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USING LIKELIHOOD RATIO TABLE AND NAÏVE BAYES CLASSIFIER METHOD TO HOLISTICALLY ASSESS CODESIGN PROGRAMMES AND METHODS

Siew, William (1);
Silva, Arlindo (1);
Rai, Bina (2)

1: Singapore University of Technology and Design;
2: National University of Singapore

ABSTRACT

The concept of inclusivity involved an understanding of people, programmes and places, embedded with complex issues. 21 student designers took part in a first-of-its-kind five-day codesign programme to develop solutions for inclusive and engaged communities with residents. This quasi-experimental study aimed to develop a value-based approach using likelihood ratio table and a Naïve Bayes classifier method to assess the success of a codesign programme, in comparison to past programmes with different design challenges. Methodology proposed a systematic investigation to evaluate this programme holistically. Students discussed with stakeholders to uncover the complexities of human and environmental factors in design at early stage of ideation, and semi-structured participants' observation tasks were considered instead of researcher's observations in the method of assessment. Selected teams were introduced to two new design methods to empathise better with seniors, i.e., Care Circle and See and Shoot. Findings revealed that these teams showed greater levels of critical inquiry when overcoming three key challenges, i.e., (1) identifying key personas, (2) examining potential use environment, and (3) access to market.

Keywords: Bayesian approach, Complexity, Design education, Design methods, Inclusivity

Contact:
Siew, William
Singapore University of Technology and Design
Singapore
william_siew@mymail.sutd.edu.sg

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1 INTRODUCTION

A recent study has identified seven key challenges faced by designers, and stakeholder identification is a contributing factor for access to market which affects design output (Siew et al., 2023). Underestimating or overestimating programme requirements with stakeholders' involvement should be avoided as the process requires resources to be put in. However, codesign programmes are often examined by a single event as there is currently no simple way in comparing the dataset of one programme with past programmes to understand whether the programme works across different settings with different design challenges. Besides that, design assessment also needs to consider adaptable activities involving stakeholders (Schmidt and Libre, 2020). Design factors such as instructional methods, contexts, boundaries, engagement techniques, and resource management (Barkley, 2010), and human factors such as stakeholders' influence and other contributing factors like participant profiles and instructors' knowledge of contexts (Thitithamawat et al., 2018) need to be addressed.

1.1 Research aim

The aim of the study is to analyse the key challenges of a design process across different codesign programmes and address the research question, **"***How can we develop a new methodical approach to evaluate solutions when design challenges are different across time?*" Solutions from student designers who are innovating solutions for seniors and/or people with reduced cognitive ability with stakeholders were examined. The goal was to compare the datasets from observational findings of designers from a codesign programme with stakeholders with past programmes with and without stakeholders using systematic investigation and deductive/inductive reasoning (Bhandari, 2022; Dam and Teo, 2022). Though different parameters and contexts added the complexities in assessing codesign programmes, an alternative approach was developed using likelihood ratio table and Naïve Bayes classifier methods to overcome this hurdle. This led to the discovery of using common challenges faced by participants to quantitatively and qualitatively assess codesign programmes, while explaining complexities in design.

2 LITERATURE REVIEW

Typically, designers can interact with targeted stakeholders to find out the underlying cause and effects problems/issues and uncover gaps (De Paula et al, 2018). One might be able to study the impact of direct interactions with stakeholders through post-programme interviews, but it is often time consuming and harder to ignite participants' memory to recall details without a structured process or template to follow. Such studies are also hard to replicate findings, and one has to consistently apply the same method of analyses across programmes. Even when contemporary methods were used to consider experiences of participants learning and applying methods, tools or some guidelines are relevant to examining design for one instance most of time. For example, Miaskiewicz & Kozar (2011) identified key personas benefits using questionnaires through the Delphi approach and Neuhauser et al. (2009) conducted a randomised controlled trial to evaluate the use of a guidebook through professional feedback in an efficacy study. Considerable amount of time and coordination efforts are needed in such approaches, and a research team need to have total control over the way research and engagement with participants is done. Due to potential differences in interpretations based on outcomes, an alternative approach using semi-structured observation tasks by self-assessment of participants could uncover complexities through students' active learning and proactive participation (Arruda and Silva, 2021).

