ICED13
INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED13
19-22 AUGUST 2013, SUNGKYUNKWAN UNIVERSITY, SEOUL, KOREA

DESIGN ACTIVITY AND TEAM INTERACTION CHARACTERISTICS: A CASE STUDY OF PROTOCOL ANALYSIS ON TEAM-BASED PRODUCT-SERVICE SYSTEMS DESIGN PROCESSES

Sang Won LEE, Jun LEE, Nanhyeon JO, Yong Se KIM
Sungkyunkwan University, Korea

ABSTRACT

In this paper, the protocol analysis on team-based Product-Service Systems (PSS) design processes is conducted to study the characteristics of design activities and team interactions. For protocol analysis, the detailed coding scheme of design activities of PSS design process is proposed and the interaction process analysis (IPA) coding scheme is utilized. Two design teams are composed to conduct team-based PSS design sessions. In the protocol analysis, the patterns of design activities during the PSS design are characterized, and it is demonstrated that the individual team member leads specific design activities and spends more times on them based on his/her knowledge level in turn. In addition, the team interaction patterns seem to depend on the personalities of the individual members due to its social nature. These findings can be used for composing design teams and guiding their design process for effective PSS design.

Keywords: product-service systems, design process, human behaviour in design, design activity, team interaction

Contact:
Prof. Sang Won Lee
Sungkyunkwan University
Mechanical Engineering
Suwon
440-746
Korea, Republic of (South Korea)
sangwonl@skku.edu

1 INTRODUCTION

Recently, significant attentions have been drawn to Product-Service Systems (PSS) which could address diverse values of consumers and create new market with more profits by providing integrated solutions of products and services. Goedkoop et al. firstly introduced the concept of PSS to simultaneously address ecological and economic issues, and defined PSS as a marketable set of products and services, jointly capable of fulfilling a user's need (Goedkoop et al., 1999). Since then, there have been active researches for systematically conceptualizing, analyzing and developing PSS (Mont, 2002; 2004, van Halen et al., 2005).

For effective PSS design, much research in developing systematic PSS design methods and processes has been conducted. Morelli initiated the development of the methodological PSS design process in a design discipline (Morelli, 2003), and Aurich et al. studied the design process of products and services by reflecting life-cycle issues (Aurich et al., 2006). Matzen and McAloone introduced the activity modeling cycle (AMC) method and studied the structured modeling framework to differentiate and categorize tasks of PSS development (Matzen and McAloone, 2006; 2008). Shimomura's group was one which made contributions on the development of service design process in their service engineering research (Sakao and Shimomura, 2007). They introduced the service model comprising flow model, scope model, view model and scenario model as sub-models, and the concept of the receiver state parameter to address value and cost of service providers and receivers. Maussang et al. borrowed the concept of the service model to develop the PSS design method incorporating agent-based value design and functional analysis (Maussang et al., 2007). In addition, the authors' group, Creative Design Institute, has been among active research groups to develop a comprehensive PSS design process, and has recently proposed the methodological PSS design process (Kim et al., 2010).

In the meantime, understanding PSS design process can be of much significance to apply the developed PSS design process methodology to actual PSS design projects for promoting their effectiveness and creativity. In this context, a protocol analysis can be quite useful since it allows effective analysis and management of the design activities with protocol data (Gero and Neill, 1998). However, there has been very little research on this issue. One interesting research on this issue can be found in (Sakao et al., 2011). They conducted the descriptive study on the team-based PSS design session via a protocol analysis. They referred to PSS layer method and used nine PSS dimensions as one of the coding schemes. In addition, the micro and macro strategies which were modified from those for a product design were used as the coding schemes. They preliminarily concluded that the iterative behaviors between values of customers and life-cycle activities for solution were found, and that the life-cycle activities might be a central role within PSS design.

While investigating the PSS design process via a protocol analysis, a unique and customized coding scheme for the PSS design process is needed since PSS design usually includes various complicated issues, which could be much different from a product design. In addition, due to the interdisciplinary nature of the PSS design, the PSS design can be conducted via teams whose members have different personalities and backgrounds, and thus, the investigation on team interaction is of much necessity.

Therefore, in this paper, the new detailed coding scheme of the PSS design process is proposed based on the specific methods used during the PSS design session. In addition, the interaction process analysis (IPA) coding scheme is adopted. The above two coding schemes are used for the protocol analysis on the PSS design sessions to investigate the characteristics of design activities and team interactions, respectively. Two PSS design teams are formed based on the personalities and backgrounds of members. After monitoring and recording all activities during the PSS design sessions, the results from the protocol analysis are analyzed and discussed. The outline of this paper is as follows. In section 2, the new coding scheme of the PSS design process is proposed and its detailed descriptions are provided. In section 3, IPA is introduced and its detailed coding categories are explained. The descriptions on the PSS design experiment including PSS design teams, tasks and experimental setting are provided in section 4. Section 5 discusses the protocol analysis and results, and section 6 concludes the paper.

2 PSS DESIGN PROCESS

2.1 Overall Process

The PSS design process consists of following six phases: (1) Requirement Identification and Value Proposition, (2) Stakeholder Activity Design, (3) PSS Functional Modeling, (4) Function-Activity

Mapping and PSS Concept Generation, (5) PSS Concept Detailing and (6) PSS Concept Prototyping (Kim et al., 2010). The schematic view of the PSS design process is given in Figure 1.

