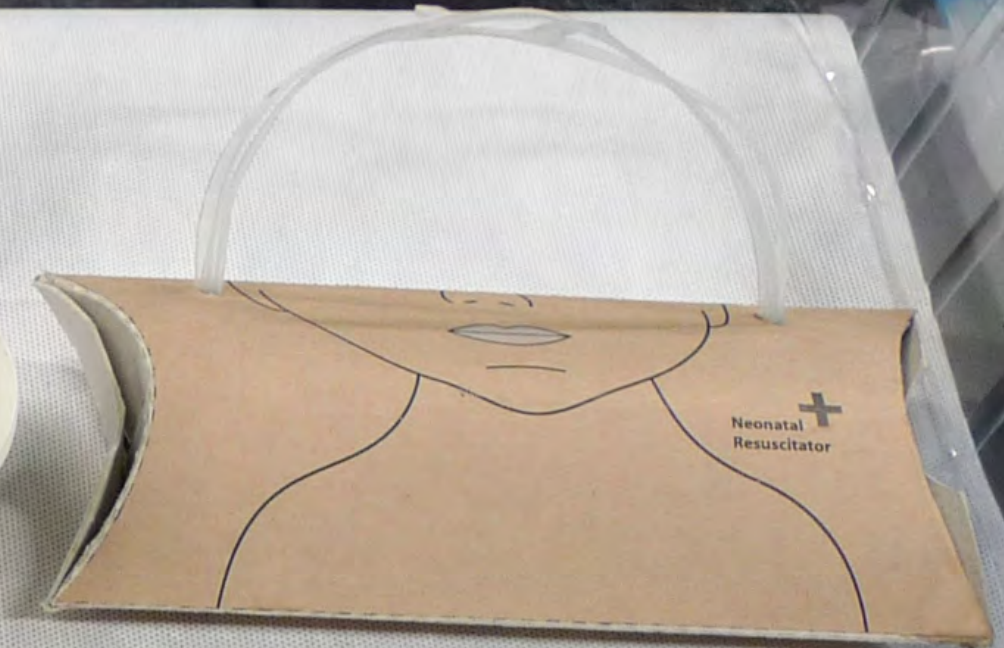


In many developing countries where culture acceptance and appropriate aesthetics heavily influenced the success of new product/system intervention, this concept opens up a wide range of opportunities for customisation. The overall aesthetics of the device can be designed / developed by the locals. Prototyping with weaving patterns and wooden cases were examples of potential concepts.

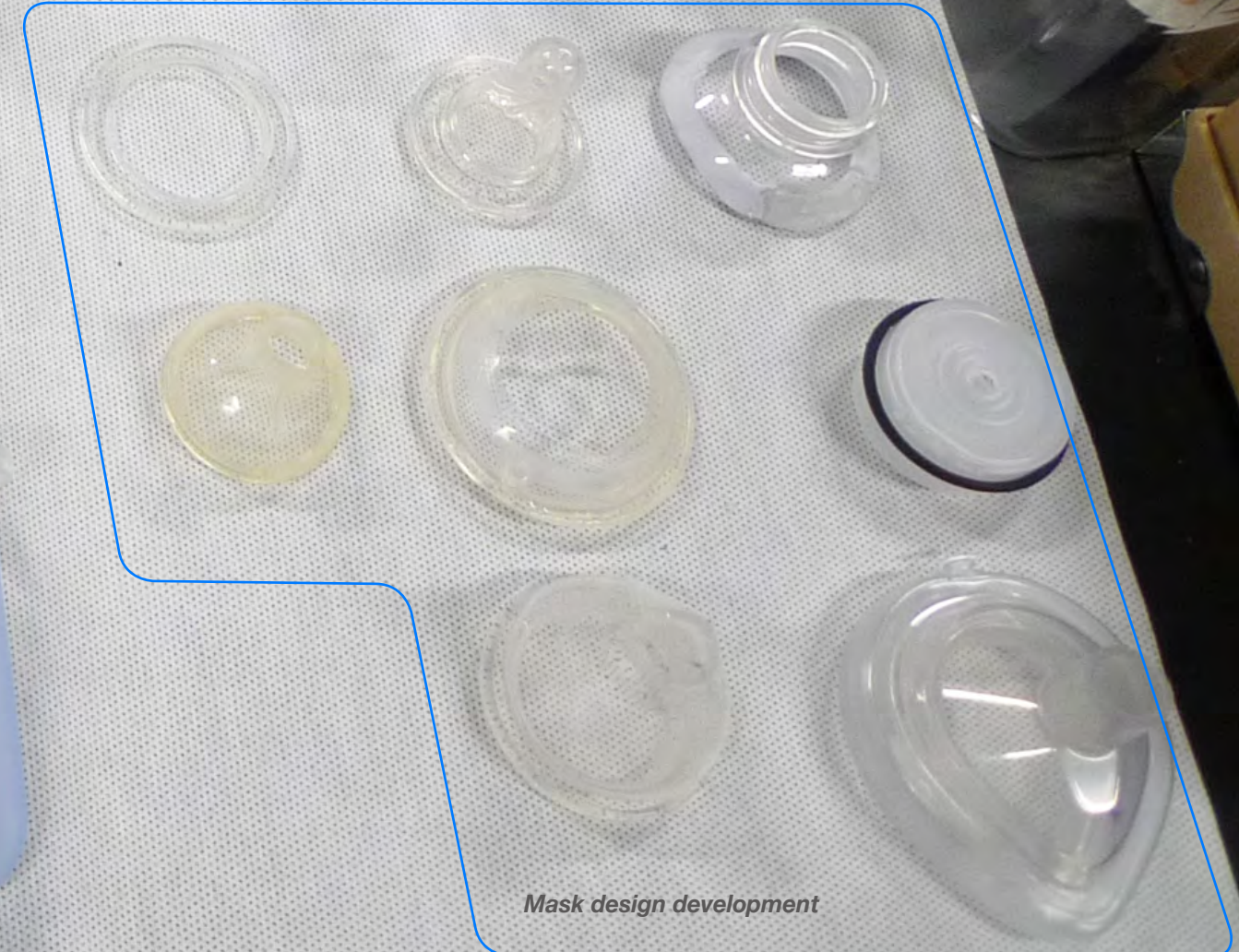




Material & form exploration

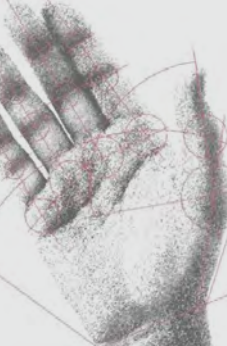


Valve experimentation



Mask design development



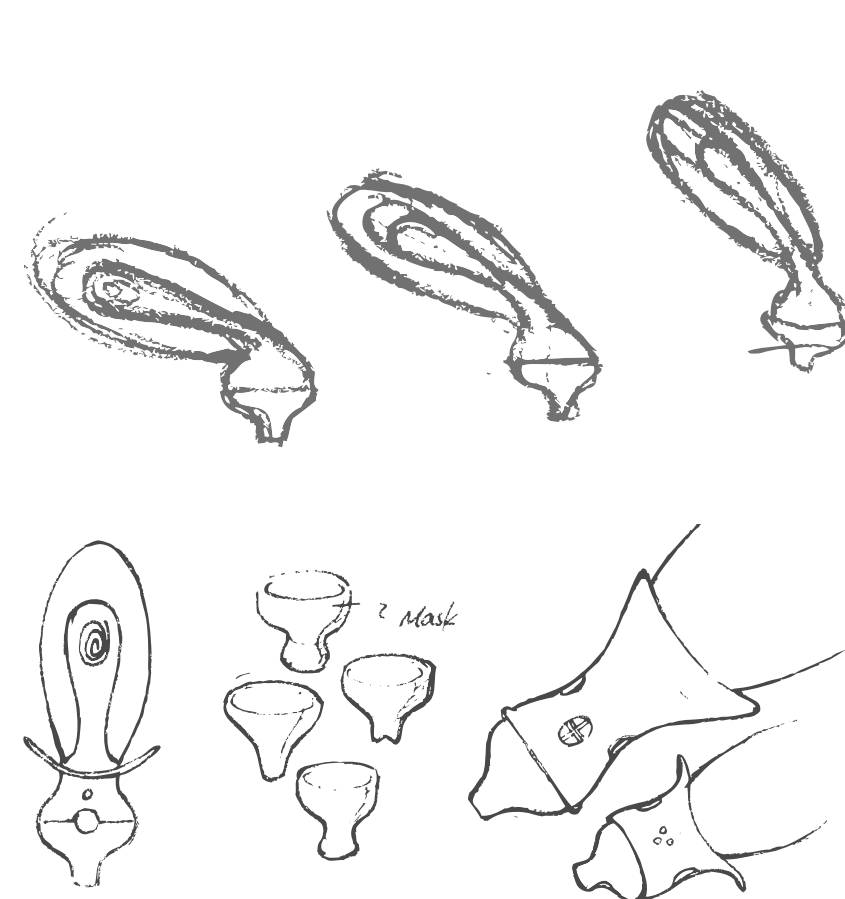


## 3.3 Ergonomics

Neonatal resuscitation requires a large amount of repetitive motion. The continuous motion of inflating and deflating caused fatigue during the procedure. It is critical to design a form and size that is comfortable for different hand sizes, techniques and scenarios. Different users operate the device differently depending on their experience, perception and environment.

