The cycle of interdisciplinary learning and theory- solution building in design research

Young-ae Hahn
Yonsei University, Wonju, South Korea

Citation

Hahn, Y. (2016) The cycle of interdisciplinary learning and theory- solution building in design research, in Lloyd, P. and Bohemia, E. (eds.), *Future Focused Thinking - DRS International Conference 2016*, 27 - 30 June, Brighton, United Kingdom. https://doi.org/10.21606/drs.2016.521

DRS2016
Design + Research + Society
Future-Focused Thinking

2016 Design Research Society
50th Anniversary Conference
27-30 June 2016, Brighton, UK

The cycle of interdisciplinary learning and theory-solution building in design research

Young-ae Hahn

Yonsei University, Wonju, South Korea
yahahn@yonsei.ac.kr
DOI: 10.21606/drs.2016.521

Abstract: This article discusses a new perspective on the sustainable product/service development process as an iterative cycle of interdisciplinary learning phase and theory-solution building phase. Such a perspective puts emphases on deductive or abductive-inductive communication activities between stakeholders, difference in research paradigms within which involved researchers act in, and how given information leads to useful insights for theory-building or solution-building via cognitive operations. The cycle is described with the author's observations made during a research project, with specific cognitive activities pronounced in stakeholders' learning and ideation activities.

Keywords: design process and method; interdisciplinary communication; deductive learning; abductive-inductive ideation

Introduction

Designing for sustainability is tackling a wicked problem that requires investigations from multiple perspectives (Rittel & Webber, 1973). An interdisciplinary team of stakeholders, i.e., scientists, design researchers, business owners, and consumers are called for co-designed solutions.

For the collaborative practice of co-design, various methods, either original or adapted from other disciplines, have been put forward. First, on the process level, methods for participants' collaboration and hands-on experimentation are emphasized. Tangible artifacts, representations and visualizations, provide a common ground for participation, expression of knowledge and opinions, analysis, reflection, and prototyping (Simonsen et al., 2014; see also Brandt, Messeter, & Binder, 2008; Dindler & Iversen, 2007; Gaver, Dunne, & Pacenti, 1999; Koskinen et al., 2011; Sanders & Stappers, 2008; Sanders & William, 2002; Sleeswijk Visser, 2009; Vaajakallio, 2012). Second, on the project level, human-centered design (hereafter HCD) process models, although some of them do not put any particular emphasis on co-designing activities, have been adopted to guide the interdisciplinary team's problem definition and other activities. *MUST* method (Simonsen et al., 2014), Owen (2007)'s *Cyclical Knowledge* model of analytical–synthetical activities in abstract–concrete realms, the *Double Diamond* model ("Introducing design methods", 2013) of divergent and convergent natures of design thinking and activities, and IDEO's *Inspiration, Ideation, and Implementation* model (Brown, 2008) for knowledge building from both learning and making.

Building on current models and methods, in this article, the author proposes a new perspective on the interdisciplinary product/service development process, with focuses on the following aspects:

1. **Deductive or abductive-inductive communication activities between stakeholders:** A project team consists of stakeholders with diverse expertise, so each person partakes in various communication relations as either an expert or non-expert. Between stakeholders, deductive or abductive-inductive communication activities occur. Deduction starts from known, established premises (scientific theories, e.g.) to draw conclusions about the design problem at hand. Deductive communication, in this study, is the act of explaining established knowledge or describing current practices for non-experts in the subject area, following the principles of deduction. During the early stages in a design project, deductive communication activities are carried out for stakeholders' proper understanding of design problems, involved actors, artifacts, environments, and their interactions. Abduction and induction, in contrast, start from observations of the design problems at hand, to propose best explanations—that may contradict established scientific theories—about them. Abductive-inductive communication, in this study, is the act of discussing new hypotheses, knowledge or solution ideas, following the principles of abduction and induction; solution ideas are devised accordingly. The author argues that, whether a communication activity is deductive or abductive-inductive is, after all, discussion of the information dependency (Gudowsky & Bechtold, 2013), types of knowledge barriers (Carlile, 2004), and types of knowledge shared (Glicken, 2000) between stakeholders. Such dimensions of interdisciplinary communication deserve more attention from the design research community, so described in length in Section 2.1 in this article.
2. **Universal or situated types of resulting knowledge:** Some issues in an interdisciplinary collaboration arise from the participating researchers' different epistemological stances on what knowledge to pursue and what methods are valid for the purpose. Scientists' theoretical studies ask well-defined research questions from an objectivist position in hypothesis-led

controlled experiments. They aim to find universal knowledge (Friedman, 2002) of how the world currently is. Design researchers, from a constructivist position, might look for possible solutions to the ill-structured research problems in discovery-led constructive design research (Koskinen et al., 2011). They intend to build situated knowledge (Lawson, 2004) of how the world can be. An interdisciplinary collaboration might provide opportunities for both theoretical and constructive types of studies. The terms will be defined in detail in Section 2.2 in this article.

