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SHAPING SMART HOME PRODUCT SERVICE SYSTEM (SH-PSS) REFLECTION CRITERIA CARDS FOR 'TILES IOT INVENTOR TOOLKIT'

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ABSTRACT
The rapid growth of the Internet of Things (IoT) has provided new opportunities for the development of Smart Home Product-Service Systems (SH-PSS) as technological solutions to various problems. However, designers face challenges in generating ideas for such systems. This study aims to address this challenge by developing an extended Tiles IoT Inventor toolkit specifically designed for SH-PSS design. The toolkit utilizes a card-based approach to identify consumer problems and explore the technical capabilities of SH-PSS during the ideation process. To assess its effectiveness, the IoT Ideation toolkit was evaluated through workshops involving user experience designers, product designers, and human-computer interaction (HCI) students. Additionally, this study identifies five attractive characteristics of SH-PSS that influence technology adoption and introduces SH-PSS Reflection Criteria Cards as part of the Tiles IoT Inventor Toolkit. Research questions are formulated to investigate the enhancement of idea generation ability, service dominance and the identification of technology adoption discontinuities using these reflection criteria cards. Hypotheses are proposed and will be tested through experiments involving control and experimental groups. This study contributes significantly to design education, providing valuable support for design practitioners and researchers in identifying consumer problems and exploring the technical capabilities of SH-PSS.

Keywords: Smart home product service system, experiment design, card game design, ideation toolkit, Tiles IoT Inventor Toolkit

1 INTRODUCTION
The design of smart home product-service-systems (SH-PSS) entails the creation of smart home products and services that fulfil consumer needs and expectations, offering a seamless and integrated experience across various connected platforms and products. Designing SH-PSS involves understanding user requirements, comprehending the smart home ecosystem, and crafting engaging user experiences. However, the design process faces challenges such as interoperability, security, complexity, compatibility, user experience, and privacy, which must be addressed to ensure successful adoption and utilization of SH-PSS. One research gap in this area is the lack of a framework and toolkit for PSS-designers to facilitate the design of technology-based interventions within the context of smart homes. Thus, this study aims to develop an extended Tiles IoT Inventor toolkit tailored specifically for SH-PSS design. The customization of the generic Tiles IoT Inventor toolkit focuses on key considerations such as context awareness, multifunctionality, cooperative capabilities, personalization, and openness in the smart home context. The developed toolkit will be evaluated by formulating hypotheses (Table 3) to address the research questions (Table 2).

2 LITERATURE REVIEW

2.1 Characteristics of Smart Home Product-Service-System (SH-PSS)
While perusing the literature, we learned that the adoption of SH-PSS by a consumer is influenced by the qualities of SH-PSS consumers looking for and product smartness[2,11,15,16]. Product smartness refers to the qualities of products which are intelligent and smart. **Product Smartness:** The literature discusses qualities that define a product as smart [2,16]: independent, adaptive, reactive, multi-

functional, ability to cooperate, humanlike interaction, and personality. **Quality consumer looking for in SH-PSS:** In previous studies various qualities, that a consumer looks for in a smart home product. These qualities are categorized as 'within the product', 'related to the usage of the product' and 'related to other products' [2,11]. These qualities are crucial as they will affect consumer behavior, on the decision to adopt smart home products. (a) Within product: Context awareness, Interpretation, Proactive, Self-description; (b) Usage: Personalisation, User friendly interaction; (c) With other products: Communication, Cooperation, Openness, Collaboration. In our previous study, we analysed all the above characteristics of SH-PSS through the Kano model approach. The kano questionnaire was designed using functional and dysfunctional questions for each characteristic. The relevant survey was performed with consumers (n=226) in the Indian context. The responses of respondents were evaluated using the kano evaluation table. Through this approach, we found five 'attractive' characteristics: ***context awareness, multifunctional, ability to co-operate, personalisation and openness***. Consumer satisfaction will improve dramatically with rising characteristics performance, but it will not drop with decreasing performance.