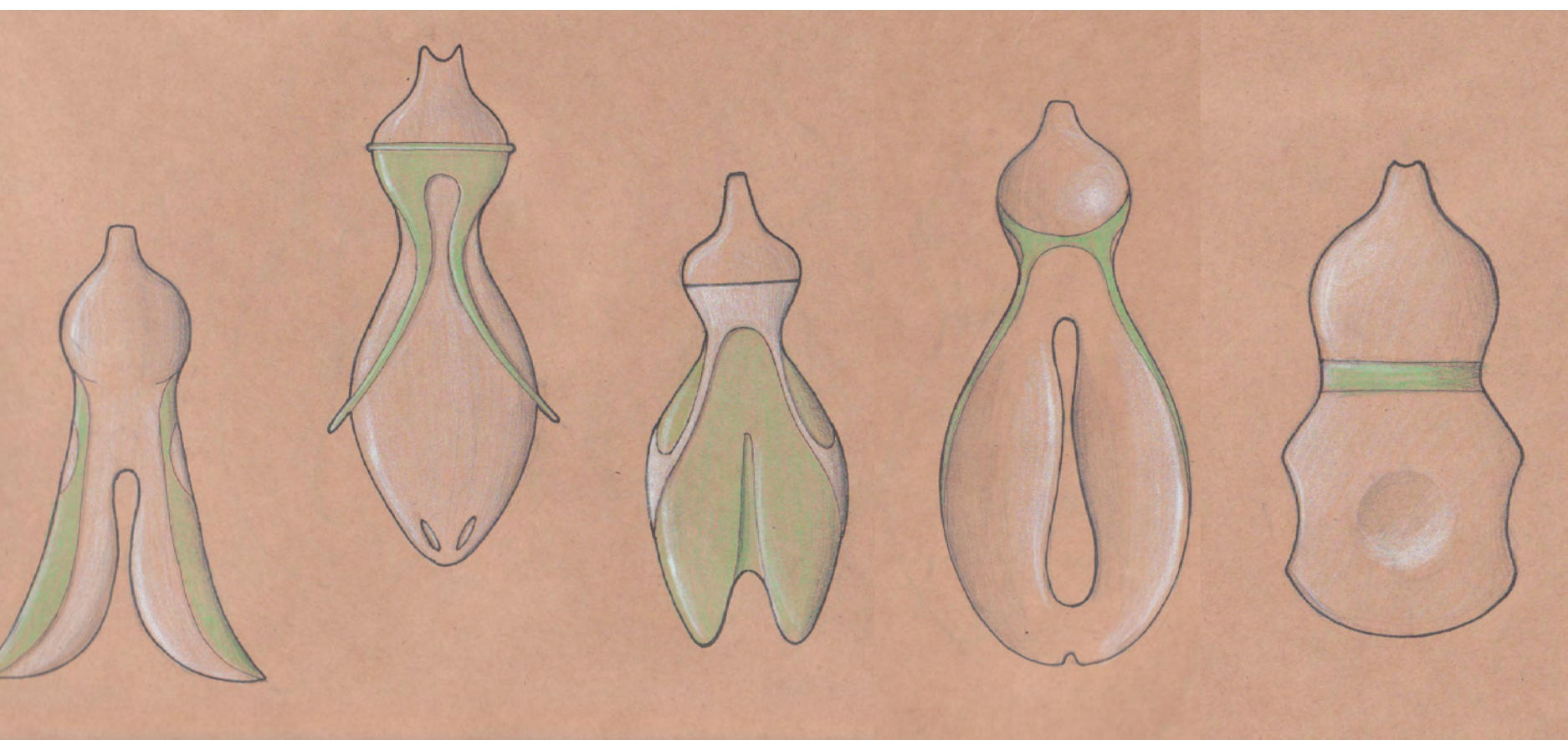
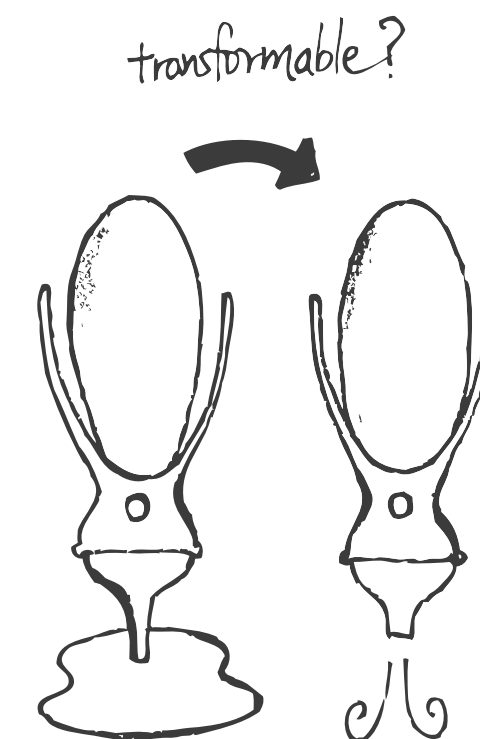
In a low-resource setting, neonatal resuscitation is commenced often in a home birth scenario where the baby is held by the mother while the traditional midwife resuscitates the baby. This is very different compare to most child birth scenarios in the developed countries where the baby is separated from the mother and resuscitation is performed on a clean flat surface.

Sketches on the right and below shows alternative forms and structures for maximising comfort and user-friendliness of the device.

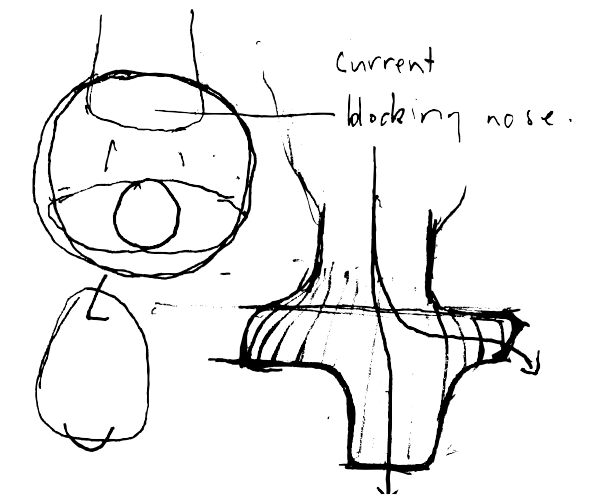
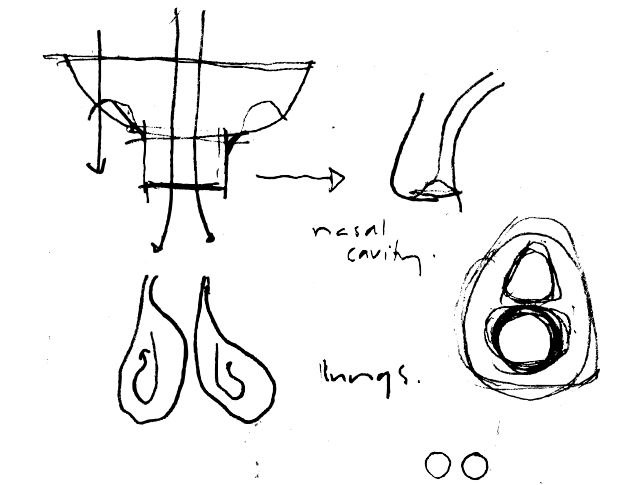


## 3.4 Suction v.s Inflation

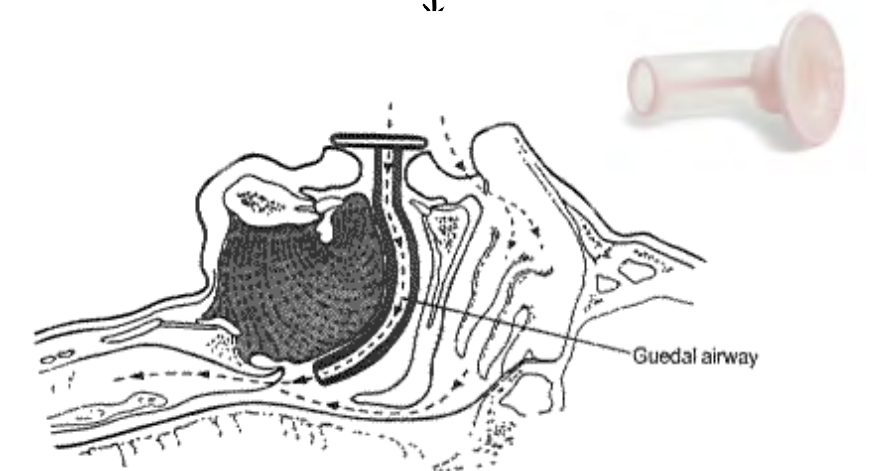
The shape of the mask resembles the form of a suction device. If the suction function can be combined with the resuscitator there will be no delay in the transition of clearing the airway fluid to delivering inflation breaths. However, achieving both suction and inflation will increase manufacturing cost and difficulty.







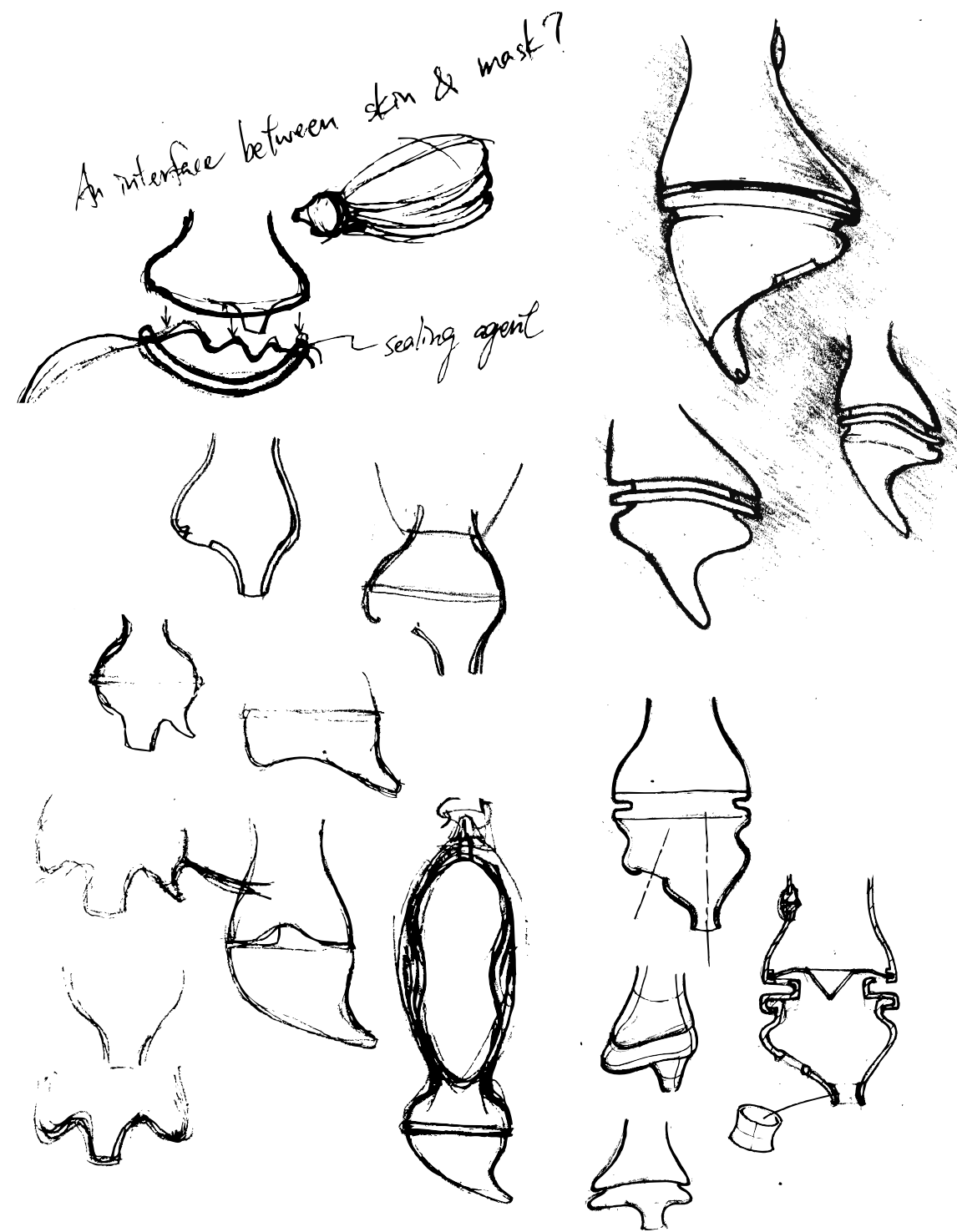
3.12



## 3.5 Mask redesign

Pediatricians and midwives suggested an integration of a 40mm gadaul into the face mask design to prevent the tongue from collapsing and blocking the airway during resuscitation. This intervention also has the benefit of preventing air from flowing into the stomach of the newborn. Photos on the left and on the next page documents the process of prototyping and testing this radical concept. Clinical trials may be required for validation.