3. **How such knowledge is generated:** While current HCD process models recognize cognitive activities (that include tinkering with physical objects) in abstract - concrete realms as key parts of the creative process, specifically *how given information leads to useful insights for theory-building or solution-building* needs to be more explicitly discussed. The author found inspirations from theories of learning (Kolb, 1984; Michalski, 1993; Peirce, 1878)—how new knowledge is generated from the learner's logical and analogical reasoning through various cognitive operations.

So this article is structured into four main sections. Section 2 is a brief introduction of theoretical backgrounds in the areas of interdisciplinary communication, research paradigms, and learning theories. Section 3 illustrates the author's conception of an interdisciplinary design research process. The process is articulated in terms of communicative activities for interdisciplinary learning between scientists and constructive design researchers. The learning leads to the scientists' theory building and design researchers' solution building. Section 4 is a provocation – whether various mental operations discussed in learning theory literature are commonly observed in both new theory building and solution designing. The author's observations made during a research project with scientists will be presented. Section 5 sums up conclusions and limitations of this article.

Theoretical backgrounds

In this section, theoretical backgrounds of the author's conception of an interdisciplinary design research process are introduced, in the areas of interdisciplinary communication, research paradigms, and learning theories.

2.1 Information dependency, knowledge barrier and knowledge type in interdisciplinary communication

Expert and non-expert collaboration, e.g., scientists explain for consumers the relationship between GHG emissions and food consumption, will reveal the information dependency relationship between them. Gudowsky and Bechtold (2013, pp. 7-9) addressed that, if experts and non-experts rely on each other in resolving certain goals, the flow of information will be two-way, but otherwise the flow will be one-way. Possible cases of information flow are: (i) unidirectional supply of information from experts to non-experts,

(ii) bi-directional one-way communication where one's opinion does not necessarily influence the others' activities, (iii) two-way dialogues for understanding each other, and (iv) two-way communication to reach a consensus after analyzing topics from different angles.

Expert and non-expert collaboration will also reveal the knowledge boundaries between them. Carlile's framework describes syntactic, semantic, and pragmatic types of boundaries between people or disciplines (2004, pp. 558–559). A syntactic boundary, caused by a difference in the areas of expertise, can be resolved by transferring knowledge. A semantic boundary created by novelty (from new lexicon or uninterpretable outcomes) calls for translation of interpretive differences. Lastly, a pragmatic boundary is created with different interests between actors. For an effective negotiation and collaboration, involved parties need to learn others' knowledge, as well as transform their own domain knowledge for others, to show how each person's knowledge is useful in solving others' problems.

Expert and non-expert collaboration, or collaborations between experts from different domains, will externalize/exchange three types of knowledge (Glicken, 2000, p. 307): cognitive knowledge ("factual arguments about issues"); experiential (or local, cultural) knowledge is built "based on common sense and personal experience"; lastly, value-based knowledge that is "derived from social interests, and is based on perceptions of social value." People's value-based knowledge becomes explicit, when they compete over limited resources and try to prioritize their needs. All three types of knowledge will emerge during a conversation of sustainable development, at varying mixtures.

Knowledge sharing between experts and non-experts beyond the personal and disciplinary barriers is a prerequisite to an effective collaboration.

2.2 Research paradigms – theoretical or constructive study

Often different research paradigms clash in an interdisciplinary collaboration. A study is (at least implicitly) built on the researcher's understanding of what the reality consists of/what can be studied (ontology), what can be known and how close the researcher and the subject can be (epistemology), and how the subject can be legitimately investigated (methodology). To start a study, Crotty (1998, pp. 3-9) suggests considering epistemology first, i.e., the researcher's philosophical belief on the nature of knowledge discoverable in the study, then it guides you to choose theoretical perspectives, research design, and particular methods for data collection and analysis.