2.2 Design Process of SH-PSS

We have identified various design toolkits in the literature that assist the SH-PSS design process [3,6,12,13] based om the concept of Design by Analogy [1,8,18]. It helps designers in the ideation process by exploring the problems faced by the consumers, taking inspiration from existing intelligent systems, exploring the technical capabilities of the smart products and smart services, idea generation process, planning implementation and mitigating implementation problems. Identified toolkits in the literature are (i) Card'n'dice, (ii) Co-create the IoT, (iii) Design Desk, (iv) IoT Ideation Design Kit, (v) Know Cards, (vi) Mapping the IoT and (vii) Tiles IoT Inventor Toolkit [6].

In this study we have identified that designers adopt a process as six stage activity as design process of SH-PSS: exploring problems faced by the consumers, taking inspiration from existing smart systems, exploring the technical capabilities of the smart products and smart services, idea generation process, planning implementation and mitigating implementation problems (Figure 1). Since understanding the consumer's problems is critical while designing a personalized smart product as it increases the system's efficiency, which further helps them adopt the SH-PSS. In our study, we have specifically taken the Tiles IoT inventor toolkit, as it helps designers explore the problems of the consumers and the technical capabilities of smart products and smart services.

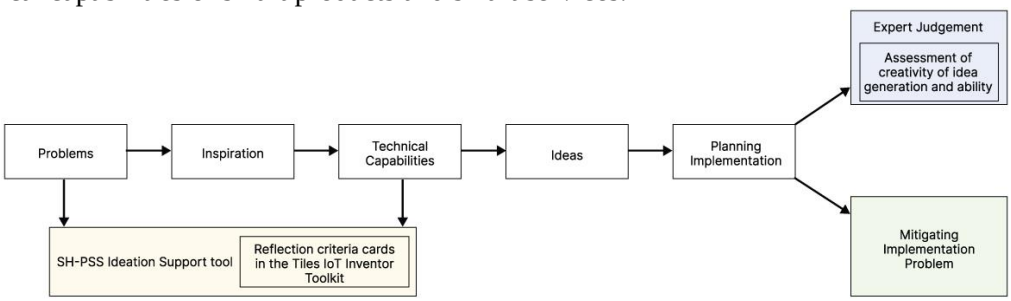

Figure 1. Ideation Design process of SH-PSS

3 RESEARCH METGODOLOGY

3.1 Design by Analogy

A classic definition of *analogy* is "the illustration of an idea with another idea that is similar or analogous to it in some significant features [8]. Design by analogy is a problem-solving technique involving using a familiar solution from one context as a model or inspiration for solving a problem in another context and developing innovative design, particularly during the ideation phase [1,18]. Designers use this method to produce creative designs. In product design, George Mestral's invention of Velcro and automobile design of the VW Beetle automobile form are some of the most cited examples of Design by analogy. Similarly, in product service system design, Design by analogy can be a valuable method to develop novel ideation. Meanwhile, Smith et al. (1993) demonstrated that analogous design might have a restricting influence on idea generation (fewer ideas are generated) and that unintentional transfer of negative design features may occur [5,17]. Therefore, it is essential to choose analogies wisely to avoid hindering effects in innovative design ideation and demonstrate the methods that keep the designer

in charge of selecting analogies that may only be beneficial, as finding relevant analogies is often tricky. Taking inspiration from previous studies, we identified technology adoption characteristics of SH-PSS [2]. These characteristics were analysed using the kano model approach to identify the attractive features. These attractive features are analogies introduced as SH-PSS reflection criteria cards in the Tiles IoT Inventor Toolkit. This method helps select relevant analogies systematically over random selection.

3.2 Tiles IoT Inventor Toolkit

The Tiles IoT Inventor Toolkit is a modular, hands-on learning system designed to teach product designers, interaction and user experience designers about the Internet of Things (IoT) enabled smart products [6]. This toolkit is a fun and educational way to learn about ideation of IoT products and can be an excellent tool for identifying and learning the consumer's problems and exploring the technical capabilities of the design brief while ideating [6,13]. The toolkit consists variety of physical tiles or cards that can be connected together to create various ideas. These decks in the toolkit are scenario, persona, missions, things, human actions, sensors, services, feedback and reflection criteria [12]. These tiles are created to inspire ideas for IoT user experiences by fostering both divergent and convergent thinking. The playbook guides the participants in designing IoT enabled smart products in a seven-step process (Table 1). Although the ideation technique is meant to be supervised by professionals, the playbook helps keep the design process visible and minimizes the need for supervision.