2.1 Bayesian theorem in design research

Previous studies of Bayesian approaches involved correlational analysis and hypothesis testing in primary care (Zhang & Schuster, 2021). Figure 1 shows Bayes' theorem, represented by a mathematical equation of conditional probability when dealing with sequential events (Bayes, 1763).

$$P(A|B) = \frac{P(B|A)}{P(B)} \times P(A), \text{ provided } P(B) \neq 0, \quad (1)$$

where A and B are two characteristics of events occurred.

Figure 1: Mathematical terminology of Bayes theorem

With above, the commonly used terms are *a prior probability*, which is an initial value of probability obtained in past events, and *a posterior probability*, which is an updated value of probability by using

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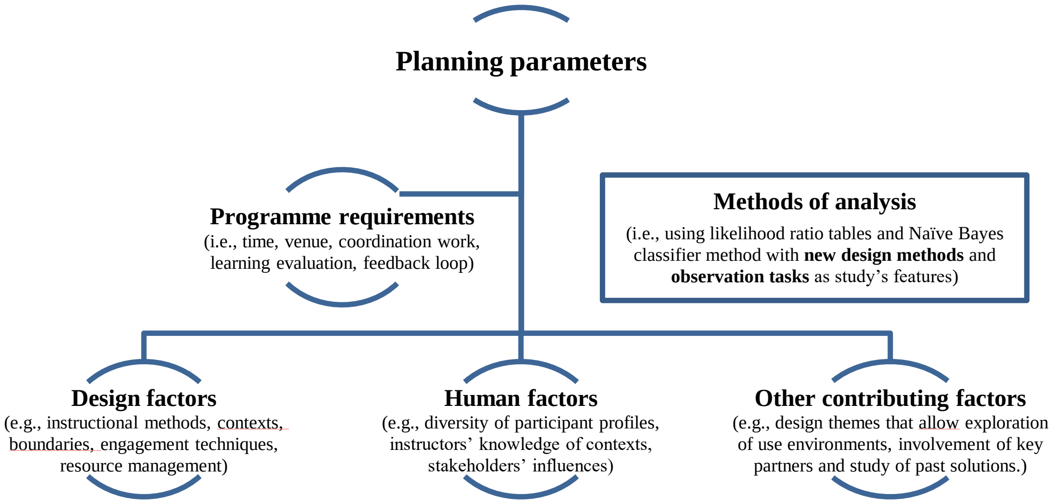
additional data that is collected at a later time from a new event. In codesign, designers take account of the addressable market and current systems and stakeholders involvement brings insights and value in the ideation stage. Variations to a codesign programme would normally render two or more datasets incomparable for a design study. To address this, one has to define the groundwork or basis for analyses to be conducted across programmes. A constructivist/interpretivist approach could be applied with new methods introduced in a codesign programme (Sebastian, 2019) using a likelihood ratio table for small sample tests (Oliveira et al., 2017).

3 METHODOLOGY

A quasi-experiment applying systematic investigation could assess programmes with different design challenges. In a new programme delivered at Codesign Week @ Health District in 2022, 21 participants engaged with residents and community partners in groups of 3 to 5 participants per team during the early stage of ideation (Siew et al., 2022). They identified problems/issues around inclusivity, and recorded difficulties faced in a design process through observations when co-creating solutions together with stakeholders. Figure 2 illustrates planning parameters and features used in this study.



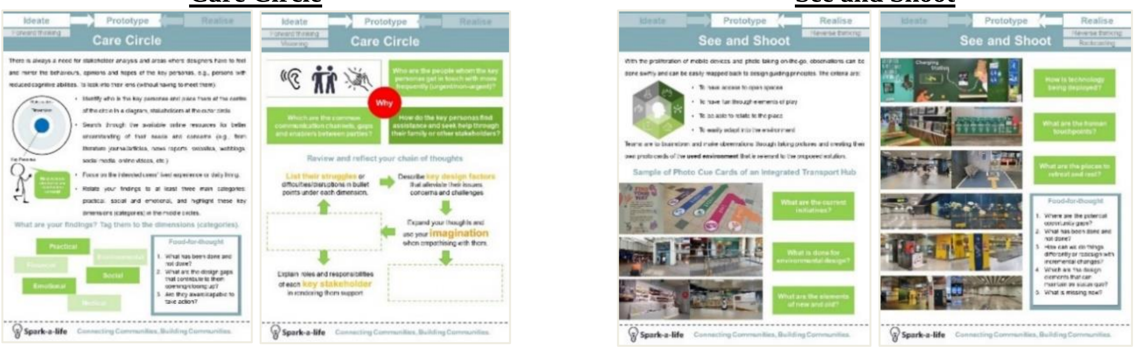
Features:

New methods	Observation tasks	Design templates	Mission
Supporting designers to engage in higher level of empathy.	Documenting the design journey and learners' experience of programme.	Explaining design outcomes with evidential support through research and critical inquiry.	Capturing the projects' goals, key problem statement, target market, stakeholders, assumptions and constraints.

Figure 2: Planning parameters and features for research design

Two new methods, Care Circle (CC) and See and Shoot (SS) methods, were introduced to participants. Selected teams applied a new empathy mapping method, and they critically reflected on their motivations of developing new/improved solutions with guiding questions in the method (Figure 3).

Care Circle **See and Shoot**



To provide identify pain points, struggles and stakeholders when design solutions for seniors and people with reduced cognitive ability. Additional findings will show team's discovery of latent needs through needs analyses.

To explore a use environment using observations or visuals to design solutions for seniors and people with reduced cognitive ability. Additional findings will show that team has considered solution is implementable or not.

Figure 3: New Care Circle and See and Shoot design methods

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4 FINDINGS

Seven key challenges from the findings of a previous study (Siew et al., 2023) helped in defining the structured approach for assessing programmes for future improvement. To explain observable effects, data was tabulated based on the list of indicators defined under each challenge to analyse the findings of teams using and not using the new design methods (see Appendix). When determining whether a posteriori factor is present, one needs to develop a way to capture observations and classify them in according to common challenges faced by designers in a design process before further analyses. Hence, a template for observation tasks were developed that allowed the researcher to define *a priori* of past programmes for quantitative analysis. The seven key challenges in design must be examined closely:

(a) Conduct stakeholder analysis
(b) Refine problem statement
(c) Identify key personas
(d) Develop user journey maps
(e) Examine potential use environment
(f) Access to market
(g) Prioritise key concepts

Table 1 showed the likelihood ratio table tabulated for three design programmes, i.e., Programme 1 without the new methods (with stakeholders), Programme 2 with CC method (without stakeholders), and Programme 3 of the codesign week with teams without new methods and teams with CC/SS method (with stakeholders). Contrasting vectors, defined as two variables in opposing directions identified based on observations made, were found from those with distinct cells of 1s and 0s during comparison. Ratios in between 1 and 0 could be ignored due to a small sample size to derive any reasonable analysis.

Table 1: Comparing likelihood ratio table of codesign week and past programmes

		Programme 1 without CC/SS		***Programme 2 with CC method***		***Programme 3 without CC/SS***		***Programme 3 with CC method***		***Programme 3 with SS method***	
	Total:	14 teams		9 teams		2 teams		2 teams		2 teams	
Key Challenges (a to f)	(a)	7	0.50	3	0.33	2	1.00	1	0.50	2	1.00
	(b)	2	0.14	3	0.33	2	1.00	1	0.50	2	1.00
	(c)	3	0.21	2	0.22	2	1.00	0	0.00	1	0.50
	(d)	3	0.21	2	0.22	2	1.00	1	0.50	1	0.50
	(e)	12	0.86	3	0.33	0	0.00	2	1.00	1	0.50
	(f)	0	0.00	9	1.00	2	1.00	1	0.50	2	1.00
	(g)	4	0.29	3	0.33	1	0.50	1	0.50	2	1.00

Table 2 comparison table illustrated the difference in teams without CC method and with CC method. As SS method is newly introduced, there is no data for comparison through the likelihood ratio. The ratio differences were taken from the codesign week programme minus the past programmes.