Collaboration between scientists and designers may lead to a theoretical study from an objectivist position. Theoretical research is based on positivist theoretical perspective where the subject of research is limited to well-defined problems. The research problem is investigated to discover objective truth about natural and man-made worlds that is believed to exist apart from the researcher's conscious mind. A theoretical study (1) organizes personal–practical observations into systematic thoughts that are applicable to different contexts, and (2) produces theories, a set of propositions, or models of natural and man-made worlds to allow for prediction of future consequences. (Friedman, 2002, pp. 399-400).

Evidently, findings from theoretical studies have been contributing to the thriving of mankind throughout the history, with knowledge of the world itself and its immensely practical applications. Such knowledge, as Friedman (2000, pp. 45-54) points out, also let design researchers understand the world, the different social, cultural, industrial and economic circumstances, and the human beings for which they design various artifacts, and foresee the outcomes of their design decisions and avoid failures.

Collaboration between scientists and designers may also lead to a constructive design research of "construction [of] product, system, space, or media […] becomes the key means in constructing knowledge" (Koskinen et al., 2011, p. 5) from a constructivist position. In contrast to the well-defined problems in theoretical research, Lawson (2004) discussed the immediate and situated nature of design knowledge (pp. 13-19) that arises from solving ill-structured, open ended, or non-formal (Dreyfus, as cited in Lawson, 2004, pp. 116-117) problems. A designer's situated—emerges as the problem situation unfolds—knowledge or experience lets her recognize more crucial issues, and match the problems and potential solutions throughout the design process. It is unique to each designer in each project.

2.3 Theories of deductive learning and abductive-inductive ideation

The cycle of deduction and abduction-induction has long been considered part of a creative process, where stakeholders' current knowledge is expanded and transformed into creative solutions. Three types of logical reasoning—induction, deduction, and abduction—are defined as follows (Peirce, 1878): deduction is an act of drawing conclusions by examining a case against given rules, while in induction, rules are induced from many connected observations over time. With abduction or hypothesis, rules are given and observations can be made, but the relationship between the rules and observations (i.e., case) are not obvious, so it is guessed considering the rules, observations, and the thinker's background knowledge. Merrel (2000) argues that the process of abduction, in fact, precedes deduction and induction, because a person has to have a hypothesis (abduction) before applying it to a larger set and making it a confirmed thesis (induction). Later, more cases will be evaluated against this confirmed thesis (deduction).

In relation to design research, first, deductive learning between scientists and designers during the problem analysis is critical in problem definition: involved artifacts, environment, stakeholders and their goals in various contexts are explained based on current scientific theories. Second, what is more interesting and deserves more attention is the abductive-inductive process of theory building and solution building during the synthesis phase. The following literature attempts to illustrate how creative ideas are born. Kolb (1984) argues that knowledge is generated from transforming the learner's concrete experience into abstract concepts or theories in a dialogical manner, through (1) a deductive phase of assimilating current scientific theories to explain problem phenomena, and (2) later through an abductive-inductive phase of accommodating, i.e., experimenting tentative hypotheses that are generated with abductive thinking. Michalski (1993)'s Inferential Theory of Learning (ITL) is more specific in what cognitive operations are relevant to transforming given information into new knowledge: generalization–specialization, abstraction–concretion, explanation–prediction, similization–dissimilization, selection–generation, agglomeration–decomposition, characterization–discrimination, and association–dissociation. The cognitive operations unfold either in an inductive direction to gain a more conceptual nature of knowledge, or in a deductive direction to show how conceptual knowledge applies to specifics.

In this article, the role of abduction that precedes induction is highlighted, because abduction can lead to either more conceptual knowledge by theory-building in scientists' theoretical research, or, to concrete solution-building in design researchers' constructive research. The cycle of interdisciplinary design research, however, starts with deductive learning to empower participating stakeholders with knowledge in the problem and solution spaces. Both deductive learning and abductive-inductive ideation are facilitated with stakeholders' communication activities.

3. The cycle of interdisciplinary design research

In this section, the authors' conception of interdisciplinary design research cycle is described (Figure 1) where deduction and abduction-induction processes unfold in an iterative manner through which new theory-solution ideas are conceived.

