Journal of Engineering Education Transformations,
Volume No. 37, January 2024 Special Issue, eISSN 2394-1707

Difficulty in Opening Glass Ampoules

Pooja Gani[1], Sanjana Patil[1], Radhika Amashi[2], Dr. Vijayalaxmi M[1]
[1]School of Computer Science and Engineering, KLE Technological University, Hubli
[2]Center for Engineering and Education and Research, KLE Technological University, Hubli
[1]01fe22bcs137@kletech.ac.in
[1]01fe22bcs069@kletech.ac.in
[2] radhika.amashi@kletech.ac.in
[1] viju11@kletech.ac.in

***Abstract*—Nurses play a pivotal role in the healthcare sector; we are all well acquainted with this fact amidst the pandemic. A significant yet underestimated task they usually face is snapping off the glass ampoule necks in order to draw the medicine into the syringe during the course of treating patients. This paper ascertains that most of the nurses who encountered this problem were prone to cuts and injuries on their hands due to the sharp edges and medicine spills from the glass ampoules respectively. Thus, the present study aims to address this concern by employing the principles of design thinking as a part of a first- year engineering course; design thinking for social innovation. An active engagement was initiated with the nurses affiliated to a multispecialty hospital situated in Hubballi, Karnataka, India. A keychain glass ampoule opener capable of opening ampoules of 4 different sizes was built as a prototype taking into account the prevention of wounds caused by the uneven edges of the glass ampoules.**

***Keywords*— ampoule opener; cuts and scratches; design thinking; glass ampoules; Nurses;**

***JEET Category*— Research**

I. INTRODUCTION

Over the course of India's historical timeline and within its diverse culture, we have encountered various saints, sages and healers who were zealous towards their service of mitigating the distress and providing ease and comfort to those who were sick in health and needed attention in health care(Jacob, M.M., 2016). The authors of this paper believe that these people have descended into the present world in the form of nurses. In fact, nurses play an indispensable role in the patient's health care. They assist the doctors, take care of the patients in their health and sickness and strive towards the recovery of the patient.

Nurses look after the patients with utmost care and compassion while being responsible and precise about their medical treatment. They are committed to a process that is described as a systematic method of providing care that incorporates the fundamental ideas of critical thinking, client- centered approaches to care, goal-oriented activities, and recommendations from evidence-based practice (EDP), and nursing intuition. The foundation for compassionate, quality- based treatment is built on a combination of holistic and scientific postulates. (Toney-Butler, 2022)

A significant yet underestimated task that the nurses usually stumble upon in their habitual workday is break opening the glass ampoules in order to access the medication inside. Often while opening the glass ampoules, most nurses are prone to experience cuts and injuries on their hands due to the sharp edges of the glass ampoules. They are also susceptible to the medicine spills on to their hands which is a serious issue to be noted. Most nurses generally turn their eyes away from the ill consequences that result from opening the ampoules. While a considerable number of them are unaware about the wide range of instruments available to do the same.

In this paper, the authors have taken the initiative to dig deep into this issue and apply the design thinking process to resolve it as a part of their first-year engineering course called Design Thinking for Social Innovation. The design thinking process involves identifying a problem faced by a community, determining the stakeholders, their wants, needs, pain and gain points. It encompasses to define a problem and ideate a plausible solution and later build and test the prototype crafted according to the potential solution. This method stimulates collaboration, iteration and refinement. It also helps us to come up with non-conventional solutions. (Interaction Design Foundation, 2021)

As a part of the course, the authors decided to engage themselves with the nurses affiliated to a multispecialty hospital named KIMS situated in Hubballi, Karnataka, India. In this context, it was ascertained that the nurses were encountering difficulty in opening the glass ampoules and were unaware of the various techniques or devices that could assist them in doing so.

Section II briefly discusses a literature review on risk of SIs and their consequences, negligence of healthcare workers on reporting injuries and efficiency of various methods of opening ampoules. Section III discusses the study's methodology, followed by the results and discussions in Section IV and finally conclusion in Section V.