## 3.6 Packaging design

Most medical device packaging are designed for the sole purpose keeping the product clean and safe. The Fisher & Paykel Healthcare packaging is an typical example. The packaging is well-designed in terms of aesthetics and gives the user a sense of reassurance.

I was inspired by the forms and material usage of existing packaging design. For example, the 360 paper water bottle from Brand Image is made from bamboo, palm leaves, and other natural plants which is food-safe, 100 renewable and water proof.



fig. 3.13 - 360 paper water bottle



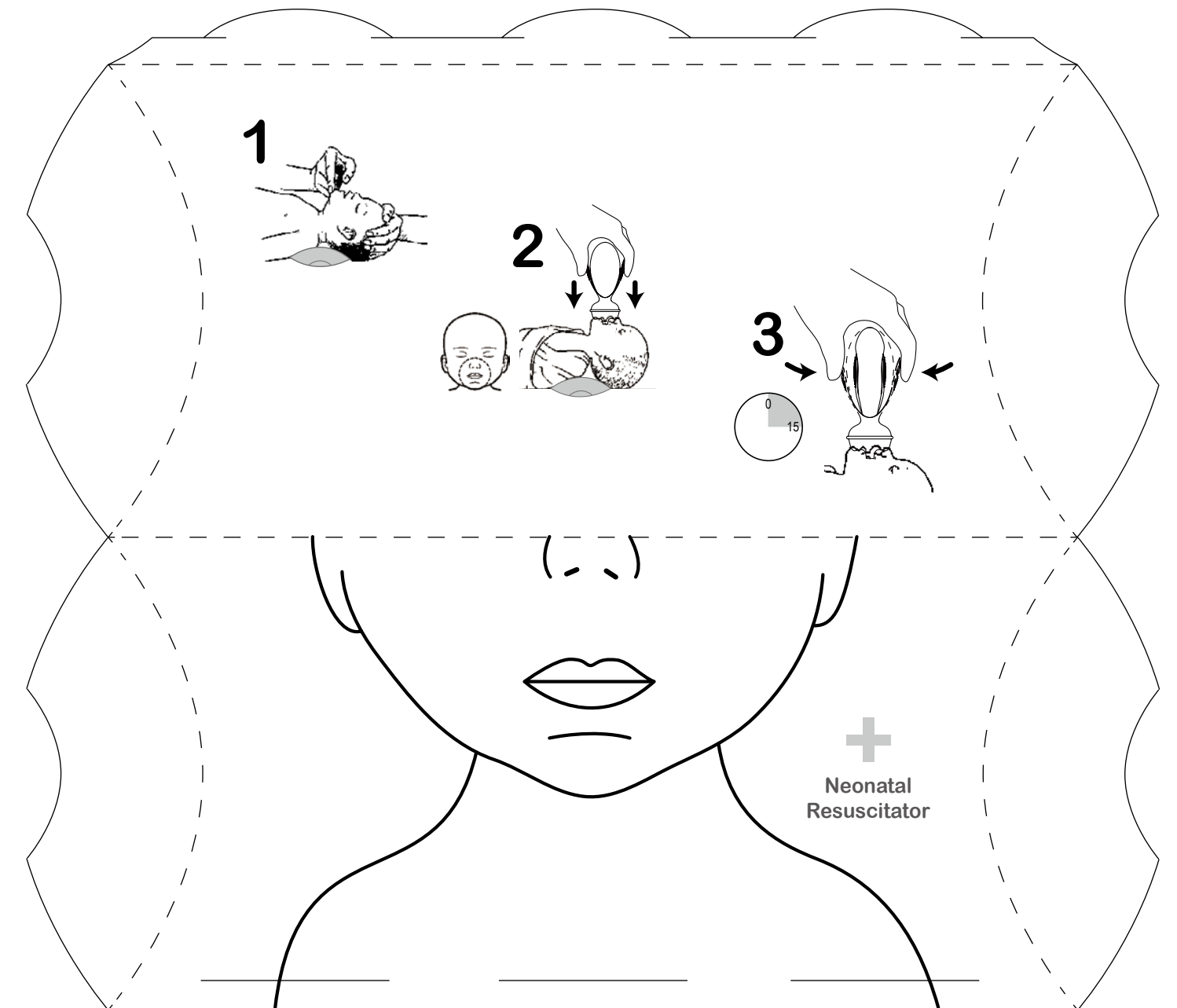
fig. 3.14 - Natural tableware packaging



fig. 3.12 - Unicef woven soccer ball



fig. 3.15 - Fisher & Paykel Healthcare (nasal cannula)



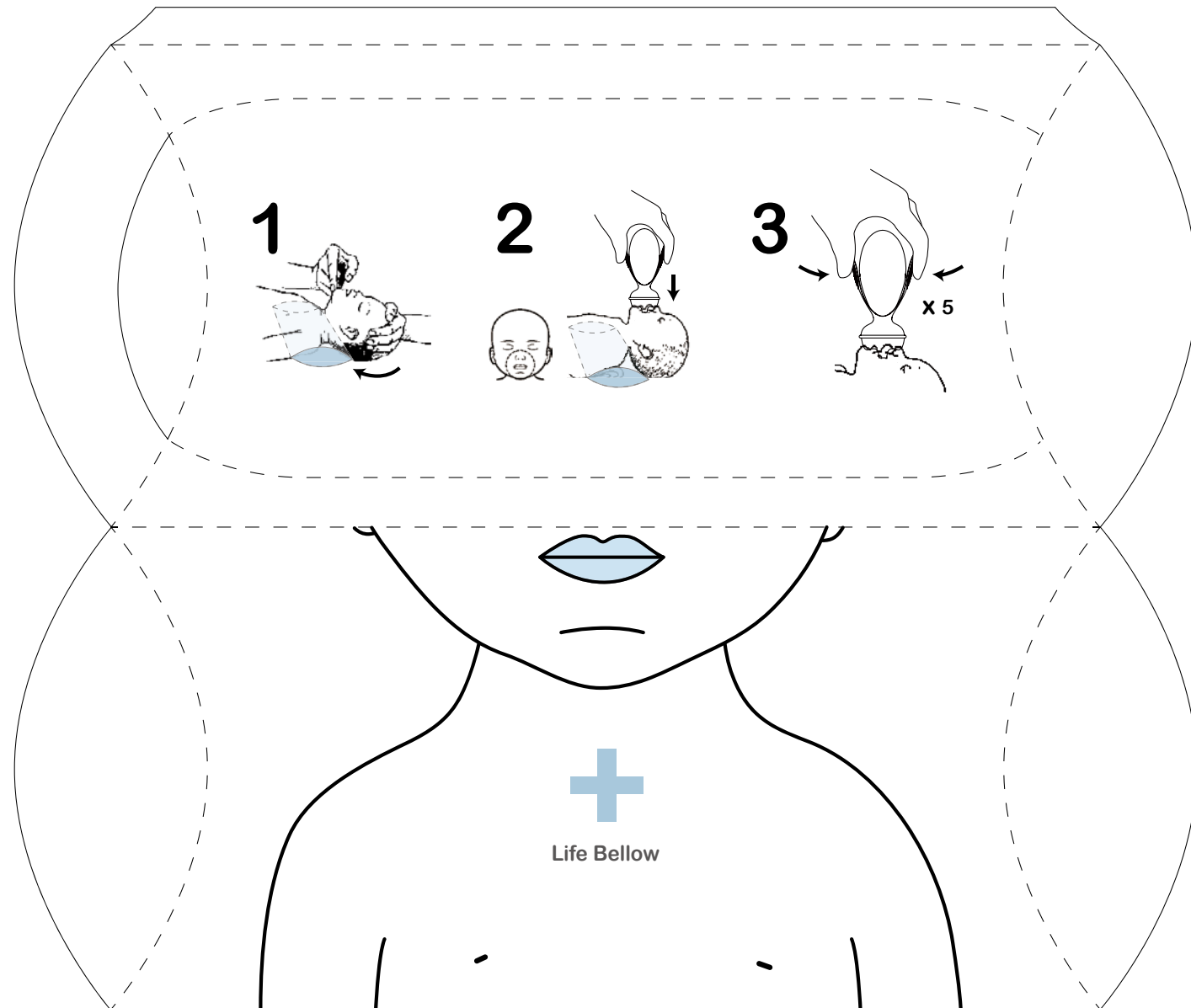
I proposed a multifunctional packaging design that acts as a pillow for maintaining the baby's face at neutral position during resuscitation. The illustration of baby's face, neck and shoulder provide visual cues for the rescuers to place the pillow at correct location. Simple Instructions are printed onto the back of the packaging for guidance. (see next page for further explanation).





A task analysis with a few users was used to evaluate the functionality, usability and feasibility of this concept. Users are surprised and delighted by this concept and suggested a few alterations. The position of the pillow should be under the shoulder rather than the neck. The instructions should be visible during the entire resuscitation process. In addition, information including precautions and warnings should be presented on the packaging.





After a few alterations and adjustments, the new packaging was more pragmatic and user friendly. The instructions are now removable and portable. The height and position of the packaging is accurately designed for the optimal airway position of the newborn.