Table 2: Comparison of likelihood ratio table and its difference (with/without CC method)

		Teams without CC method					***Teams with CC method***				
		Programme 1		**Programme 3**		**Ratio Difference**	**Programme 2**		**Programme 3**		**Ratio Difference**
	Total:	14 teams		2 teams			9 teams		2 teams		
Key challenges (a to f)	(a)	7	0.50	2	1.00	0.50	3	0.33	1	0.50	0.17
	(b)	2	0.14	2	1.00	0.86	3	0.33	1	0.50	0.17
	(c)	3	0.21	2	1.00	0.79	2	0.22	0	0.00	-0.22
	(d)	3	0.21	2	1.00	0.79	2	0.22	1	0.50	0.28
	(e)	12	0.86	0	0.00	-0.86	3	0.33	2	1.00	0.67
	(f)	0	0.00	2	1.00	1.00	9	1.00	1	0.50	-0.50
	(g)	4	0.29	1	0.50	0.21	3	0.33	1	0.50	0.17

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Comparisons of team solutions with new methods between programmes substantiated the findings on involvement or non-involvement of stakeholders in a codesign programme. Involvement of stakeholders (residents and community partners) supported critical inquiry of teams using:

- *Care Circle*: From ideating to prototyping phases, teams were more supported when conducting needs analyses with information on needs of key personas with stakeholders' engagement.
- *See and Shoot*: Importance of access to market raised designers' curiosity to conduct critical inquiry on use environment, which helped teams prioritise key concepts/ideas in prototyping phase.

From the likelihood ratio tables, teams that used new design methods critically reflected on:

- *Identifying key personas*: To understand the key personas' needs and concerns through a multi-dimensional lens, e.g., practical, emotional, social, medical, financial and environment.
- *Examining potential use environment*: To gather primary/secondary data on the possibilities with or requirements by stakeholders on solutions' use environment and related contributing factors.
- *Access to market*: To relate to the design themes, according to human factors in the addressable market segments/target audiences.

More insights were drawn from three codesign programmes to find relevant "entry points" through contrasting vectors for further discussion. Table 3 provided explanations through qualitative analysis.

Table 3: Further analysis with consideration of planning parameters as contributing factors

Review	Classifier	Explanation
Table 1	Stakeholder involvement	(f) was a contrasting vector (opposing directions) because Programme 1 had stakeholders involved while Programme 2 did not involve stakeholders.
	Codesign with new methods	(c) and (e) were two contrasting vectors (refer to Table 1). The codesign week programme encouraged participants to look at human and environment factors that support health and wellbeing. These contributing factors were not reinforced in past programmes.
		Based on the new programme, teams with CC method were high on (e), and teams with SS method were high on (a), (b), (f) and (g), i.e., a ratio of 1. As method cards were introduced as a feature, teams were guided to use critical inquiry in their discussions intentionally.
Table 2	Programme planning and mode of delivery	(c), (e) and (f) were three contrasting vectors between teams with CC method and teams without. As past programmes were held virtually and codesign week programme was a hybrid, teams dedicated time into discussions where access to market was not an issue. They interacted with residents and community partners, so teams was more intuitive in developing personas.
		(f) revealed a difference between codesign week programme and past programmes for teams without CC method. This suggested that the type of stakeholders influenced design outcomes.

5 DISCUSSION

This study used a Bayesian method with likelihood ratio table to holistically assess codesign programmes with varying planning parameters, e.g., programme requirements, design, human and other contributing factors. Participants' observational data captured during the workshop helped researcher to establish valuation in design[1]. CC and SS methods increased participants' awareness of the addressable market and use environment:

i. *Comparison of (e) between Programmes 1, 2 and 3*: When comparing teams between the past and new programmes (with and without CC/SS method), an inconsistency was found in (e). A contrasting vector was found in the new programme but not in past programmes (Table 1). The new methods seemed to have nudged teams to look deeper at human (personas and stakeholders) and environment factors (for solution implementation) in relation to perceived health benefits.

ii. *Difference in (c) across Programmes 1, 2 and 3*: For CC, there is a difference in results for (c) when looking at the two likelihood ratio tables. There is a contrasting vector for codesign programme and not in past programmes. The difference in ratio may be explained by the involvement of stakeholder (i.e., residents and community partners), which aided teams with details on problems/issues that their key personas faced in relation to health.

iii. *Difference in (g) for Programme 3*: The results for (g) for teams with SS method (1.0) showed a difference when compared with teams with CC method (0.5) and teams without the use of new methods (0.5), but there is no contrasting vector (Table 1). Remaining challenges (excluding e) did not show any differences between with SS method and without. This may mean that stakeholder involvement has influence over addressable market.