II. LITERATURE REVIEW

This part of the paper contains the literature survey of various authors who have researched on various topics pertaining to the

This paper was submitted for review on September 02, 2023. It was accepted on November 15, 2023.
Corresponding author: Pooja Gani, Computer Science and Engineering, KLE Technological University, Karnataka, India.
Address: Vidyanagar, Hubballi, India, 580030 (e-mail: 01fe22bcs137@kletech.ac.in, 01fe22bcs069@kletech.ac.in, radhika.amashi@kletech.ac.in, viju11@kletech.ac.in).

risk of opening the ampoules and the fear of not reporting the injuries observed in the nursing community around the globe.

Anna Patsopoulou et. al, present a study on exposure of dangerous and deadly pathogens that are being transmitted to blood as a result of neglected cuts from sharp objects during daily clinical procedures of health care workers. Despite the high SI rate many employees fail to report injuries because they underestimate the danger of infection, think it will take too long, or are concerned about seeming unprofessional. This study concludes the need of specialized training and education regarding SIs and its consequences to be addressed (Patsopoulou, 2022).

Po- Hsiang Liu et al. demonstrate the considerable risk that ampoule-related accidents pose to healthcare professionals due to the sharp, jagged edges that are created when the ampoule's neck is broken. This study created a multifunctional, simple- to-use ampoule opener. When compared to ampoules opened by hands, it was observed to have a lower rate of sharp injuries (Liu, 2018).

Pujen Tri Rahayu et. al, conducted research which aimed at innovating ampoule bags as a preventive measure for workplace accidents. In this regard, most respondents found the ampoule bag to be more effective in preventing injuries compared to gauze. However, some respondents considered it impractical. According to this, injuries can be prevented by breaking the ampoule in outward direction and replying on material to wrap the entire neck. (Rahayu, 2020)

A study by Natthacha Chiannilkulchai et al., breaking ampoules could end up in severe injuries in addition to a lack of confidence in nurses. Increasing their risk of contracting a blood-borne illness and also missing work as a result of these accidents. Ampoule openers are advised to avoid harm. However, these openers aren't accessible, so the most common practice is to manually open ampoules, which requires skill to perform securely. This study intends to evaluate the efficacy of several manual ampoule opening techniques while taking into account a number of variables, including the probability of damage, the length of the sharp edge, and other risk factors (Chiannilkulchai, 2020).

Ron Stoker conducted a case study which highlighted the dangers associated with broken glass ampoules in pharmaceutical products and also the issue of jagged edges, glass shards, and potential contamination due to ampoule breakage. The paper summarizes the risk involved with glass ampoule breakage, the historical prevalence of such injuries among healthcare workers, and introduces DAB as a practical solution. It highlights the impact of DAB on enhancing safety and reducing contamination risks (BREAKERS).

According to research by Kevin Hambridge et al., sharp injuries are more likely to happen when handling glass ampoules, preparing injections. These factors contribute to Sharp injuries, but inexperience is the main cause. Following the sharp injury, some nursing students reported psychological effects. According to the study's findings, sharp injuries are widespread among nursing students and can have a variety of psychological effects on a person. (Hambridge, 2021)

A study provided the new method to snap-off the neck of sealed ampoule. The idea of novel opener tool is preparing the grinding slice inside rubber ring, so users could put the ampoule inside the rubber ring and then rotated the rubber ring to snap-off the neck of ampoule (Liu, 2012). The document introduces a recently devised method for opening ampoules, yet the proposed solution remains unimplemented. The authors posit that, while this method may effectively address the issue of needle stick injuries, there is a substantial risk of tiny glass fragments contaminating the medicinal contents.

To avoid nicking the hand, a simple and effective technique with materials available in the clinic is used. The method uses syringe tubes that come from disposable plastic syringes and the described tool is inexpensive, safe, and handy. They have proposed the use of 2.5-mL and 5-mL syringe tubes to open the 1-mL and 5-mL glass ampoules, respectively (Zhang W, 2022). A syringe tube as mentioned in this paper, however, cannot be used to open all types of ampoules. Second, if the ampoule becomes crushed, the medicine should not be injected with that syringe tube. Third, because the tube is composed of plastic, if the ampoule head is not correctly positioned in the tube, it may slip. Fourth, the ampoule opener is not readily available. An optimal-sized injectable antibiotic vial is used to minimize hand damage while opening an ampoule (Mukhtar, 2023).