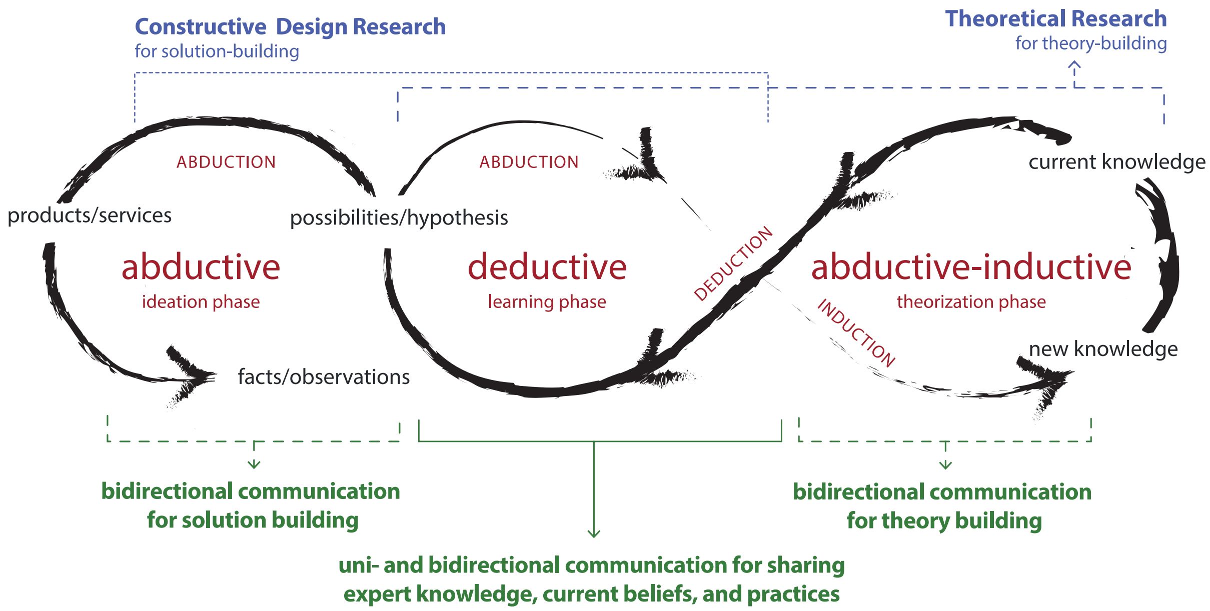

Figure 1 The cycle of interdisciplinary design research: learning and theory-solution building.

The first phase in the cycle is the deductive communication activities for learning at the center, where (1) experts' knowledge—typically presented in abstract theories and principles—is communicated for non-experts' theoretical understanding of research problems in a unidirectional manner (Gudowsky & Bechtold, 2013), and (2) all stakeholders' current beliefs and practices are shared in forms of cognitive and experiential types of knowledge in a bidirectional manner; popular understanding of research problems, and how stakeholders' current practices improve or exacerbate the problems are uncovered (Glicken, 2000). With deductive communication, syntactic and semantic types of knowledge boundaries (Carlile, 2004) can be crossed. For sustainable product/service development, deductive communication activities are of particular importance, because non-expert stakeholders (e.g., consumers) need significant empowering through learning experts' scientific knowledge, to apprehend the problem phenomena and acquire relevant vocabulary; otherwise their contributions become naive and useless. During the first phase of deductive learning, stakeholders' daily observations are illuminated with scientists' conceptual knowledge.

The second phase in the cycle is the abductive-inductive communication activities where original insights were conceived. From the learning/understanding experience in the first phase, stakeholders move on to (1) ideation on the left side, where activities invite them to exercise creative power in devising local and indigenous solutions, or (2) theorization of the right side to develop new theories and models. Ideas are developed in two different directions, in a more abstract direction for theory-building, and in a more concrete direction for solution-building. The new theories and solutions will be communicated as established knowledge in a deductive manner for a while, before their efficacies are questioned and replaced with other theories and solutions. In this phase, information dependency relationship is bidirectional; stakeholders' unweighted ideas pitched in from diverse perspectives, and later the ideas are prioritized, negotiated, validated, or connected to many of other concepts to form promising solutions or dominant theories in the end; ideas are further developed through active brainstorming, discussions and negotiations. Particlularly with negotiations, value-based type knowledge (Glicken, 2000) is revealed and the pragmatic type of knowledge boundaries (Carlile, 2004) can be crossed.

In the next section, with examples of a research project the author has participated, how such an interdisciplinary communication activities led to theoretical and constructive knowledge development, and what cognitive operations entail in the process will be illustrated.