[1] Researcher opines valuation in design as co-creating and describing a process of elucidating value of design through value constellations (Speed and Maxwell, 2015)

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iv. *Difference in (e) across programmes 1, 2 and 3 (Table 2)*: The results for (e) for teams without the use of new methods suggested examining potential use environment (e) was not an issue to students when designing a solution. When comparing those teams with CC/SS method and those without the use of new methods, there seems to be a greater awareness of (e) for their proposed solution which is not consistent with the earlier likelihood table. Teams who used CC/SS method showed higher level of critical inquiry and empathy than teams who did not use them.

In summary, the new design methods introduced increased the level of empathy of participants developing solutions for seniors and disability group. Although there were complexities in problems/issues identified with different user personas (e.g., people with dementia), the Naïve Bayes classifier method offered an alternative approach in design research. This Bayesian approach is applicable to programmes that are not initiated by research or may not have direct access to stakeholders. With the new design methods, designers are more likely to find ways to identify and discuss human and environment factors. By inductive/deductive reasoning and fact finding, researcher could reveal whether there is higher level of critical inquiry and empathy despite their challenges faced in a design process. Initial ideas developed also influence on the way designers discuss and affirm their claims from problem identification to opportunity statement. Hence, technology selection and implementability[2] in relation to practical, emotional and social dimensions can be a critical aspect for future studies as well, summarised in Table 4.

Table 4: Key dimensions and criteria for technology selection and implementability

	Practical dimension	Emotional dimension	Social dimension
Description	Factors that contribute to an understanding of the target audience(s)' behaviours/desires.	Factors that contribute to an understanding of the target audience(s)' attitudes/feelings.	Factors that contribute to an understanding of the target audience(s)' beliefs/opinions.
Technology selection	Building coherence through insights drawn from used cases (Heron & Reason, 1997).	Explaining with appreciation of situation and reflective practice (Schön, 1992).	Constructing meaning of one's lived experience living in the complex world (Love, 2003).
Implementability	Reliability criterion, e.g., operational requirements.	Technical criterion, e.g., aesthetics and ease of use.	Epistemological criterion, e.g., simplicity and validity.

With the above dimensions and criteria, programmes with different topic given by programme organisers using the same design methods can support researchers in deepening the study on understanding of complexities in design through comparative and contextual analyses. This alternative approach helped to determine whether *a posteriori* factor is present and common challenges in design identified were examined further (Siew et al., 2023). When examining the level of critical inquiry through the seven key challenges, one can be agile by adapting activities to the different programme requirements by sponsors/organisers (Karhapää et al., 2021). If such procedure in analysis is consistently applied across different codesign programme, it could empower researchers in their hypothesis development during descriptive and prescriptive study.

6 ETHICS, LIMITATIONS AND FUTURE WORK

There was no prior study to relate to innovating solutions through codesign programme and methods with seniors and people with reduced cognitive ability, and data exploration is required. Using an alternative method (i.e., likelihood ratio), the data collected were analysed and reported. Ethical considerations were factored in, such as privacy of residents involved in codesign processes. Hence, there were no mention of findings relating to residents and their background. Permission was given by the organisers to make observations for the study during the programme and participants' consent were collected during registration process. Additionally, the researcher found some key explanation to the challenges that student designers faced in design even though the sample is small. The likelihood ratio method and deductive/inductive reasoning were considered because of:

- *Small sample and nature of programme*: Considering that design workshops are not carried out in the same way due to contextualisation, training delivery and thematic factors.
- *Planning of design workshops*: Codesigning with stakeholders in various programme settings to deliver the programme's purpose and/or learning outcomes.

[2] Researcher defines implementability (ˌɪmplɪmenəˈbɪləti) in design as having the clarity to determine and support with evidence on whether the solution can be developed and implemented successfully.