Furthermore, there is a patented device specifically designed for accessing glass ampoules. The tool uses a technique which comprises a structure with an elongated housing possessing a longitudinal axis and an inner cavity. The housing features an open end, a closed end, and sidewalls forming part of the inner cavity. Additionally, there is a lid that is either flexibly affixed to the elongated housing near the open end. This breakage allows for the separation of the lower liquid portion from the lid(Starr, 2004). The effectiveness of this device may rely on achieving the correct alignment of the ampoule within the housing, as any misalignment during the process might lead to unintended breakage or spillage. It involves multiple steps, including positioning the ampoule, pressing the lid, and bending the housing. If each step requires careful execution, it could add to the overall time taken for the process.

Taking into consideration of all these facts, the authors of this paper have tried to apply design thinking to tackle the problem at hand. Design thinking is generally defined as an analytic and creative process that engages a person in opportunities to experiment, create and prototype models, gather feedback, and redesign (Razzouk, 2015).

III. METHODOLOGY

The methodology section of the paper contains discussions on the approach used in addressing a social challenge. The challenge pertains to the nursing community, and the authors have employed the design thinking process to tackle the issue of nurses at multispecialty Hospital, Hubballi encountering difficulties while opening glass ampoules. This case study is done as a part of the

first-year engineering course and it includes the following 5 phases.

1. Empathy
2. Define
3. Ideate
4. Prototype
5. Testing

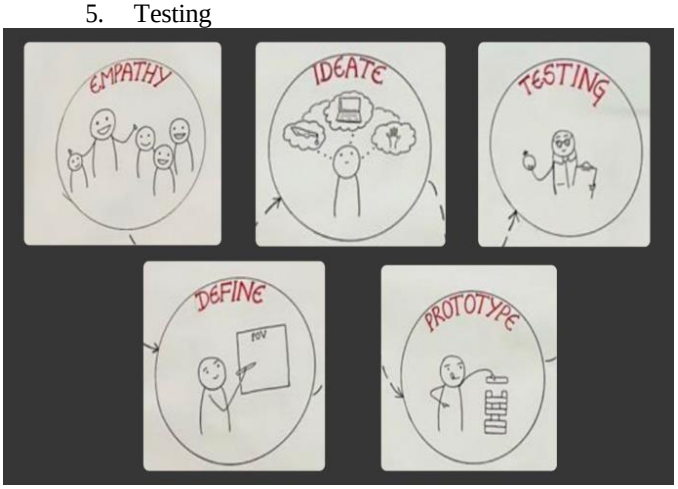

Fig. 1. Design thinking phases

A. EMPATHY

In the empathy phase, the learning's acquired are the need to develop a sense of empathy towards stakeholders in order to gain insights on their needs, wants and objectives. This was accomplished with multiple visits to community (hospital) which included observation, engagement and interaction with the stakeholders by conducting personal as well as group discussions to make the authors acquainted to the difficulties faced by them while opening the glass ampoules. They were interviewed with open ended questions which aided us in gaining a deeper understanding of their situation.

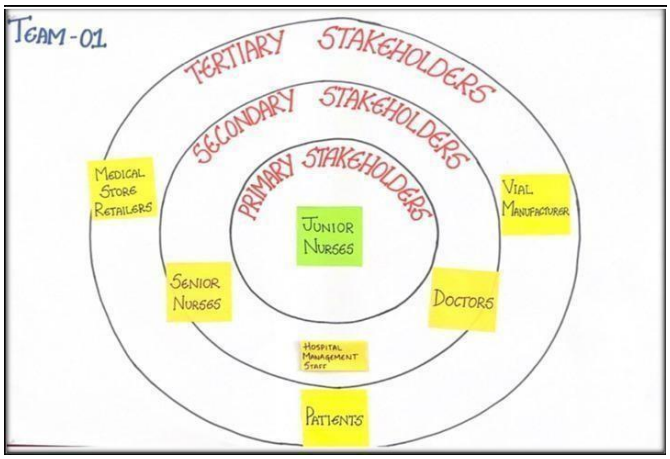

Fig.2. Stakeholder Map

The questions raised to the stakeholders during their community visit are listed in *table 1.0*. The fig.2 shows the different stakeholders to be considered for addressing the social challenge. Due to paucity of time and support from the hospital management authors could only engage, interact and interview the primary stakeholders, i.e., nurses.