Cognitive operations for theory-building and solution-building

In this section, the author would like to present a speculative—because it has not been proven with a large set of data—idea of how creative theories and design solutions are conceived from given information, inspired from Michalski (1993)'s seminal work and observations made from an interdisciplinary research project. The bottom line is that the seemingly whimsical inspirations for new theories and design solutions are, in fact, products of the thinker's background knowledge transformed with logical and analogical reasoning. Unlike the popular myth of creativity as a flash of insight, researchers argue that it comes with "deeply structured representations that […] admit limited, structurally guided alterations." (Gentner et al., 1997, p. 34) In other words, a creative idea is born when the thinker has a clear, structured understanding of the current concept, and also is capable of altering the current structure to change the concept itself or the relationship among the elements of the concept. With such backstage operations, the thinker finds either new explanations of the problem phenomena, or latent relevancy between the problem and solution ideas.

The research project the author has participated, in a team of scientists and design researchers, caterers, and consumers, lasted for two years. Together, the team investigated (1) knowledge and communication that caterers and consumers need, in order to build common competence, understanding, and practices toward sustainable development, (2) customers' current lunch practices, willingness and hindrances to behavioral changes, and understanding of climate changes, and (3) future developmental paths for new catering services and targeted changes in the consumer behavior with following research activities.

4.1 Deductive learning-understanding phase

The study started with learning activities designed to provide stakeholders contextualized scientific information (Figure 2, left). Stakeholders' daily observations were illuminated with scientists' conceptual knowledge of GHG emissions from food production and consumption. Active discussions on sustainable catering in environmental-technical, economical, and socio-cultural aspects followed. Equipped with scientific theories and principles, non-expert stakeholders became fluent in vocalizing four GHG types, frequent emission events, the networked actors/activities, and involved chemical processes.

Figure 2 Deductive learning and understanding activities between expert and non-expert stakeholders.

Then understanding activities followed (Figure 2, center) to uncover stakeholders' current knowledge and practices of having catering lunch meals. The activities evoked discussion on consumers' knowledge, concerns, interests, and preferences in eating at public catering venues. Their ideas of (i) current, usual, and realistic lunch, (ii) ideal lunch, and (iii) sustainable lunch at public catering cafeterias were described with printed cards of food ingredients. Stakeholders shared where and what they prefer to eat, along with personal circumstances (e.g., living with a girl friend who cooks for him, having stomach problems with some food items) and attitude towards sustainability (considering taste and nutrient more than environmental concerns). In another session (Figure 2, right), the different, abstract values that consumers seek in food were clarified with concrete examples.

From the learning-understanding activities, the author observed learners' *assimilation* (Kolb, 1984) of current scientific theories that are applied later to explain problem phenomena. For instance, from lecture sessions, the environmental-technical knowledge boundary between scientists and consumers, the economic-managerial knowledge boundary between caterers and consumers, and the socio-cultural knowledge boundary between consumers and scientists–caterers, are mediated by supplying scientific concepts, catering business guidelines, and various analytical viewpoints to expand understanding of consumer behaviour. Sessions for understanding explored different values of food and how consumers interpret them. Stakeholders' following cognitive operations are observed.

Generalization→Specialization: Generalization refers to the making of a larger set by adding more elements that fit the description, while specialization means reducing the larger set into smaller subsets by making distinctions between them. In this deductive phase, the consumer's vague understanding of scientific concepts were specified by differentiation and making contrast.

- Classification of GHGs into four gas types (CO_2, CH_4, N_2O, and F-gases), according to molecular structure, potency, concentration, and lifetime in the atmosphere.
- Comparison of fertilizer types in relation to N_2O emission.
- Nutrient types in the plate model.
- Categorization of food based on season, nutrient and environmental impacts.
- Classification of catering practices, different preparation processes and the types of meal served.

Prediction →Explanation: Explanation elaborates the underlying causes and following consequences of the given facts, while a prediction is made based on understanding of the causal relationship. In this study, the complexity of ecosystem, and the causal relations of how actors and their interactions with the material world lead to GHG emissions was explained.

- Meat farming and CO_2, N_2O, and CH_4 emissions.
- Industrial processes and F-gas emissions.
- Fossil fuel, electricity and other energy consumption and CO_2, N_2O emissions.
- Food and other organic waste and CH_4 emissions.
- Urbanization, construction and CO_2 emissions.
- CO_2, ocean acidification and biodiversity.

Abstraction →Concretion: Abstraction reduces details in a description of a set of elements, to transform the description into higher-level concepts, while concretion is about finding specific examples of scientific theories and abstract concepts. In this study, the different, abstract values that consumers seek in food were clarified with concrete examples.