# 3.7 Material & Manufacture design

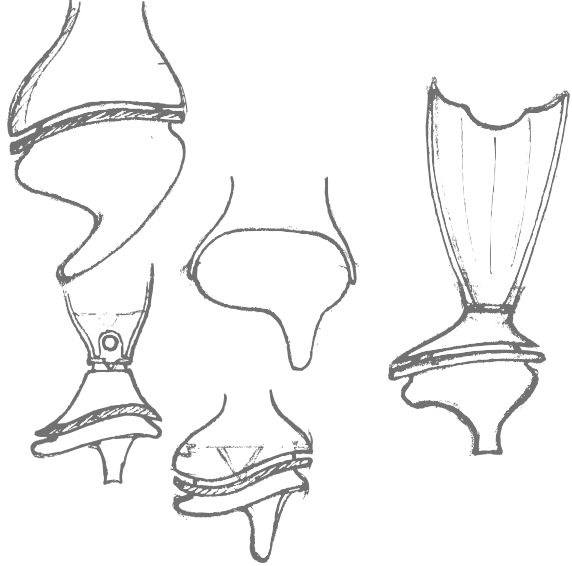
**Minimal parts:** In order to reduce the cost of the resuscitator minimising the numbers of parts is a key design consideration.

**High heat and chemical resistance:** The material selection must be highly resistible to high temperature (minimum 100 °C) and any chemicals. Users should be able to disassemble and sterilise the device in hot boiling water.

**Strength:** The material and construction of the design must endure certain impacts. This means if the device is dropped by the user it would not break and should not affect the overall performance of the device.

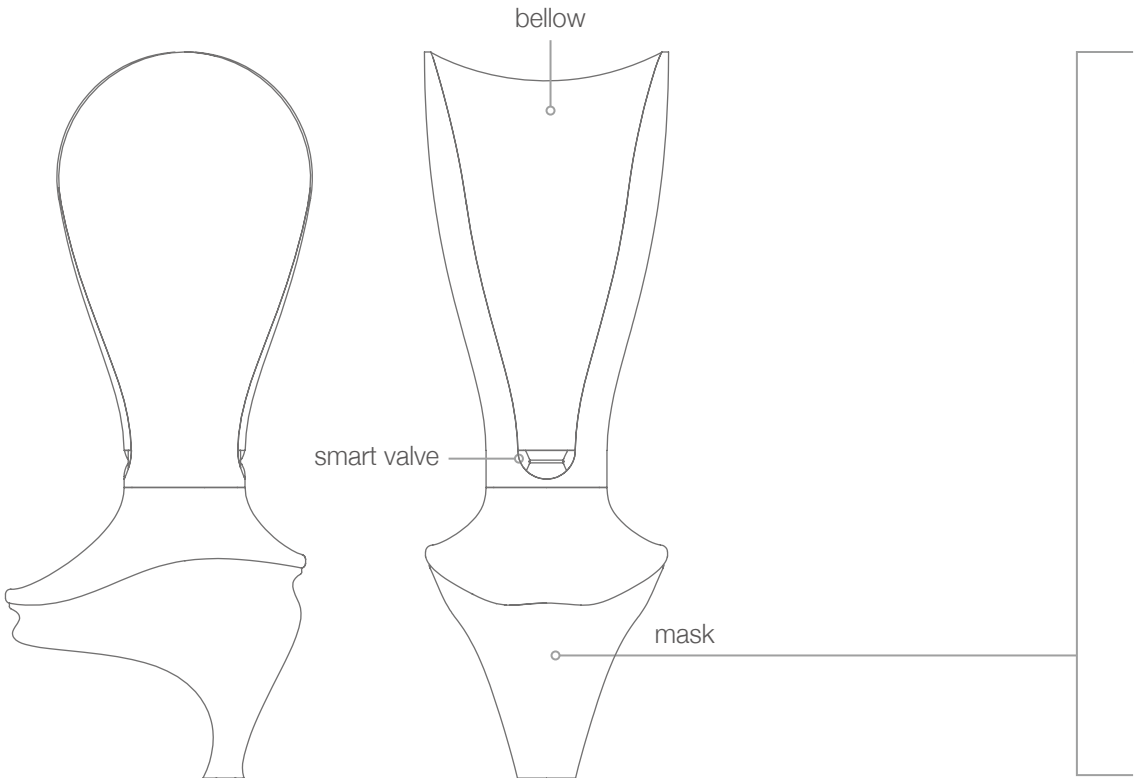
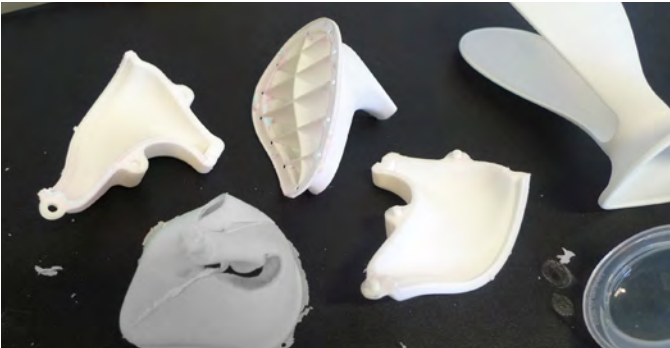
Polymer Type	Attributes	* Tg, °C
Polyvinyl chloride	Excellent chemical resistance, thermal stability, EtO sterilizable	40 (flexible) 80-90 (rigid)
Polystyrene	Moisture and gamma-radiation resistant, high stiffness	90-100
Polymethyl methacrylate	Exceptional clarity, optical properties	105
Acrylonitrile butadiene styrene	Good stiffness, strength, impact and chemical resistance	100-120
Polycarbonate	Strength, Stiffness, toughness, ductility	150
Polysulfone	Tough, stiff, high strength, high heat and chemical resistance, low creep	195
Silicon	High heat and chemical resistance, flexible	250

\* Glass transition temperature (Tg).It represents the lower end use temperature since a material cannot be processed or worked with once its temperature drops below Tg.



Experimentation with silicon moulding

The face mask is made by injecting liquid silicon into a 3D printed, three-part mould. The first trial failed due to the uneven distribution of pressure through out the mould leaving massive air bubbles.





## 3.8 Design evaluation

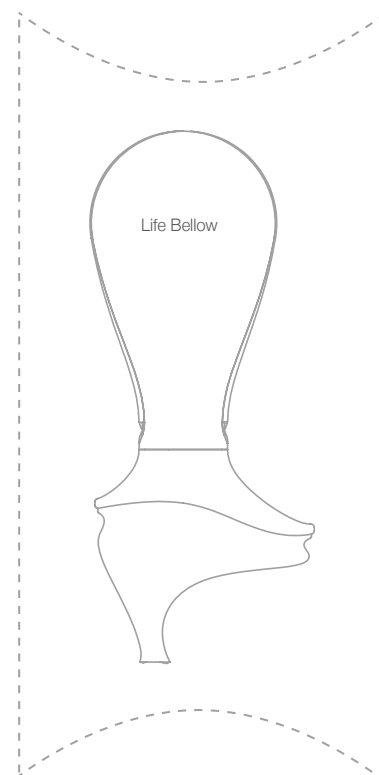
### Functionality

There are four key interventions addressing the functionality of the resuscitator. First of all, the issue with sustaining baby's neutral position is solved by integrating packaging design into the procedure as a shoulder support. The packaging also included a simple instruction and warning to guide the users through out the resuscitation. Second innovation lies in the radical design of the mask seal. The pacifier-like mask rolls over the newborn's mouth and nose as the user applied minimal pressure, creating an airtight seal (However, this concept require clinical trials for further validation). Prevention of over-inflation is the third intervention. The smart valve design releases excessive pressure and volume during inflation. It also act as an air inlet valve for reinflating the bellows. Lastly, The 5-second initial breaths is achieved by the material design of the bellows.



### Usability

The multi-purpose packaging and the redesign of the resuscitator really empowers both experienced and inexperienced user to effectively deliver neonatal resuscitation in different scenarios. Context A, B and C respectively represents modern hospital, home birth, and single-rescuer scenarios. The resuscitation device is designed to cater different needs in different situations. The device can be sterilised easily by placing it in boiling water for 5 minutes.



### Aesthetics

The form of this life-saving equipment is under continuous development. Additional user feed back and contribution is required to develop appropriate aesthetics for various contexts. Customisation may be a concept that will be applied to future prototypes. As this tool becomes more integrated in different countries and communities, the users and stake holders should be redesigning the design language. The form and aesthetics of the resuscitator should leave rooms for such development.

At this stage, I decided to follow the principle of form follow function and explore notion of minimalist design.

According to the midwives, all medical products should be designed with a clean, safe and durable aesthetic. The goal is to challenge the stereotype of current manual resuscitator while retaining the user perceptions of medical devices.





## 3.9 Development phase reflection

The journey of learning and practicing sustainable design has been inspiring and thought-provoking, but at the same time it is exhausting and full of irony.

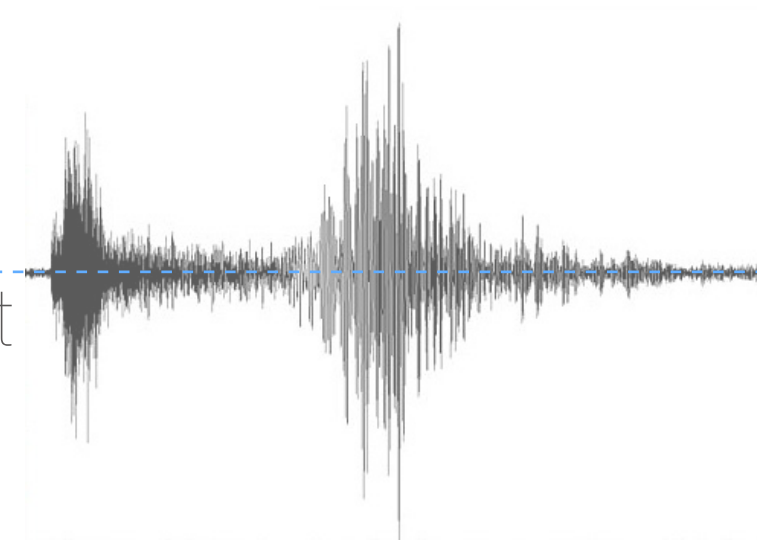
The more I practice neonatal resuscitation on the baby manikin, the more I find it daunting. I often question myself, "Is this the right thing to do?" or "What if the intervention is inherently wrong?". But I realise that there are experts who supports my concepts and encourages me to step up and deliver. It is definitely reassuring and comforting to be accepted and affirmed by professionals and end users. I acknowledged that this project has a long way before it can be called a success. Clinical trials are huge obstacles that prevent me from advocating my design process and solutions. However, there are always alternatives such as manikin simulation or animal testing.