TABLE I

QUESTIONS RAISED TO STAKEHOLDERS

Sl no.	Questions raised to stakeholders
1.	What is your normal procedure of opening the glass ampoule?
2.	What are the problems that occur due to snapping of theneck of ampoules?
3.	How do you deal with the scratches and cuts experiencedwhile cracking the ampoules?
4.	How did you end up learning the process of opening the ampoules?
5.	How much time did you take to start opening the ampoules without facing any difficulties?
6.	What are the health issues that you face if the medicine/liquid falls on your skin?
7.	Is there any existing solution to open the glass ampoules?
8.	Do doctors face this problem of opening the glass ampoules?

B. DEFINE

The define phase consists of analyzing and segregating the data collected from the interviews from the previous phase in order to spot the recurring pain and gain points shared by the stakeholders with the aim of having inferred to their needs and desires. The interview data was transcribed and qualitative thematic analysis using affinity map was conducted to arrive at themes such as improper equipment, inexperience in handling the glass ampoules, after effects and ignorance. Fig 3 and 4 show the affinity and empathy maps respectively.

Fig.3. Affinity Map

During this phase, data also helps authors to create a stakeholder persona which is one of the tools for empathizing

with stakeholders. The synthesis of the interview data and the preliminary research helped authors to create an empathy map as shown in fig 4. Finally, authors consolidated the outcomes from stakeholder person, affinity map and empathy map to define our POV statement, i.e.,

[Nurses at KIMS, Vidyanagar Hubli] needs a way to[overcome the challenges faced when opening glass ampoules, such as the risk of injury and contamination, which can negatively impact patient care and put the nurses at risk] because [these issues highlight the need for improved tools and equipment, as well as a proper training and education for nurses on safe and effective techniques for opening glass ampoules]

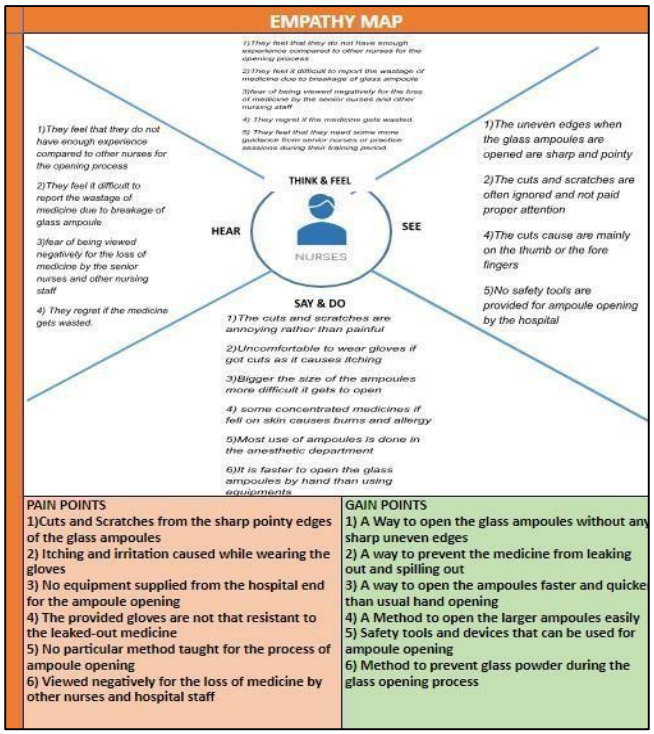

Fig.4. Empathy Map

C. IDEATE

In the ideate phase, the requisite task was to come up with various solutions to solve the problem at hand. Some of the ideas generated were creative, practical and innovative while others were high budget and not so practical. The recommended method to generate these ideas was through a brainstorming process (Figure 5).