Table 1. Activities participants are asked to perform in the Tiles IoT Inventor Toolkit

	Activities
1	*Start by selecting a **Persona** and a **Scenario** that you have agreed to focus on*: What specific needs or problems are you trying to solve for the user selected? You can place the chosen Scenario and Persona cards in the card placeholders at the bottom left corner of the board
2	*Refine the **Mission:*** Challenge yourself to think creatively about the purpose or mission of your idea. Use up to three Missions cards to challenge and guide your idea.
3	*What objects are central to your user?* What objects are central to your users and how they can help solving the needs you have identified? Look through the **Things** cards, select a few of them as your starting point and place them on the card placeholders in the THINGS section of the board.
4	*What actions trigger the Thing?* Explore what types of input are needed, whether they are **Human Actions, Sensors or Services** from a connected source. A **thing** can have multiple triggers, and the same trigger can affect multiple **things**. Place your selections on the card placeholders in the TRIGGERS section of the board.
5	*How does the object respond when it is triggered?* Responses allow the object to communicate back to the user when it is triggered, either by a direct **Feedback** from the object itself or by sending data to an app or service through **Services**. (RESPONSES section of the board)
6	*Flesh out the idea:* The Storyboard section of the board is your sandbox to describe and illustrate the idea you are working on. Try to make notes and sketches to show how, where and when the concept works and looks, and what it might feel like to use it. Imagine a story which depicts a use case for your object, you can sketch each step on a post-it and stick them in the boxes.
7	*Reflect and improve:* Look through different **Criteria** and discuss how well your concept scores on each. Select a few strengths and weaknesses of the concept and see if you can come up with improvements to resolve the weaknesses, you can change the other cards and the storyboard if you feel the need. Write down a brief description of the final idea in the Elevator Pitch box.

3.3 Experiment Design

For validating and testing the intervention in the toolkit through introduction of additional reflection criteria cards, we have formulated three research questions (Table 2), which addresses technology adoption, service dominance and idea generation's ability enhancement. To answer these research questions, we have planned the set of experiment, where two sessions were planned as it's part. In the first session, the participant ideated without the additional proposed reflection criteria cards (**Control Group-Treatment 1**), while in the second session the same participants ideated with proposed reflection criteria cards (**Experiment Group-Treatment 2**). In both the experiment session, the participants were asked to ideate for the given design brief. A total of 15 designers (user experience designers, product designers, and human-computer interaction HCI students) participated in the study through workshops.

Table 2. Defined Research Questions

	Research Questions
RQ1	Do these design ideations elicit technology adoption in significant number of the target consumer?
RQ2	What is the smart home PSS design framework with special emphasis to service dominance?
RQ3	How to customize the generic PSS design toolkit in the context of smart home PSS design considering context awareness, multi-functionality, ability to co-operate, personalization, openness? (Idea generations ability enhancement)

Figure 2. SH-PSS Reflection Criteria Cards for Tiles IoT Inventor Toolkit

4 RESULT

4.1 Proposed SH-PSS Reflection Criteria Cards for Tiles IoT Inventor Toolkit using Design by Analogy

Osborn (1953) suggested that the innovative solution emerges on breaking out of a conventional pattern, either perceptual or cognitive, which unlocks the way for a broader range of alternatives. The mind works on a pattern that leads to solving a problem under the influence of prior knowledge and may affect creativity [14]. Therefore, we have presented an intervention in the seventh step of the Tiles IoT Inventor toolkit process (Table 1), which is the introduction of five additional SH-PSS reflection criteria cards.

These reflection criteria cards are ***context awareness, ability to co-operate, multifunctional, personalisation and openness*** (Figure 2). The reason behind making it a card tool is that they are simple to understand and easy to manipulate. Physical cards make the design process visible and less abstract [7,10]. Moreover, they serve as a tool to communicate while designing in a team.