During the development phase, I learned that looking at Third world constraints from a new and positive perspective, rises abundant opportunities for radical solutions and entrepreneurship. Poverty and other wicked problems can be seen as opportunity for enlightenment for both developing and developed world. New relationships will emerge. Humanitarian design can turn the seemingly impossible goals and dreams into reality.

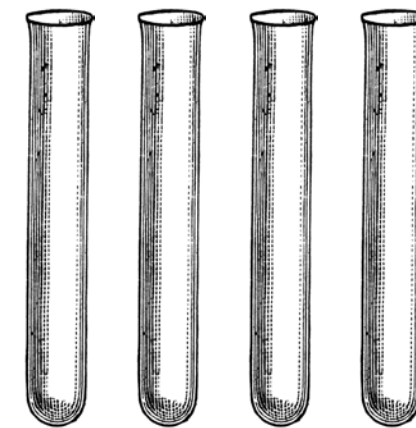
I am proud to be the agent for change. Design thinking has become the best tool for shaping a more sustainable and positive future.

# 危機就是轉機

Crisis is the turning point





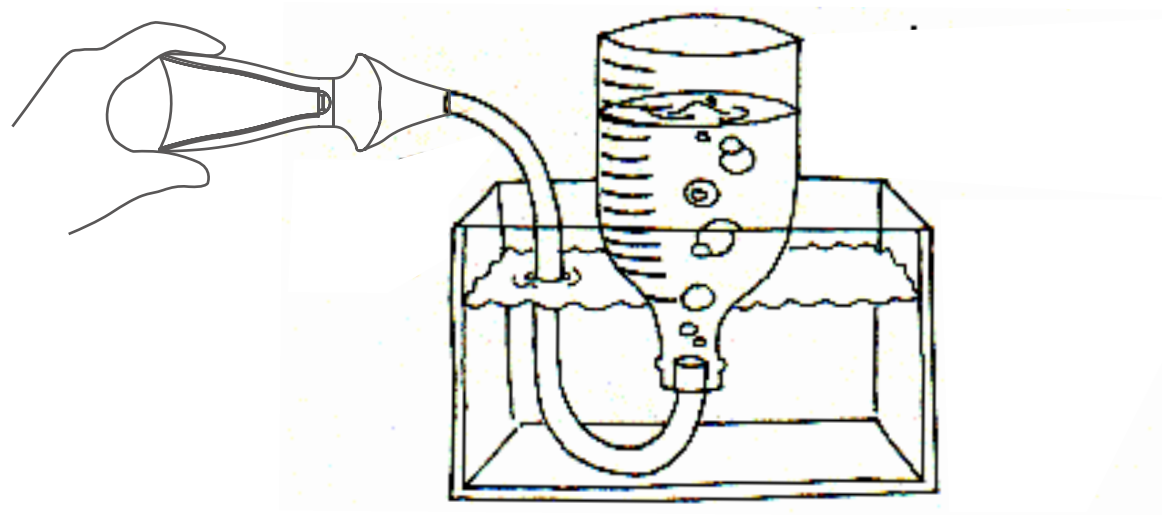


## 4.0 Validation phase

4.1 Air volume displacement

4.2 U-tube pressure test

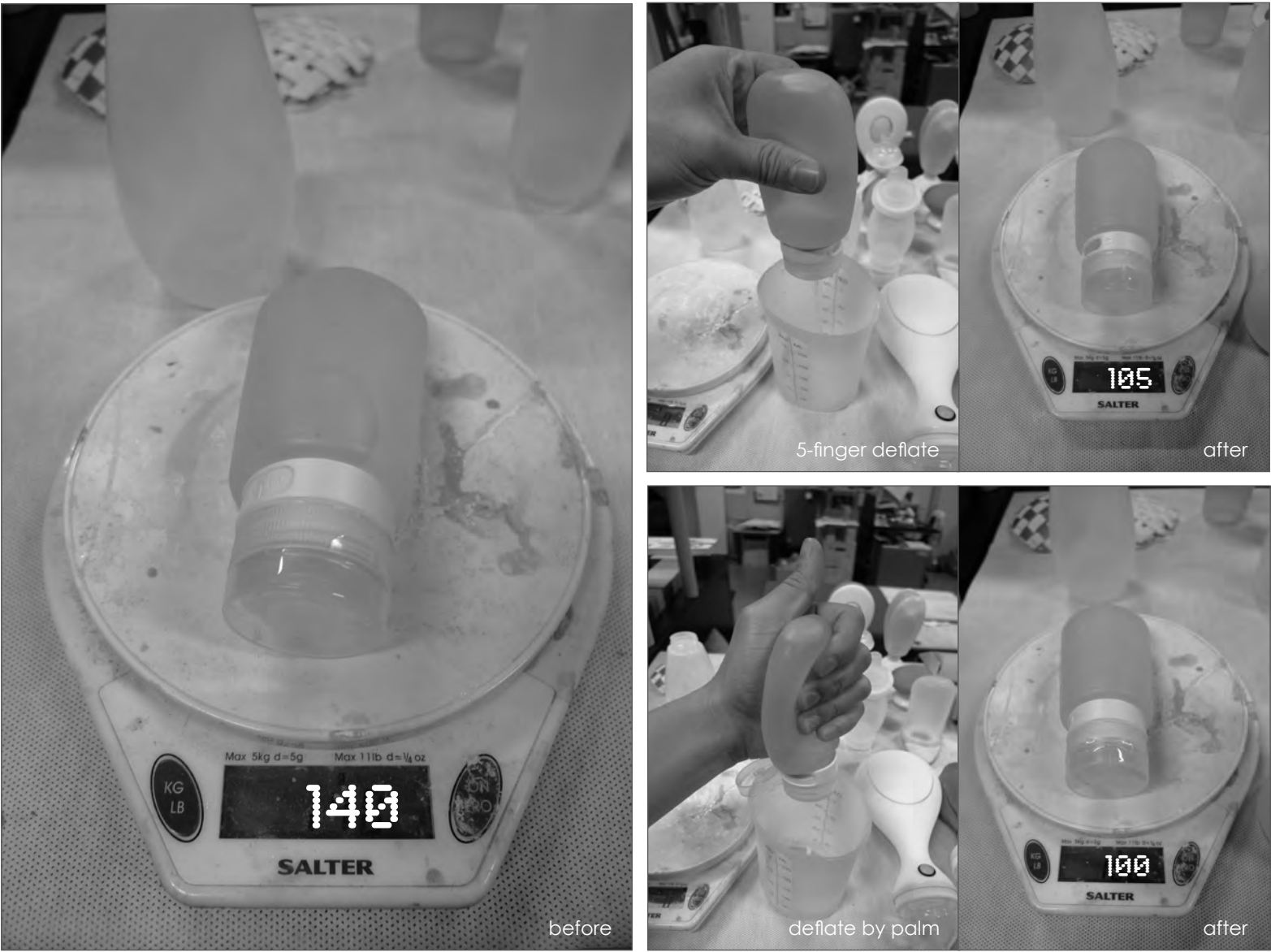




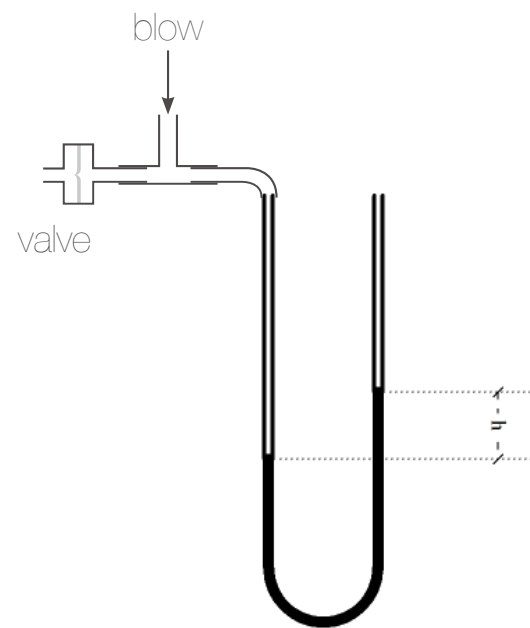
#### 4.1 Air volume displacement

For an average term baby, their lung capacity is approximately 30 ml. This experiment examines the relationship between the hand width of the users deflation techniques and the amount of air volume they deliver. Model A represents the new intervention while Model B represents the existing bag-valve-mask device. The data clearly shown that Model A was able to control the air volume regardless of hand width and techniques compared to Model B which the air volume is directly proportional to the hand width.

Model A				Model B			
hand width (cm)	4-finger deflate (ml)	5-finger deflate (ml)	deflate by palm (ml)	hand width (cm)	4-finger deflate (ml)	5-finger deflate (ml)	deflate by palm (ml)
7	30	28	31	7	30	40	45
7.5	31	30	29	7.5	35	40	55
7.5	31	32	31	7.5	40	35	57
7.7	30	30	30	7.7	44	45	70
8	29	29	28	8	45	49	65
8.6	29	30	31	8.6	44	50	72
9	30	29	30	9	47	48	75



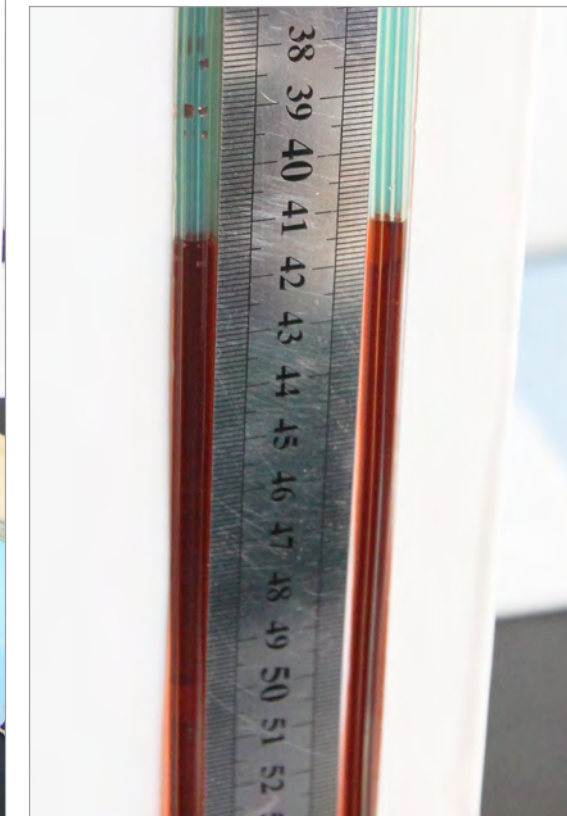




## 4.2 U-tube pressure test

The resuscitation device must provide enough pressure to provide adequate ventilation but not too much to cause damage to the newborn's lungs. 30 cmH<sub>2</sub>O for the outlet pressure and 5 cmH<sub>2</sub>O for the PEEP (positive end-expiratory pressure) was recommended by practitioners. The U-tube pressure manometer was designed to validate the models. The data bellow shows that model A was a success while model B failed to provide adequate outlet pressure. It is clear that the pressure relief valve is functioning properly while the PEEP was too high. PEEP valve requires further development.

	model A (cmH <sub>2</sub> O)	model B (cmH <sub>2</sub> O)	pressure relief valve (cmH <sub>2</sub> O)	PEEP valve (cmH <sub>2</sub> O)
test 1	30	22	30	10
test 2	29	25	28	7
test 3	29	19	29	8
test 4	30	20	29	11



30ml of dyed liquid, a T-piece tube, a long flexible tube and a ruler is required to carry out this experiment. The only variable that are changing is the air volume of models and the deflation rate of the operator's hand.