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- *Interaction with key stakeholders*: Finding possibilities for learning designers to engage key stakeholders, e.g., residents and partners, to understand and solve real-world problems.

Through this structured approach, the holistic assessment could explain the use and success factors of critical reflection on methods used in supporting designers across three examples of design programme. Though findings could be unique and context-specific to the teams in their documentation, there is impetus for universities to experiment with these kinds of design research studies. Technology selection was only relevant in the contexts they looked at, and this skillset of knowing and selecting technology to deal with problems cannot be fully replaced by machine. Using this approach, further investigation on students designs with/without prior design experience or knowledge of relevant fields is possible by:

i. Studying commonalities between programmes and examine the correlations between human, environment and other contributing factors through the lens of participants.
ii. Introducing ways that allow researchers to manage variants in practice and acquire the know-how when dealing with difficulties on logistical or administrative aspects of a research trial.
iii. Nurturing the ability to establish meaningful connections in finding casual relationships and/or correlations between topics/themes in design evaluation.
iv. Gathering perspectives in devising suitable models in the progressive development and a data structure for construct-based multi-dimensional data interpretation and analysis in research.
v. Linking various observed patterns of technology selection and implementability from human and environment determinants.
vi. Exploring research collaborations and trials with better tools to facilitate the discussion based on programme requirements, such as using composite design methods and assessment matrices.
vii. Specifying potential savings in resources with pseudo-mathematical approaches by design, e.g., development time, data acquisition costs and stakeholder engagement.

With this study as a key reference point, one could be enabled to focus on the right things to examine deeper into what happened in a design process. With mixed methods, observation tasks and Bayes theorem supported the assessment of designs, where python programming, machine learning models or other sophisticated ways of analysis were not necessary with a small sample. Researcher can apply this methodology to reproduce results using Naïve Bayes classifier method by examining a design process across "same, but different" design programmes involving/not involving stakeholders and other contributing factors in the early stage of ideation. While the study saw that the types of stakeholder matter when assessing design programmes with different design challenges, it was unable to conclude whether the frequency of stakeholder participation will improve learning and design outcomes. Inter-university collaborations may to tackle this gap in future studies with larger samples, describing ways to interpret the patterns designers searched, discussed and communicated concepts/ideas. When the sample is big, there may be more observed factors other than the seven key challenges and deeper insights to technology selection and implementability from teams applying CC/SS method. Further research should then consider to replicating this approach in more contexts and expand its usefulness with statistical methods to increase data equivalence (Chambers, 2013).

7 CONCLUSION

"[A] machine learning algorithm can achieve greater accuracy with fewer training labels if it is allowed to choose the data from which it learns." – Settles (2009)

Change is a constant even across similar design programmes due to the need to consider contextualisation in programme delivery for different participants. There is no one-size-fits-all methodology to study and translate participants' design outcomes into meaningful interpretations and test the performance of success factors (or key challenges) for programme development. This study presented a new way to compare small datasets of programmes with different design challenges. Findings were analysed using a tabular representation and basic excel functions without algorithmic code. This was possible through observation tasks, where participants documented their design journey. Seven key design challenges were itemised and labelled for evaluation. When coding data, a likelihood ratio approach analysed new information that updates the probability of initial value of past events (Stengel et al., 2003). Learning the instances of unlabelled data and underlying causes of a contrasting vector could add value to research contribution, which required a human annotator to discuss findings independently. In this study, CC and SS methods enhanced designers' work where there was stakeholder participation. They exhibited higher level of critical inquiry on addressable

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market and use environment. With this study as a precursor to a Bayesian approach, researchers could experiment new ways in finding the influence of new empathy mapping methods on technology selection and implementability.