Hypothesis Testing: Control Group and Experimental Group: A group of participants will be recruited and randomly assigned to either the control or experimental group to ensure unbiased distribution of potential confounding factors. The control group will serve as a baseline comparison, receiving no specific intervention or access to the Tiles IoT Inventor toolkit. Both groups will receive a design brief for an SH-PSS project and engage in an ideation session. The control group will rely on their existing expertise, while the experimental group will utilize the Tiles IoT Inventor toolkit to assist in idea generation. Participants in both groups will document and submit their ideas for evaluation based on predetermined criteria such as innovation, feasibility, and relevance to SH-PSS design. The generated design ideas and evaluation scores will be collected for analysis, enabling a comparison between the control group's ideation outcomes without the toolkit and the experimental group's outcomes with the toolkit. Through this controlled experiment, the aim is to assess the impact of the Tiles IoT Inventor toolkit on idea generation in SH-PSS design, providing valuable insights into its effectiveness in enhancing the technology adoption, service dominance and idea generation's ability enhancement quality of design ideas within the smart home context.

Table 3. Working Hypothesis

		Working Hypothesis
1	H_1	In the ideations, there is significant difference between ratings of peers on the **Perceived Ease-of-use** attribute, for a design concept in T1 and T2.
2	H_2	In the ideations, there is significant difference between ratings of peers on the **Perceived Usefulness** attribute, for a design concept in T1 and T2.
3	H_3	In the ideations, there is significant difference between ratings of peers on the **Context Awareness** attribute, for a design concept in T1 and T2.
4	H_4	In the ideations, there is significant difference between ratings of peers on the **Muti-functional** attribute, for a design concept in T1 and T2.
5	H_5	In the ideations, there is significant difference between ratings of peers on the **Ability to co-operate** attribute, for a design concept in T1 and T2.
6	H_6	In the ideations, there is significant difference between ratings of peers on the **Personalization** attribute, for a design concept in T1 and T2.
7	H_7	In the ideations, there is significant difference between ratings of peers on the **Openness** attribute, for a design concept in T1 and T2.
8	H_8	In the ideations, there is significant difference between ratings of peers on the **Service dominant** attribute, for a design concept in T1 and T2.

5 CONCLUSION

This study draws inspiration from a generic IoT toolkit and aims to make a focused toolkit for smart home product-service-system (SH-PSS). The SH-PSS reflection criteria cards (***context awareness, ability to co-operate, multifunctional, personalisation and openness***) in Tiles IoT Inventor Toolkit developed in the current study is through a structured approach for SH-PSS ideation. The proposed tool is devised based on the principle of Design-by-Analogy. The developed technique is a card-based tool representing the contextual meaning of each as a source of inspiration representing textual and visual cues for reflection criteria cards in the Tiles IoT Inventor Toolkit. In the last section, we have formulated a hypothesis to answer the research question, which addresses technology adoption (perceived ease of use and perceived usefulness), idea generation ability enhancement and service dominance. These hypotheses should be tested in the experiment with the control and experiment groups.

This study will be a significant contribution to design education, and it is expected that design practitioners and researchers will get help in identifying consumer problems and explore the technical capabilities of SH-PSS. It provides a structured framework and domain-specific cards that guide students in designing Smart Home Product-Service-Systems (SH-PSS), allowing them to grasp the complexities of SH-PSS design and consider factors like context awareness, multi-functionality, cooperation, personalization, and openness. The toolkit promotes a user-centred approach by incorporating cards related to scenarios, personas, missions, human actions, and feedback, encouraging students to empathize with end-users and develop a holistic design perspective. The toolkit also facilitates interdisciplinary collaboration, enabling effective

communication and knowledge integration among students from different backgrounds, including user experience designers, product designers, and HCI students. By offering a common language and framework, it supports collaborative ideation and the development of comprehensive SH-PSS solutions. Overall, the Tiles IoT Inventor toolkit is a valuable resource in design education, empowering students with essential skills to tackle the challenges of designing user-friendly and innovative smart home products and services, preparing them for the evolving landscape of IoT and its applications in smart homes.