- Healthy food: foods traditionally collected from forests (mushroom, berries, fish caught from the lake, and game meat), as opposed to cultivated foods (rye and other grains, and bread made of such grains).
- Eco-friendly food: domestic foods, foods made of leftovers because of food waste reduction.
- Profitable food: items that are inexpensive to produce but yield higher profit margins, such as alcoholic drinks, soft drinks, and coffee.
- Super food (healthy, eco-friendly, and profitable altogether): fried potato, onion, and meat mix) made of locally grown ingredients, because they can be made of healthy, leftover, and inexpensive vegetables.

In summary, deductive activities led stakeholders' shared knowledge ground building. With the learning-understanding experience, design researchers, caterers, and consumers started co-exploration of new theories and design solutions, as described in the next section.

4.2 Abductive-inductive theory-building and solution-building phase

Abductive-inductive communication activities in this phase explicitly asked for new theory and solution ideas by staging collaboration, maintained their explorative and creative attitudes, and facilitated their enacting and envisioning of how the world could be. Particularly, comments made on current catering services led to hypotheses of how new, improved services might yield the targeted effects. Involved cognitive activities are generalization–specialization, abstraction–concretion, explanation–prediction, association–dissociation and agglomeration–decomposition.

Scientists' abductive-inductive theory-building: With the inductive theory building on the right side in Figure 1, scientists (nutritionists and sociologists) participated in the study conducted a qualitative study of investigating sustainable food culture in the catering business sector. Caterer and consumer interview data reveal:

- Caterers are not convinced of using more local, seasonal, or organic ingredients: the environmental benefits of local ingredients are ambiguous to them, and the unstable availability, higher costs, and the municipality regulations of tendering make caterers hesitant of using seasonal-local or organic food.
- Consumers do not know what GHGs are, how GHGs are emitted from food production and consumption, and how food items impact the environment.
- Consumers' rather surprising understanding of food sustainability: wild food was frequently described as eco-friendly, because it does not incur any

agricultural cost, due to the country's unique natural environment and lifestyle. While the idea has a logical ground, it takes the consumer's attention away from the core issue: the sustainability of daily-consumed cultivated food.

- Consumers showed a wastage-focused attitude (Hall & Prior, 2011), thinking more about avoiding waste, unaware of major GHG emissions from food production, especially meat or dairy farming.
- Consumer comments revealed that few consumers were reasonably knowledgeable or interested in looking up the GHG emissions when they were in a fast-moving lunch line.
- Consumers see no rewards in choosing more plant-based, organic, local, and seasonal catering menus.

The scientists proposed two tentative models as research outcomes. First, a *sustainability model* calculates the ecological sustainability of the catering meals, to quantify CO_2 emissions in an average portion. Second, a *communication model* calls for improved sustainability communication via diversified touch-points to change the consumers' perception for the better. The two models will be developed into more rigorous scientific theories with more controlled, large-scale experiments.

Consumers and caterers' abductive solution-building: Scientists' research findings, and the assimilated knowledge in the previous phase guided the design researchers' solution-building on the left side in Figure 1, to develop tools to communicate the quantified ecological information of lunch menus, and a service design concept for food sustainability communication as part of customer experience at catering places (Figure 3).

While consumers proposed rather naïve ideas during the deductive learning phase, the ideas were refined in this ideation phase, after caterers resolved their questions and critically discussed their proposals, with explanations on (i) government regulation on hygiene, safety and quality control in the kitchen where raw proteins are handled, (ii) various challenges at the caterer's working environment, and (iii) how abiding by the regulation is in both the customer's and caterer's best interest. Ideas put forward include:

- Improved procurement criteria – choosing fresh or processed ingredients depends on the type and quantity of meals served.
- Displaying provenance when it is available.
- Cooking methods for preserving or enhancing nutrition, appearance, and flavour of the food, while reducing energy consumption.
- Food waste reduction by adjusting meal portion sizes of a la cartè menus.
- Repurposing CH_4 from waste landfill sites.
- Handling of unsold food - consumers wanted to see unsold food to be donated, but for consumer safety and due to caterer's limited resources, it should be discarded after reheated once.
- Seasonal, organic, and local menu ideas.

For the *communication model,* design research team hypothesized that providing more information and immediate, tangible rewards in the context of eating may improve consumer awareness and behavior. Consumers' current knowledge or beliefs were considered as a starting point of a new communication strategy. Ideas for encouraging them towards sustainable menus, while easing their cognitive burden, were put forward via the abductive process of reframing the problem situation, causality, and the involved product, process, and people. Some ideas were developed based on the quantified CO_2 data calculated with the *sustainability model.* Two major directions are:

- For off-site communication, an information system was proposed for a group of collaborating catering venues. The site displays their menus, availability, waiting time in real-time, to distribute consumer demands in the neighborhood, while encouraging sustainable eating. In this system, sustainability information gradually unfolds, starting from simple sustainability rating. If consumers are interested, comprehensive nutritional values and provenance information is provided.
- For on-site communication, during serving and dining, plates, napkins, and serving table signs guide consumers to the preferred behaviour. After dining, disposal signage guides consumers to properly sort waste.