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APPENDIX

Table A1: Observation tasks for participants in a design process

Challenge	List of selections
Conduct stakeholder analysis	a. Difficulty in identifying stakeholders involved (e.g., community partners). b. Difficulty in identifying stakeholder challenges (e.g., methods used to search/find out). c. Difficulty in describing the concerns on the sustainability of existing solutions. d. Difficulty in researching the needs/concerns of the target audience(s). e. Difficulty in concluding the relevance of problem/issue.
Refine problem statement	a. Difficulty in understanding the concept of "How might we" (HMW). b. Difficulty in applying 5W1H to refine the HMW statement. c. Difficulty in identifying the possible problem areas during the team discussion. d. Difficulty in finding relevant information before deciding on the main problem area. e. Difficulty in zooming into a main problem area to refine HMW statement.
Identify key personas	a. Difficulty in defining the personas and how they relate to the proposed solution(s). b. Difficulty on knowing how the persona(s) encounters and resolves the problem. c. Difficulty in addressing the confusion on personas is due to problem being too generalised. d. Difficulty in addressing the confusion on personas is due to problem being too specific. e. Difficulty in addressing the confusion on personas is due to struggles in evaluating suitable existing solution(s) (e.g., solution pros and cons).
Develop user journey maps	a. Difficulty in applying the mapping based on the user personas derived. b. Difficulty in knowing how the existing solution(s) is/are used by target audience(s). c. Difficulty in (re)imagining improved/new solutions or functionalities/features. d. Difficulty in finding the gaps based on the touchpoints to the existing solution(s). e. Difficulty in finding the gaps based on the touchpoints to the improved/new solution. f. Difficulty in diving into the details on each phase of a user journey mapping based on identified touchpoints. g. Difficulty in describing the personas' emotions in response to the proposed solution.
Examine potential use environment	a. Difficulty in determining potential use environment to be hybrid, digital, or physical. b. Difficulty in describing the hybrid interface for the proposed solution(s). c. Difficulty in describing the digital platform for the proposed solution(s). d. Difficulty in describing the physical environment for the proposed solution(s). e. Difficulty in identifying suitable use environment(s) for the proposed solution(s). f. Difficulty in describing the identified use environment(s) for the proposed solution(s). g. Difficulty in evaluating the potential use environment(s) for the proposed solution(s). h. Difficulty in describing rationale behind decision-making on preferred use environment(s).
Access to market	a. Difficulty in finding an entry to the market of interest. b. Difficulty in entering the market with the speed of advancement in technology. c. Difficulty in searching for suitable stakeholders in the market. d. Difficulty in establishing rapport with suitable stakeholders due to time constraints. e. Difficulty in establishing rapport with suitable stakeholders due to resource constraints. f. Difficulty in establishing rapport with suitable stakeholders due to buy-in constraints / lack of "what is in it for them". g. Difficulty in recruiting the desired target audience(s) of a suitable participant size. h. Difficulty in sourcing the budget for pre-development which is required in a pitch. i. Difficulty in finding out how people might be comfortable using existing solutions. j. Difficulty in examining the factors that people like/dislike the existing solutions. k. Difficulty in examining the factors that people like/dislike the potential solutions. l. Difficulty in examining the factors that people like/dislike the proposed solution.
Prioritise key concepts	a. Difficulty in knowing about the discipline/field/industry of interests (e.g., dementia). b. Difficulty in understanding key concepts surrounding the relevant discipline/field/industry in which the problem lies. c. Difficulty in technology application/innovative concepts (e.g., AI and face recognition). d. Difficulty in finding relationship between concepts/seeing their correlations or causations. e. Difficulty in prioritising concepts/ideas to develop potential solutions. f. Difficulty in deciding on the key functionalities/features for initial development of the proposed solution. g. Difficulty in evaluating feasibility of functionalities/features of proposed solution. h. Difficulty in evaluating viability of functionalities/features of proposed solution. i. Difficulty in evaluating desirability of functionalities/features of proposed solution.