The distance between the low end point and the high end point of the red liquid measures the amount of pressure of each test subjects. For instance, 50 cmH<sub>2</sub>O - 20 cmH<sub>2</sub>O = 30 cmH<sub>2</sub>O (centimetre of water).



## 5.0 Discussion & Conclusion

Sustainable design should be the next modernism. A paradigm shift is needed urgently in today's wasteful and irresponsible society. Design is at the core of it. The concept of designing for mass production has breed a culture of consumerism. As Jackson Living (2010) points out that consumerism "is a story about us, people, being persuaded to spend money we don't have on things we don't need to create impressions that won't last on people we don't care about." Today, human beings has been confronted with environmental, social and economic crisis all over the world. It is time to ask ourselves, Is there a new way to live and prosper?' Designers need to take initiative and collaborate with the public in order to construct a more sustainable and harmonised future (Ciegis, 2009).

There are two billion people worldwide who are in need of food, clean water, shelter and better healthcare. It is clear that most designers had excluded the marginised and underserved population. Pilloton (2009) urges "designers to stop talking big and start doing good." We need to think and act at a global level while recognising and celebrating human diversity (Coleman, 2007). There is no better time than now for designers to embrace extreme constraints and view limitations as opportunities for innovation and growth.

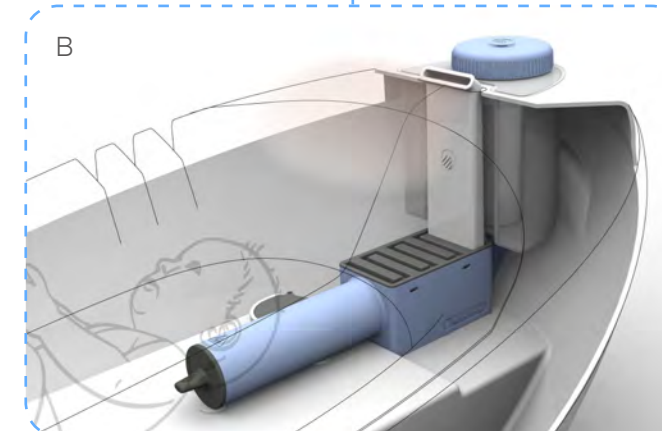
Healthcare industry in Western countries has developed to a point where technology advancement has override the importance of human factors, while healthcare systems in the Third world struggles to provide basic medical needs to the public. There seems to be two different problems but originate from the same root. It is all about listening and observing people of their true needs while humanising and employing appropriate technologies (Papaneck, 1985).

In 2010, I was involved with Fisher & Paykel Healthcare for redesign a medical humidifier for ICU(intensive care unit) patients with breathing difficulties. This experience allowed me to understand that psychosocial factors plays a major role in patient recovery. The result was a intuitive humidification system that empowers the nurses to bring patient care to a new level of comfort and reassurance (figure A).

Designing a humidification system (figure B) for a low-cost incubator that will be used in developing world settings (In 2011) has lead me to explore the notion of inclusivity and social responsible design. The outcome was a simple and noble invention featuring ceramic panels as evaporative medium while filtering 99% water-born bacterias. The ceramic medium can be manufactured economically and locally.

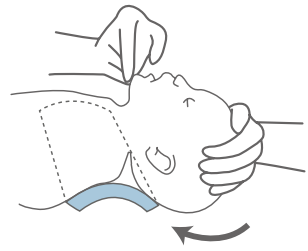
This year, utilising Third World constraints as innovation drivers for the developed world is the theme. I used neonatal resuscitator design as a case study for exploring appropriate technologies and aesthetics for both developing and developed world (figure C). It is through co-designing and co-creating with users, including midwives, paediatricians and neonatologist, that suitable and desirable interventions are established. The research project focuses on responsibility in design process and solutions while embracing constraints and fostering positive social impact.

I believe designers must go beyond the mentality of 'us vs. them' and establish new relationships between different worlds. After all, we are global citizens. So lets redefine a meaningful sense of prosperity and celebrate life by designing towards a sustainable and responsible future.

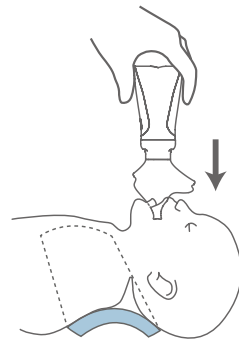




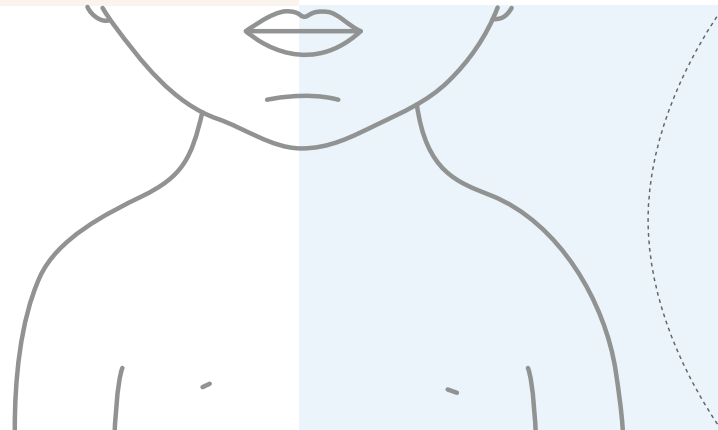
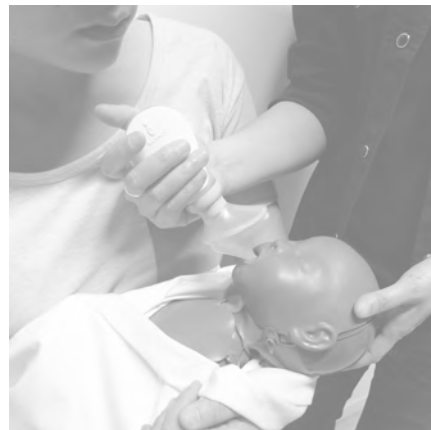
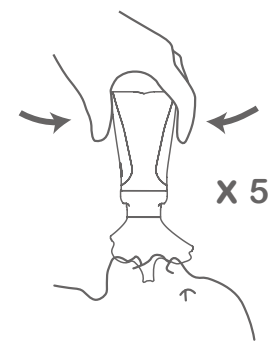
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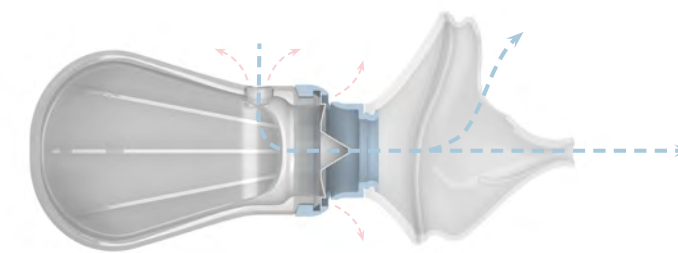


## 6.0 Final Exhibition

### Design Proposal

There are four key innovations addressing the functionality of the resuscitator. First, the issue with sustaining baby's neutral position is solved by integrating packaging design into the procedure as a shoulder support. The packaging also includes simple instructions and warnings to guide the rescuer through out the resuscitation. The second innovation lies in the design of mask seal. The pacifier-like mask rolls over the newborn's mouth and nose as the user applied minimal pressure, creating an airtight seal. The pressure relief valve is the third feature which prevents over-inflation of baby's lung. The valve releases excessive pressure and volume during inflation. It also act as an air inlet valve for reinflating the device. Lastly, The 5-second initial breaths are achieved by controlling the air flow rate with the one-way valve.

The multi-purpose packaging design and the redesign of the resuscitator empowers both experienced and inexperienced user to effectively deliver neonatal resuscitation in different scenarios. The resuscitation device is designed to cater different needs in different context such as modern hospital, home birth, and a single- rescuer scenario. The form of this life-saving equipment follows the principle of 'form follows function' and explore notion of minimalist design.



--- air inlet  
--- air outlet







“Charles Eames, the renowned designer, offered the view that design is defined by the willingness to embrace constraints.”

Design inspired by Third World constraints is the core principle of this research project. It often means a ruthless pursue of affordability, accessibility and reliability. Products and systems must be low cost, low maintenance, intuitive to use and highly reliable to meet users' needs. Embracing these constraints lead to highly creative solutions, which may have profound impacts on people's health and well-being. Through empathising and co-designing with users I was able to research and design from the grass-root level. The level of connection brought livelihood to the design process and the result is rewarding.

This research project applied user-centred design principles to enhance the experience and effectiveness of neonatal resuscitation for inexperienced rescuers in both the developing and developed world contexts. The claim that 'design has a social agenda' and 'the need for designers to aspire for a paradigm shift to include the underserved population' will be met if field testing is carried out and proven successful.



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## Appendices



# The story of Baby Job

*An example of how Helping Babies Breathe is saving newborn lives in Kenya*

Key:

Sherri: Sherri Bucher (PhD), Assistant Professor of Research, Indiana University School of Medicine and Helping Babies Breathe—Kenya investigator, January 2009 to present.

Mary: Mary Wekesa, Maternal-Child Health and Family Planning nurse, Bokoli sub-District Hospital, Kenya. Helping Babies Breathe Master Trainer.