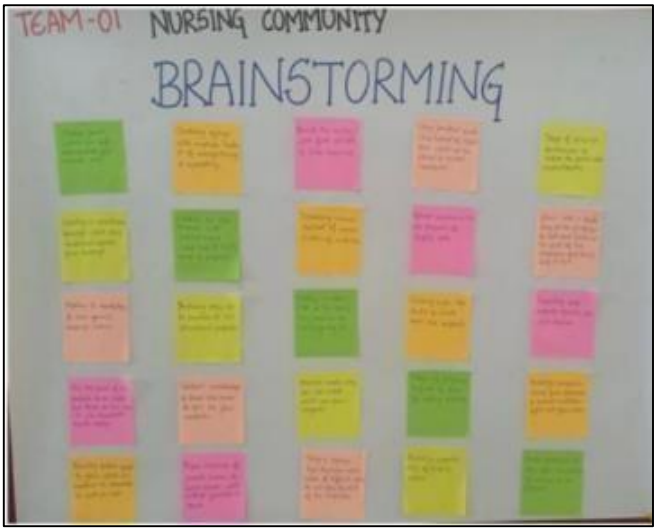

Fig.5. Brainstorming

TABLE II
SCAMPER

S	C	A	M	P	E	R
Substitute	Combine	Adapt	Modify/Magnify/Minimize	Put into other use	Eliminate	Rework/Rearrange/Restore
Using handy Snap it tool to open the ampoules WITH Glass ampoule scorer	Spread awareness of presence of safety tools. WITH Conduct workshops to train the nurses to open glass ampoules along with spreading awareness about ampoule cuts.	NA -	Designing ampoule with pen like opening WITH Designing an ampoule cutter with different sizes of holes to open ampoules of different sizes.	Providing better quality gloves which are resistant to chemicals as well as cuts WITH Making gloves which are durable and safe which can be used during medical treatments.	Providing small first aid box to the nurses WITH Using anti-infactants after opening the ampoules.	Importing safe ampoules openers like click-openers WITH Reuse the click openers to "VIBRAC" structured ampoules

TABLE III
DEGREE OF IMPACT V/S FEASIBILITY GRAPH

Degree of Impact	**High Impact**	1. Producing OPC structured ampoules 2. Increasing volume instead of concentration of medicine 3. Producing ampoules of only volume 5 ml or more 4. Manufacture ampoules by low-cost metal which are paramagnetic. 5. Combining syringe with ampoule instead of manufacturing them separately	1. Designing an ampoule cutter to cut and open the neck of the ampoule 2. Conduct workshops to train the nurses to open glass ampoules along with spreading awareness about ampoule cuts 3. Using an opener type keychain with holes of different sizes to cut and open the neck of the ampoules 4. Gloves with a blade ring at the forefinger to rub and loosen up the neck of the glass ampoule and easily snap it out 5. Marking the glass ampoules with painted color- coded lines to easily break the ampoules
		High Impact & Low Feasibility	**High Impact & High Feasibility**
	Low Impact	1. Using glass ampoule scorer 2. Making gloves which are safe and durable for ampoule cuts 3. Making the top part of the ampoule less dense so that the syringe can be directly penetrable 4. Usage of SEM-ED spectrometers to reduce the particulate contamination 5. Creating a membrane through which only medicinal liquids can pass	1. Using anti-infectants after opening the ampoules. 2 Replacing glass material of ampoule with polymeric substance 3. Using powdered medicines instead of liquid ones which can be stored in normal containers 4. Using powered medicines instead of liquid ones which can be stored in metal containers 5. Adding rubber cap on the top of ampoules
		Low Impact & Low Feasibility	**Low Impact & High Feasibility**
		Low Feasibility	**High Feasibility**

TABLE IV
HIGH IMPACT AND HIGH FEASIBILITY SOLUTIONS

Sl no.	High Impact & High Feasibility Solutions
1.	Designing an ampoule cutter to cut and open the neck of the ampoule
2.	Conduct workshops to train the nurses to open glass ampoules along with spreading awareness about ampoule cuts
3.	Using an opener type keychain with holes of different sizes to cut and open the neck of the ampoules
4.	Gloves with a blade ring at the forefinger to rub and loosen up the neck of the glass ampoule and easily snap it out
5.	Marking the glass ampoules with painted color-coded lines to easily break the ampoules

During the idea evaluation, various criteria like ease of use, effort in creation, efficiency and cost were generated, and were ranked from 1-5. Selected ideas were graded on these criteria and the one with the highest score was taken further (table 5.0). The selected idea was to use an ampoule opener keychain with different holes to break open the ampoule. Figure 6 shows the 2D sketch of the selected idea.

IV. RESULTS

D. PROTOTYPE

In the prototype phase, the finalized idea was converted to a feasible prototype which was an ampoule opener keychain built for opening different sizes of ampoules which included ampoules of the sizes like 2ml, 5ml, 10ml and 20 ml. The solution was first designed using Autodesk software for 3d visualization of the solution. Further the prototype was fabricated and built using acrylic sheets. Fig. 6 shows the 2D model of the solution.