REFERENCES

[1] Christensen B. T. and Schunn C. D. The relationship of analogical distance to analogical function and preinventive structure: The case of engineering design. *Memory and Cognition*, 2007, 35(1), 29–38. https://doi.org/10.3758/BF03195939

[2] Leeladhar G. and Kalita C. P. Adoption of Socio-Cultural Aspects in PSS Design for Smart Home Products: An Integrative Review. *Archives of Design Research*, 2022, 35(4), 7-29.

[3] Gianni F., Mora S. and Divitini M. Rapid prototyping internet of things applications for augmented objects: The tiles toolkit approach. In *Ambient Intelligence: 14th European Conference*, AmI 2018, Larnaca, Cyprus, November 12-14, 2018, Proceedings 14, pp. 204-220. (Springer International Publishing)

[4] Gram-Hanssen K. and Darby S. J. "Home is where the smart is"? Evaluating smart home research and approaches against the concept of home. *Energy Research & Social Science*, 2018, 37, 94-101.

[5] Jansson D. G. and Smith S. M. Design fixation. *Design Studies*, 1991, 12(1), 3–11.

[6] Kurze A., Totzauer S., Deschamps-Sonsino A. and Berger A. A. Collaborative Landscaping Exercise of IoT Design Methods. In *Proceedings of the 31st Australian Conference on Human-Computer-Interaction*, 2019, pp. 307-311.

[7] Lafrenière D., Dayton T. and Muller M. Variations of a theme: CARD-based techniques for participatory analysis and design. In: *Conference on Human Factors in Computing Systems*, 1999, pp. 151–152. https://doi.org/10.1145/632716.632807

[8] Leclercq P. and Heylighen A. 5. 8 Analogies per Hour. In: J. S. Gero (Ed.), *Artificial Intelligence in Design '02*, 2002, 285–303. Springer, Netherlands. https://doi.org/10.1007/978- 94-017-0795-4_14

[9] Liu A. C. and Chou T. Y. AN INTEGRATED TECHNOLOGY ACCEPTANCE MODEL TO APPROACH THE BEHAVIORAL INTENTION OF SMART HOME APPLIANCE. *International Journal of Organizational Innovation*, 2020, *13*(2).

[10] Lucero A. and Arrasvuori J. The PLEX Cards and its techniques as sources of inspiration when designing for playfulness. *International Journal of Arts and Technology*, 2013, 6(1), 22–43 https://doi.org/10.1504/IJART.2013.050688

[11] Davit M., Papagiannidis S. and Alamanos E. A systematic review of the smart home literature: A user perspective. *Technological Forecasting and Social Change*,138, 2019, 139-154.

[12] Mora S., Gianni F. and Divitini M. Tiles: a card-based ideation toolkit for the internet of things. In *Proceedings of the 2017 conference on designing interactive systems*, 2017, pp. 587-598.

[13] Mora S., Gianni F., Nichele S. and Divitini M. Introducing IoT Competencies to First Year University Students With The Tiles Toolkit. In *Proceedings of the 7th Computer Science Education Research Conference*, 2018, pp. 26-34.

[14] Osborn A. Applied Imagination: Principles and procedures of creative thinking. *Scribner New York*, 1953.

[15] Pirola F., Boucher X., Wiesner S. and Pezzotta G. Digital technologies in product-service systems: a literature review and a research agenda. *Computers in Industry*, 2020,123, 103301.

[16] Rijsdijk S. A. and Hultink E. J. How today's consumers perceive tomorrow's smart products. *Journal of Product Innovation Management* 26, no. 1 2009, 24-42.

[17] Smith S. M., Ward T. B. and Schumacher J. S. Constraining effects of examples in a creative generation task. *Memory & Cognition*, 1993, 21(6), 837–845. https://doi.org/10.3758/ BF03202751.

[18] Wood K. L., Linsey J. S. and Markman A. B. Modality and representation in analogy. Artificial Intelligence for Engineering Design, *Analysis and Manufacturing: AIEDAM* 22(2), 2008, 85–100. https://doi.org/10.1017/S0890060408000061.