Emily: Emily Wekesa (no relation to Mary), mother of a baby saved by Helping Babies Breathe techniques in October 2009.

Davis: Davis Wekesa (no relation to Mary), father of a baby saved by Helping Babies Breathe techniques in October 2009.

Josephine: Josephine Wanyama, lab technician at Bokoli sub-District Hospital in Kenya; although previously untrained on Helping Babies Breathe, she assisted Mary Wekesa when Emily and Davis’ son was born with breathing difficulties in October 2009.

Notes:

--Interview was conducted by Sherri Bucher on October 8th 2010 at Bokoli sub-District Hospital in Kenya. English portion of the interview was transcribed by Bucher; Kiswahili portions were translated and transcribed by Dr. Olive Konana.

--Nurses are called “Sister” in Kenya.

--Interview was videotaped. Videotape is available for review, but is of poor quality.

The excerpts below provide various accounts of Baby Job’s harrowing birth and successful resuscitation, as well as thoughts

about the Helping Babies Breathe program from the viewpoint of (1) Baby Job’s mother (Emily); (2) his father (Davis); (3) the nurse who saved Baby Job because of her Helping Babies Breathe training (Mary); and (4) a hospital lab technician (Josephine) who, although untrained on Helping Babies Breathe at the time of Job’s birth, was instructed by Mary, in the midst of the crisis, on various steps to follow, and as a result, contributed to Job’s successful resuscitation.

Emily: 2009. When the baby was born, I truly did not know whether he would be fine, because when he was born, at the beginning, when the time came, truly this sister (i.e., nurse) helped me. Because at the beginning, you pulled my water? (i.e., ruptured the membranes to facilitate delivery)

Mary: Hmmmm

Emily: Now, when the baby was just born, the baby was dead. And, this sister ran and took, there were...were...various instruments there, and she came to help me. She took them and put them in the baby’s nose. When she put them in the baby’s nose, and in the month, and she started to pull out, there were things like...like...secretions...that were stuck in the nose, and she started to pull and pull and pull...

Mary: Mucous from mouth and nose...that’s what she’s saying

Emily: And that’s when the baby started to wake up...after a very long time had passed indeed

Josephine: .....But when the mother delivered, I was worried. I had never seen that, that...what...type of a baby coming up. It was flat (i.e., limp and not moving). And bluish. So I was very worried. And Mary said “let us try, this kid might come back.” So she started doing it. So I saw as if she was taking time...because she wiped the baby first. She wrapped, then she opened up the chest (i.e., opened the cloth within which the baby was wrapped to expose the chest and watch for breathing) and started removing the secretions. After which she told me to give her the what? Ambu bag? What?

Mary: A bag and mask...ambu bag, yes

Josephine: Yes. And she told me, so, I assisted her to press inside this and we saw the chest coming up.... so...afterwards, but the mother was very worried. She was asking “Is my baby dead?” Because, there, there was no sign of life.

Mary: And also the father of the baby was also there very much worried. But I’m sure they now have the testimony. They have something to tell others in the community about hospital delivery. The importance of hospital delivery. And with the equipment and with the skills babies can survive. Yeah. And that’s why, in this community now neonatal deaths are very much reduced. Josephine: Anyway, I was also impressed because I learned something new. I can be caught alone and I think I can apply the same...

Sherri: Aye! (laughter) Good!

Josephine: I can apply the skills to make another baby survive.

Sherri: Yeah!

Josephine: So, we thank you for the training for our people because they come and train us on job. Although I’m not a nurse, I’m not (laughs) but I can do it, it come come on your way.

Sherri: Yeah. Were you surprised at how simple it was?

Josephine: What?

Sherri: The program. That it was simple? The...you mentioned that you were concerned because you thought “oh, sister’s taking time to dry.”

Josephine: Oh...

Sherri: Sister’s taking time to dry...

Josephine: Oh, this baby will die (laughs). Because it was not breathing.

Emily: And I thank sister Mary to assist my child to get a life

Sherri: It’s true, yeah, thank you. And he (i.e., Baby Job) is very active. I’m gonna zoom in on him. (laughter)

Mary: So Job’s father, do you have something to say?

Davis: Yeah, mine is just to thank Dr. Sherri for the health care, for encouraging us..umm..I also thank the sisters here sister Mary and um...umm...also...but you are most welcome next time...

Sherri: Thank you. And have you shared your...your story about Job with other people? Neighbors? Friends? You mentioned the

grandmother was at the delivery...

Davis: Yeah

Sherri: What, what has been the grandmother’s feelings about her grandson? I mean...  
Emily: My mother was worried

Mary: She was worried and after that she became excited

Emily: Yes

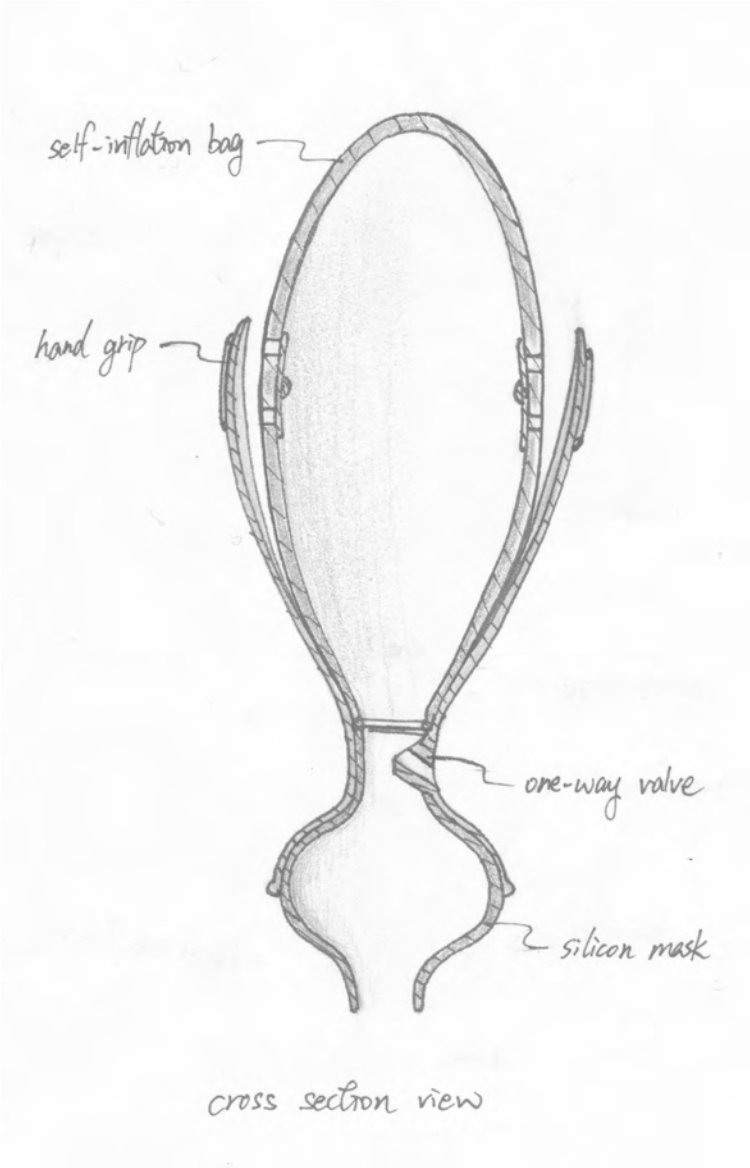
Mary: So Dr. Sherri is asking you, do you share your joy and story with other women in the village?

Emily: Yes, we share and I tell them about how my baby was born, about how he had no life, and we say that...even if...you know, I say that if I was not near sister, I don’t know if my baby would be alive.

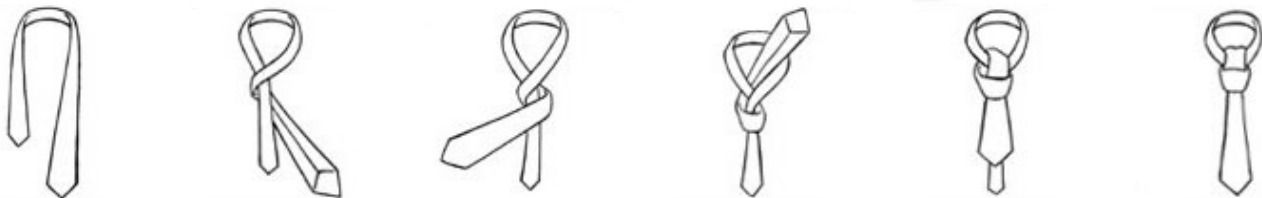
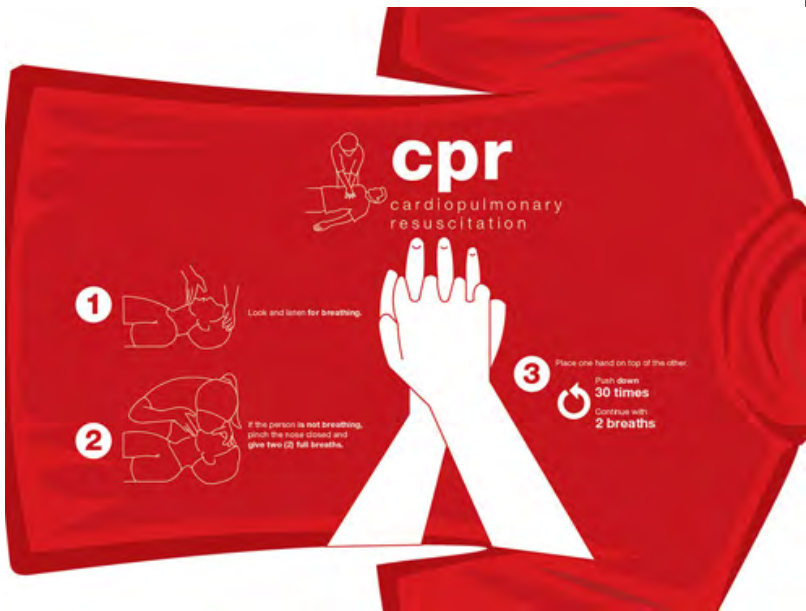
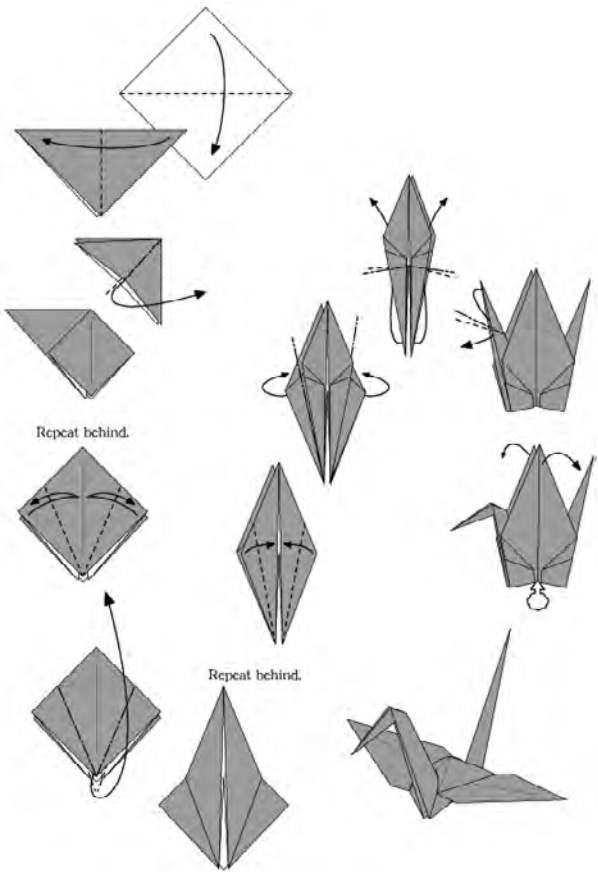
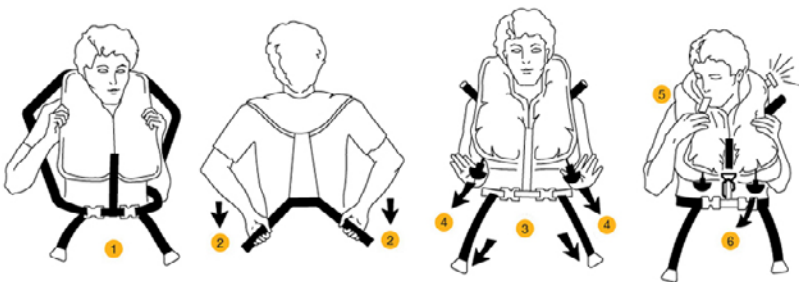