The authors also gathered the feedback from the stakeholders for the prototype and gained valuable insights for additional improvements.

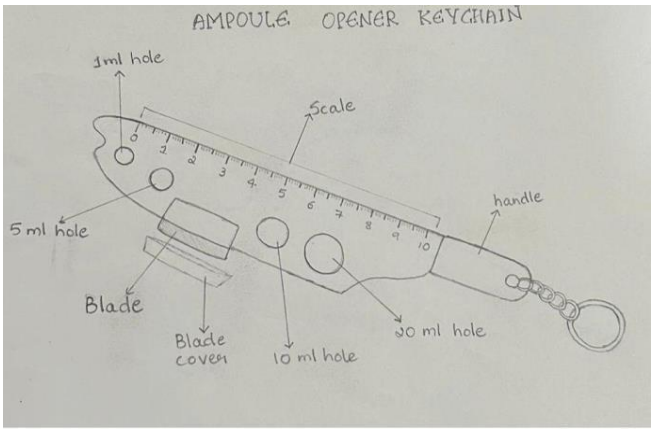

Fig.6. 2D model of the prototype

TABLE V
IDEA EVALUATION: FACTORS VERSUS SUITABILITY

Criteria	Ranking (1 to 5)	Designing an ampoule cutter to open the glass ampoules		Conduct seminars with awareness and workshops to train the nurses		Using an ampoules opener keychain with different holes to break open the ampoule		Making a blade ring for fingers to snap open the ampoules		Marking the glass ampoules with painted colour coded lines to easily break the ampoules.	
	A	Score B	C=A*B	Score D	C=A*D	Score E	C=A*E	Score F	C=A*F	Score G	C=A*G
Ease of use	5	4	20	3	15	5	25	4	20	4	20
Effort in creation	4	2	8	4	16	3	12	3	12	3	12
Efficiency	5	3	15	4	20	4	20	3	15	3	15
Cost	3	2	6	3	9	3	9	2	6	3	9
TOTAL			49		60		66		53		56
Selected Idea is								Using an ampoules opener keychain with different holes to break open the ampoule			

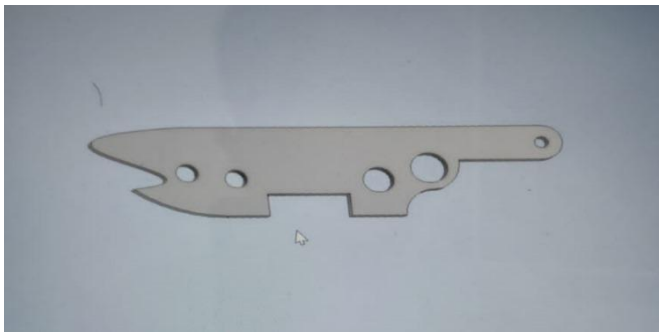

Fig.7. 3D sketch on Autodesk

Fig.8. Physical prototype

E. TESTING

This phase of design thinking involves testing of the prototype which is built based on all of the data collected during the entire process. Here, the authors of the paper asked the end user to test their prototype and provide them with honest feedback.

In this phase of the design thinking process, the authors conducted the evaluation of the prototype in participation of their stakeholders, who happened to be the junior nurses in multispecialty Hospital. They did so by asking the participants to test the prototype for different sizes of ampoules such as 1ml, 5ml, 10ml, and 20ml. Following this, a session concentrating on interactive feedback was carried out later, during which stakeholders were presented with inquiries. The following table features the questions raised to the stakeholders. Overall positive feedback was received from the end users in which they quoted "I was able to open the glass ampoules of different sizes without experiencing any cuts or scratches to my hands", "there was a very minimal glass particle production compared to that produced when snapped from bare hands", "your prototype offered a better method for opening the glass ampoules than the previous ones" and "We all would like to appreciate the simplicity and convenience of using your prototype. The only further improvement that we wish is for a sturdier and sharper blade". Figures 8 represent the final physical prototype and testing of the prototype by a nurse respectively.