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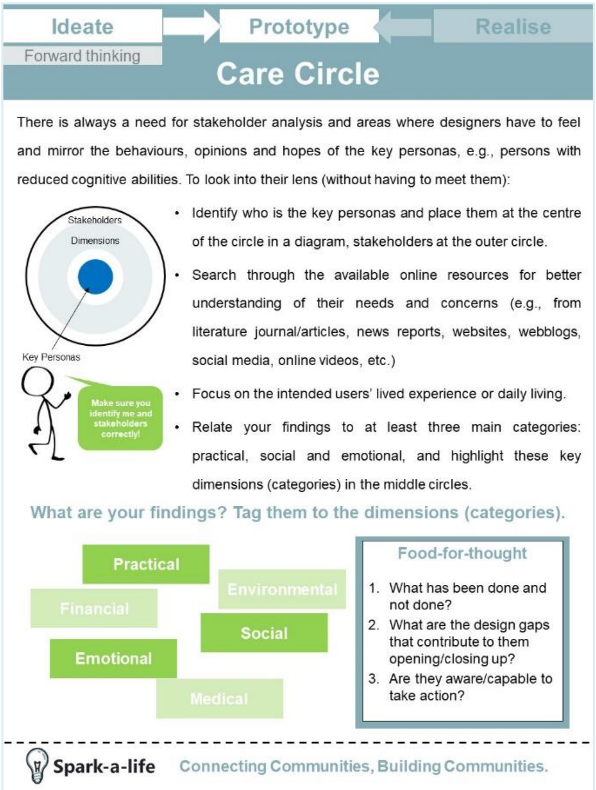
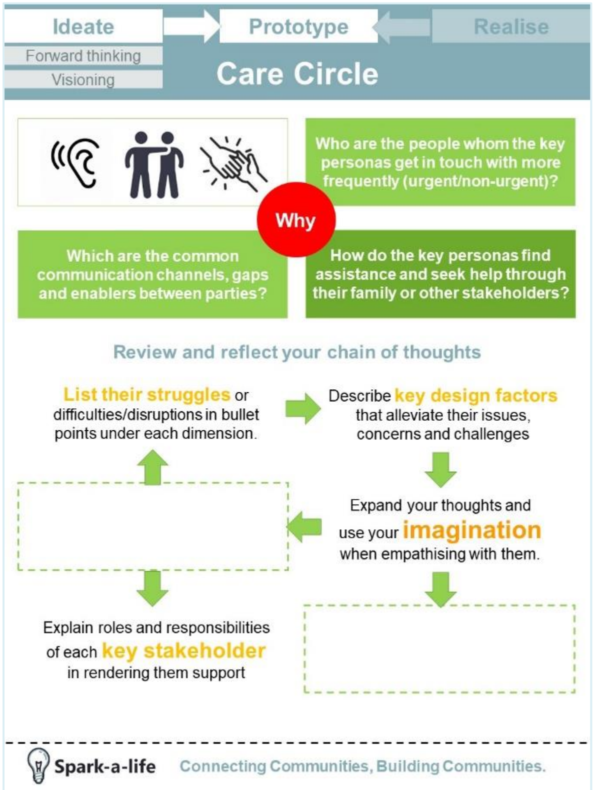
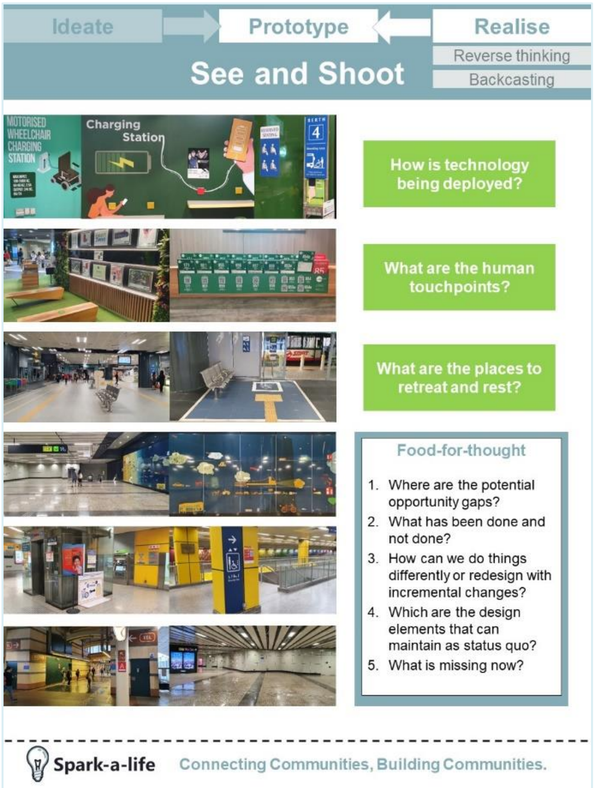
Table A2: New care circle and see and shoot design method cards







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