Appendix 2

I addressed issues regarding ergonomic form, grip design, valve design, colours, and validated mechanics of the concept with rigorous scientific testing. When a fully functional model is produced, field testing will be executed with users and experts for final feedback and suggestions.



Instructional design inspiration







## History

Children and adults can suffer breathing difficulties. Resuscitators were used for these emergencies, as well as for victims of smoke inhalation, drowning and electric shock.

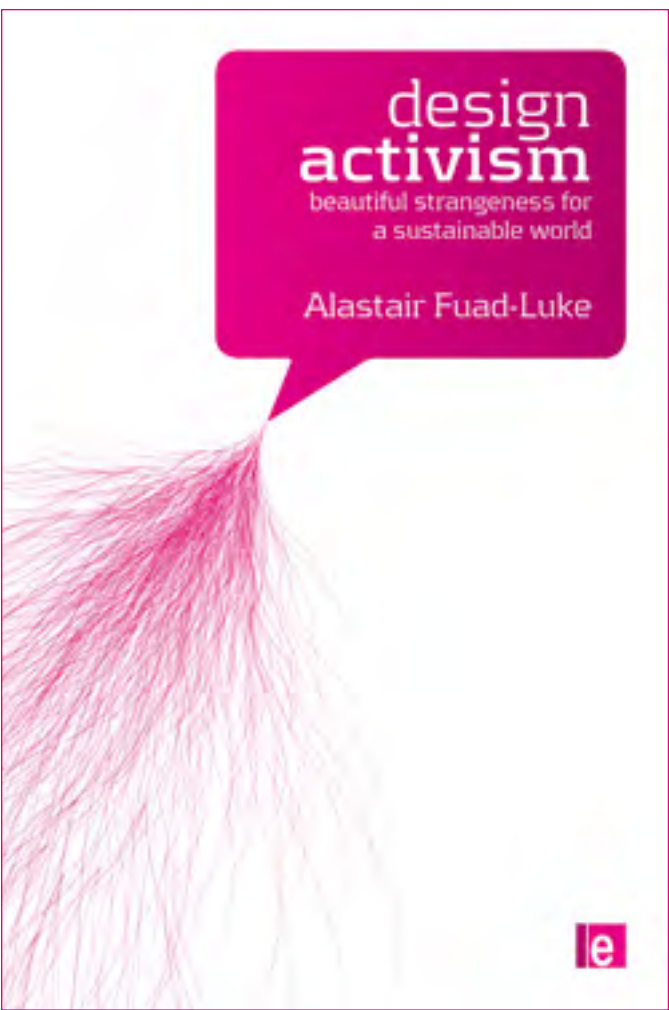
Dr. F. A. Duncan Alexander (1908-1983) was the director of anesthesia services at Albany Hospital when he and his colleague, Dr. Charles E. Martin, developed this resuscitator. Made by the Foregger Company, it was patented in 1942. This attempted to improve on direct mouth-to-mouth resuscitation in several ways. It placed the operator at a slight distance, so that the patient's breathing could be observed at the same time. It limited the force of exhaled air entering the lungs, an important consideration for infants. It also had a filter to reduce the exchange of microbes, and a port for attachment to a source of additional oxygen. The resuscitator could be fitted with a range of mask sizes, but it was primarily intended for pediatric use.

Lungmotors were made by the Lifesaving Devices Company of Chicago. The infant model had to be used with caution to protect the small, fragile lungs of these patients; but anxious rescuers could pump too forcefully. Like the Pulmotor, these devices were condemned by studies which showed that they were liable to do more harm than good.

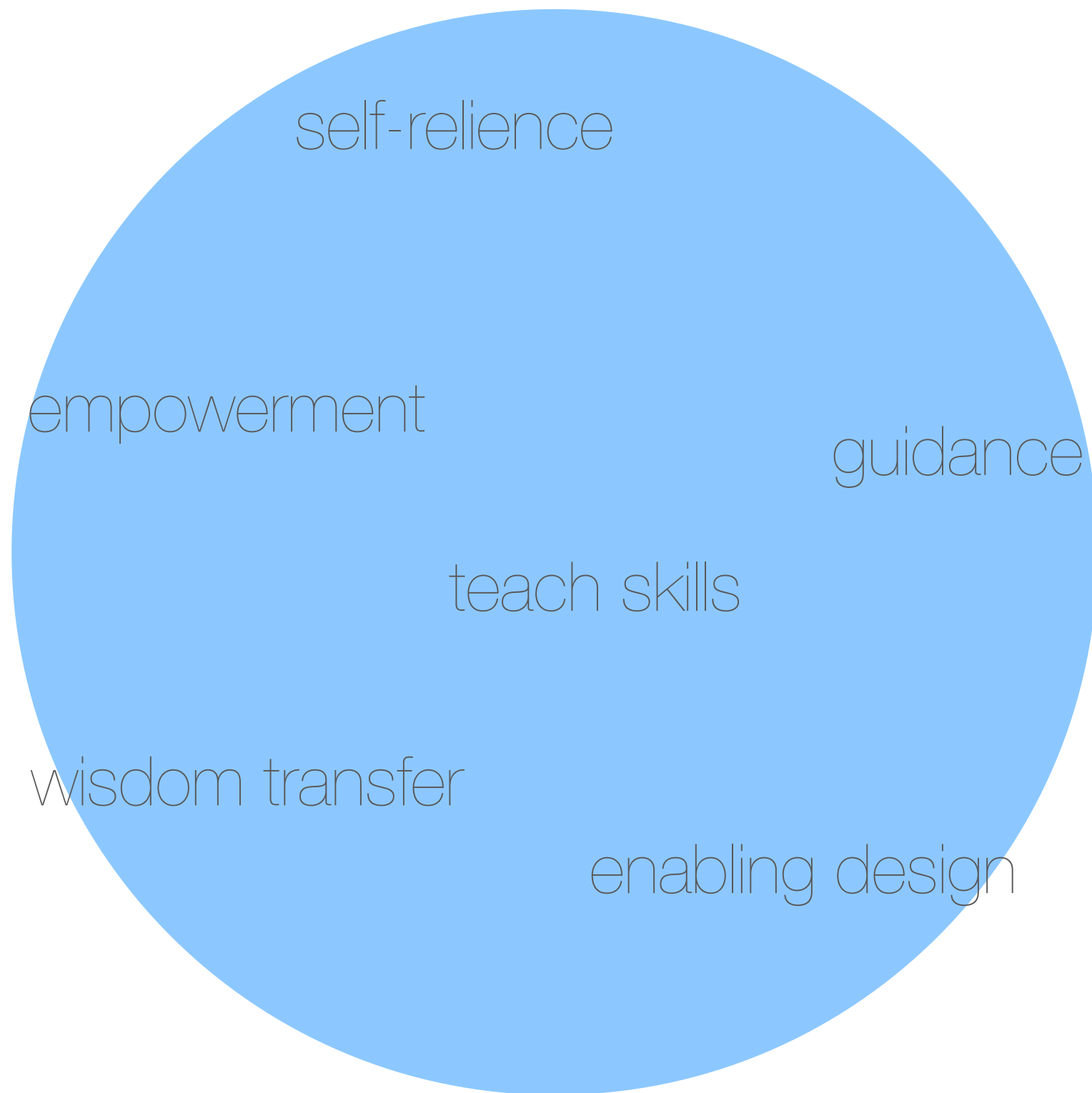




It turns out that great artists choose to constrain themselves all the time. Some of Picasso's most moving works were made in his blue period, when he constrained himself – consciously or otherwise – to a limited, stark color palette. While I love buildings where Antonin Gaudi used a bricolege of colored tile, his most moving building, Sagrada Familia, shows the architect constrained to simple, smooth white shapes. And it wasn't until I bothered reading up on Joan Miro that I realized that he was a phenomenally technical painter before he decided to constrain himself to expressive, colorful, childlike compositions that look, at first glance, like doodles. Innovation comes from constraint. And most of us aren't smart enough to know what to do with a blank canvas.







" Give a man a fish  
and you feed him for  
a day. Teach a man  
to fish and you feed  
him for a lifetime "

This is a Chinese Proverb. "If you give a man a fish you feed him for a day. If you teach a man to fish you feed him for a lifetime." It is better to teach someone how to do something than to do it for them. Giving someone a fish is good for the short term, but it is better to teach them how to do it so that in the long term they can take care of themselves. This is a metaphor for empowerment and enabling through design. This quote implies that design is not just about improving convenience and comfort, It should be about fostering skills and wisdom.