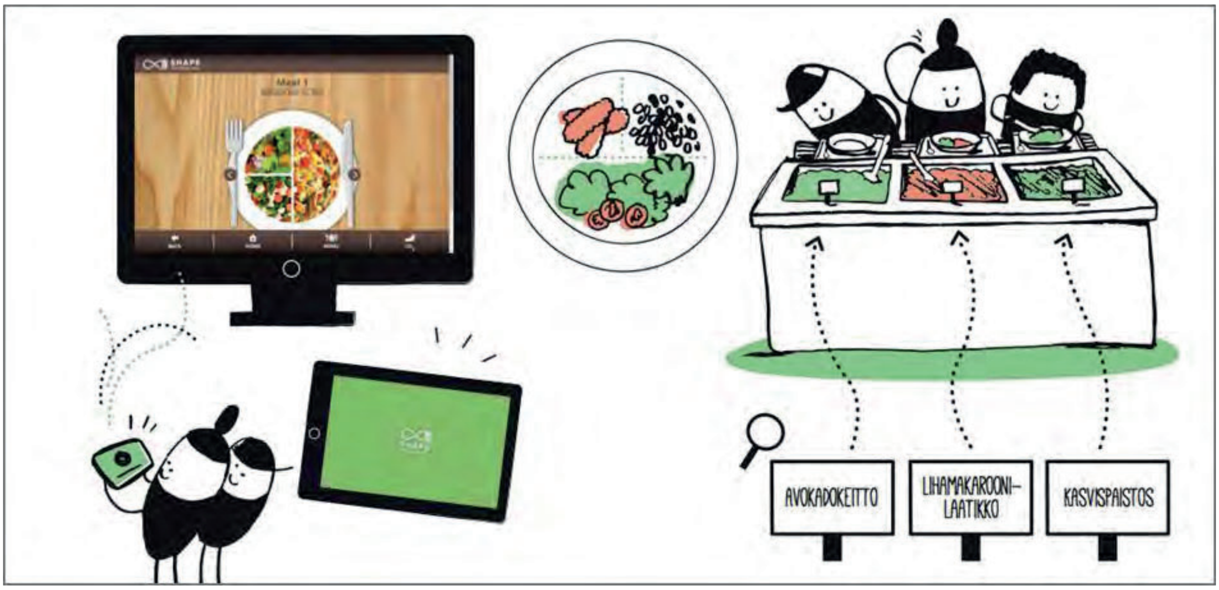

Figure 3 A collection of solutions for off-site and on-site sustainability communication: online systems for food nutrition, availability, and sustainability information (left), and on-site signage of food ingredients to encourage consumers to make more healthy and sustainable choices.

Conclusions

This article discussed a new perspective on the sustainable product/service development process as an iterative cycle of interdisciplinary learning phase and theory-solution building phase, with emphases on deductive or abductive-inductive communication activities between stakeholders, difference in research paradigms within which involved researchers act in, and how given information leads to useful insights for theory-building or solution-building via cognitive operations. In the first phase, stakeholders' deductive learning occurs across the environmental-technical, economic, and socio-cultural knowledge barriers between them. Their daily challenges and current practices were accounted for with contextualized scientific knowledge. In the second phase, scientists' inductive theory-building guides design researchers' co-exploration of design solutions with non-expert stakeholders. While non-expert stakeholders' suggestions are corrected, accepted, or transformed with the experts' in-depth knowledge, the discussions inspire them to materialize the abstract concept of sustainable product/service in local or personal contexts. Whether cognitive operations observed from both theory-building and solution-building are analogous in nature is the subject of future studies.

References

Introducing design methods. (June 2013) Retrieved from http://www.designcouncil.org.uk/news-opinion/introducing-design-methods.

Brandt, E., Messeter, J., & Binder, T. (2008) Formatting design dialogues - games and participation. *Codesign, 4*(1), pp 51-64.

Brown, T. (2008) Design thinking. *Harvard Business Review, June*, pp 85-92.

Carlile, P. R. (2004) Transferring, translating, and transforming: An integrative framework for managing knowledge across boundaries. *Organization Science, 15*(5), pp 555-568.