TABLE VI
QUESTIONS RAISED TO STAKEHOLDERS DURING FEEDBACK

Sl no.	Questions raised to stakeholders during feedback.
1.	How would you describe your experience using the glass ampoule opening prototype in terms of safety and handling?
2.	Can you compare the amount of glass particles produced when using the prototype to that of when the ampoules were snapped by bare hands?
3.	Can you comment on the effectiveness of the prototype for opening glass ampoules?
4.	Are there any other features or improvements you would like to see in future iterations of the prototype?

V. CONCLUSION

This paper presents the challenges faced by the nurses while opening the glass ampoules and their unawareness in using conventional glass ampoule openers. It also highlights their ignorance in reporting the injuries caused during the ampoule opening process. Thus, the authors of this paper try to solve this issue by applying the design thinking process. They tried to do so by taking in consideration the requirements from the stakeholders and effectively incorporating them to build a feasible prototype. A glass ampoule opener in the form of a handy keychain was designed as the prototype, which was capable of opening ampoules of various sizes like 1ml, 5ml, 10ml, and 20ml. It also included additional amenities like a blade for scratching the neck of the ampoule and a scale for measurement as requested by the stakeholders. Overall positive feedback was received from the end users accounting for the prevention of injuries and medicine spills, simplicity, and ease of use of the prototype. The only further improvement that was quoted was for a sturdier and sharper blade. By incorporating the additional improvements, the paper provided an effective tool to open the glass ampoules which was user-friendly and functional. The market currently offers 4-5 types of ampoule openers. Despite the acknowledged risks and injuries of manually snapping open ampoules, the majority of stakeholders persist in this method. This inclination arises from limited awareness about alternative tools, discomfort in their utilization, and the absence of such amenities in numerous hospitals. Additionally, effective tools are often expensive and beyond the reach of hospitals in tier 3 cities and below. In contrast, our prototype presents a simple and economical solution to counter the risks associated with sharp ampoule edges and injuries resulting from medicine spills. Being a compact keychain model, it proves to be convenient and portable for nurses during their ward shifts.

REFERENCES

BREAKERS, A. I. G. A. Preventing Injuries from Glass Ampoule Shards.

Chiannilkulchai, N., & Kejkornkaew, S. (2020). A comparative study of ampoule breaking and resultant injury among registered nurses. *Pacific Rim International Journal of Nursing Research*, *24*(1), 89-101.

Hambridge, K., Endacott, R., & Nichols, A. (2021). Investigating the incidence and type of sharps injuries within the nursing student population in the UK. *British Journal of Nursing*, *30*(17), 998-1006.

Jacob, M. M. (2016). *Indian pilgrims: indigenous journeys of activism and healing with saint Kateri Tekakwitha*. University of Arizona Press.

Liu, B. S., Lee, J. T., & Lien, C. W. (2012). Ergonomic evaluation of novel tool for snap-off the neck of ampoule. *Work*, *41*(Supplement 1), 1174-1177.

Liu, P. H., & Lien, C. W. (2018). Systematic innovation by user-centered design: Case study in ampoule opener design. *International Journal of Systematic Innovation*, *5*(2).

Mukhtar, M., & Mukhtar, S. (2023). A novel use of glass vial as a safe ampoule opener. *Journal of Cutaneous and Aesthetic Surgery*, 10-4103.

Patsopoulou, A., Anyfantis, I., Papathanasiou, I. V., Fradelos, E. C., Malliarou, M., Tsaras, K., ... & Papagiannis, D. (2022, July). Reported injuries from sharp objects among healthcare workers in central Greece. In *Healthcare* (Vol. 10, No. 7, p. 1249). MDPI.

Pechini, M. P. (1967). Washington, DC: US Patent and Trademark Office. *US patent*, (3.330), 697.

Rahayu, P. T., Asmiati, D., & Santosa, A. (2020). Technique to open an ampoule with an "Ampoule Opener" tool.

Razzouk, R., & Shute, V. (2012). What is design thinking and why is it important?. *Review of educational research*, *82*(3), 330-348.

Toney-Butler, T. J., & Thayer, J. M. (2022). Nursing process. In *StatPearls [Internet]*. StatPearls Publishing.

Zhang, W., Gu, L., Zhang, Y., & Lu, H. (2022). Syringe tube as ampoule opener: A safe, simple, and effective tool in dermatologic surgery. *Journal of the American Academy of Dermatology*, *86*(3), e101-e102.