Creswell, J. W. (2009) *Research Design – Qualitative, Quantitative and Mixed Methods Approaches.* Los Angeles, London: SAGE Publications.

Crotty, M. (1998) *The foundations of social research*. Thousand Oaks, CA: SAGE Publications Ltd.

Dindler, C., & Iversen, O. S. (2007) Fictional Inquiry—design collaboration in a shared narrative space. *Codesign, 3*(4), pp 213-234.

Friedman, K. (2000) Creating design knowledge: From research into practice. *IDATER 2000 Conference,* Loughborough. pp. 31-69.

Friedman, K. (2002) Theory construction in design research: Criteria, approaches, and methods. In *Commonground: Proceedings of the 2002 Design Research Society International Conference,* London, UK, pp. 388-414.

Gaver, B., Dunne, T., & Pacenti, E. (1999) Cultural probes. *Interactions, 6*(1), pp 21-29.

Gentner, D., Brem, S., Ferguson, R. W., Markman, A. B., Levidow, B. B., Wolff, P., and Forbus, K. D. (1997) Analogical reasoning and conceptual change: A case study of Johannes Kepler, *Journal of the Learning Sciences, 6*(1), pp 3-40.

Glicken, J. (2000) Getting stakeholder participation 'right': A discussion of participatory processes and possible pitfalls. *Environmental Science & Policy, 3*, pp 305-310.

Gudowsky, N., & Bechtold, U. (2013) The role of information in public participation. *Journal of Public Deliberation, 9*(1), pp 1-35.

Hall, L., & Prior, G. (2011) *Exploring food attitudes and behaviours: Findings from the food and you survey 2010: Food safety segmentation.* (No. JN 197020 Food and You Segmentation Report). N/A: Food Standards Agency.

Kolb, D. A. (1984) *Experiential learning: Experience as the source of learning and development.* Englewood Cliffs, NJ: Prentice Hall.

Koskinen, I., Zimmerman, J., Binder, T., Redström, J., & Wensveen, S. (2011) *Design Research Through Practice. From the Lab, Field, and Showroom*. San Francisco, CA: Morgan Kaufmann.

Lawson, B. (2004) *What Designers Know.* Boston, MA : Elsevier/Architectural Press.

Merrel, F. (2000) *Abducting the process of abducting: An impossible dream?* Unpublished manuscript.

Michalski, R. S. (1993). Inferential theory of learning as a conceptual basis for multistrategy learning. *Machine Learning, 11*, pp 111-151.

Owen, C. (2007) Design thinking: Notes on its nature and use. *Design Research Quarterly, 2*(1), pp 16-27.

Peirce, C. S. (1878) Illustrations of the logic of science, *Popular Science Monthly*, vol. 13.

Poggenpohl, S., & Sato, K. (2003) Model of dissertation research in design. *Proceeding of the 3rd Doctoral Education in Design Symposium, Tsukuba, Japan.*

Rittel, H. W. J., & Webber, M. M. (1973) Dilemmas in a general theory of planning. *Policy Sciences, 4*, pp 155-169.

Sanders, E., & Stappers, P. J. (2008) Co-creation and the new landscapes of design. *Codesign, 4*(1), pp 5-18.

Sanders, E., & William, C. (2002) Harnessing peoples creativity: Ideation and expression through visual CoCommunication. In J. Langford, & D. McDonagh-Philip (Eds.), *Focus groups: Supporting effective product development*. New York, USA: Taylor and Francis.

Scrivener, S. (2000) Reflection in and on action and practice in creative-production doctoral projects in art and design. *Working Papers in Art and Design, 1.*

Seliger, M., & Hahn, Y. (2015) *Thesis design: Research meets practice in art and design master's theses.* Helsinki, Finland: Aalto ARTS Books.

Simonsen, J., Svabo, C., Strandvad, S. M., Samson, K., Hertzum, M., & Hansen, O. E. (2014) *Situated design methods*. Cambridge, MA: MIT Press.

Sleeswijk Visser, F. (2009) *Bringing the everyday life of people into design* (Doctoral Dissertation).

Vaajakallio, K. (2012) *Design games as a tool, a mindset and a structure* (Doctoral dissertation).

About the Author:

Young-ae Hahn, is an assistant professor of Visual Communication Design. She currently studies (i) the nature and formation of designerly knowledge, (ii) persuasive solutions for healthy and sustainable lifestyles, and (iii) participatory systems for promoting social inclusion.