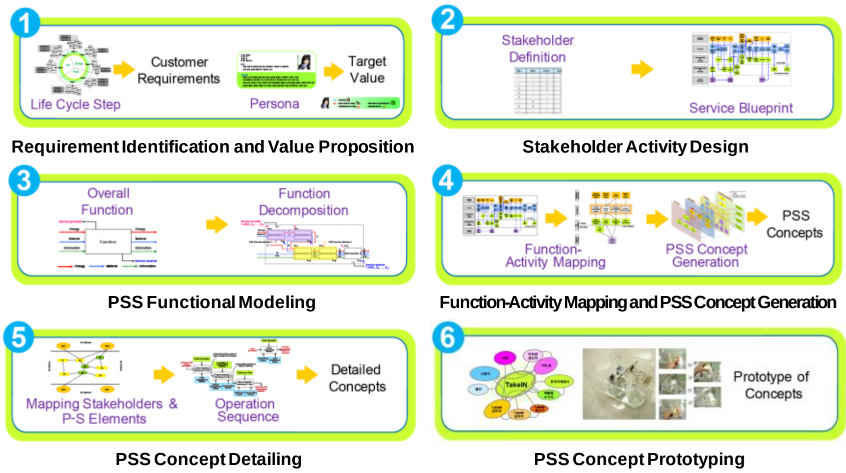


Figure 1 Product-Service Systems (PSS) design process (Kim et al., 2010)

In the first phase of “Requirement Identification and Value Proposition”, needs and requirements of various stakeholders of different life-cycle steps associated with a specific product were analyzed and identified. Then, values are assigned to the extracted needs and requirements based on the E3 value framework (Cho et al., 2010). After the target values are chosen, the needs and requirements related those target values are further considered. In the second phase of “Stakeholder Activity Design”, specific stakeholders and their related activities are defined and generated by reflecting those needs and requirements which are identified from the previous stage. In this phase, the service blueprint method is used to tangibly and visually document how and where service receivers and service providers interact (Shostack, 1982). In addition, the scenarios for PSS can be analyzed and generated by using the service blueprint method. Meanwhile, those activities are detailed by addressing various associated context elements on the basis of the context-based activity modeling (Kim et al., 2010). The third phase is “PSS Function Modeling” in which designers define an overall function of PSS and decompose it into a number of sub-functions to effectively accommodate various activities of stakeholders. After generating the activities and functions, they are appropriately mapped together to conceive critical service elements and product elements in the phase of “Function-Activity Mapping and PSS Concept Generation”. In this phase, a function layer is inserted into the service blueprint to produce the service blueprint with function. In this service blueprint with function, the specific pairs of activities and functions are chosen to define service elements and generate product element concepts by incorporating ‘affordance’. The phase of “PSS Concept Detailing” covers summarized and detailed descriptions on generated PSS concepts and their business models. The final phase of the PSS design process is “PSS Concept Prototyping”, which involves building of physical prototypes and story-telling of PSS scenarios.

2.2 Detailed Coding Scheme

In order to meaningfully analyze PSS design, the overall PSS design process should further be deployed into more detailed sub-design activities. The definitions of each sub- activity are summarized in Table 1, and they will be used as the subclasses for the protocol analysis coding scheme of the PSS design process. As can be seen in Table 1, total 17 subclasses were identified.

3 INTERACTION PROCESS ANALYSIS (IPA)

The Interaction Process Analysis (IPA) was adopted for analyzing interaction and communication behaviors in design teams (Bales, 1950). When comparing interaction patterns between teams or between each member in a team, the IPA could be effectively applied. As a matter of fact, it has been extensively applied to small group interaction analysis. The IPA coding scheme is composed of 12 categories, which fall into two major areas; social-emotional area (categories 1-3, 10-12) and task area (categories 4-9). The social-emotional area is further divided into positives (categories 1-3) and negatives (categories 10-12). Task area is neutral, and it consists of two parts. Categories of 4 to 6 are associated with giving answers or contributions for solving a problem faced by a team, and categories of 7 to 9 are related to asking questions in a task oriented area. In Figure 2, the IPA coding scheme is given with brief explanations and codes for each category.

Table 1 Definitions of coding scheme for PSS design process protocol analysis

Primary class	Subclass	Codes
Requirement Identification & Value Targeting	Select a target product for PSS design	TAP
	Define and analyze life-cycle steps related to the target product	LCS
	Identify and analyze various stakeholders for life-cycle steps	STH
	Extract needs and requirements of stakeholders	REQ
	Assign and relate E3 values to the needs and requirements	E3V
Stakeholder Activity Design	Generate and analyze as-is/to-be scenarios of PSS	SCN
	Generate activities and address/analyze their context elements	CBAM
	Generate and analyze service blueprints as sequence of activities	SBL
PSS Function Modeling	Define/decompose functions and analyze their inter-relations	PSSF
Function-Activity Mapping & PSS Concept Generation	Link activities and functions and generate service blueprint with functions	FAM
	Define service elements by considering stakeholders, activities and functions	SEM
	Extract affordances based on function-activity interaction analysis	AFF
	Generate product elements reflecting extracted affordances	PRT
PSS Concept Detailing	Link service and product elements and describe overall concept of PSS	PSSC
	Generate and analyze business model of PSS	BIZM
PSS Concept Prototyping	Building prototypes and story-telling of PSS scenarios	PSSP
Process remarks	Designer's informal remarks	INFR

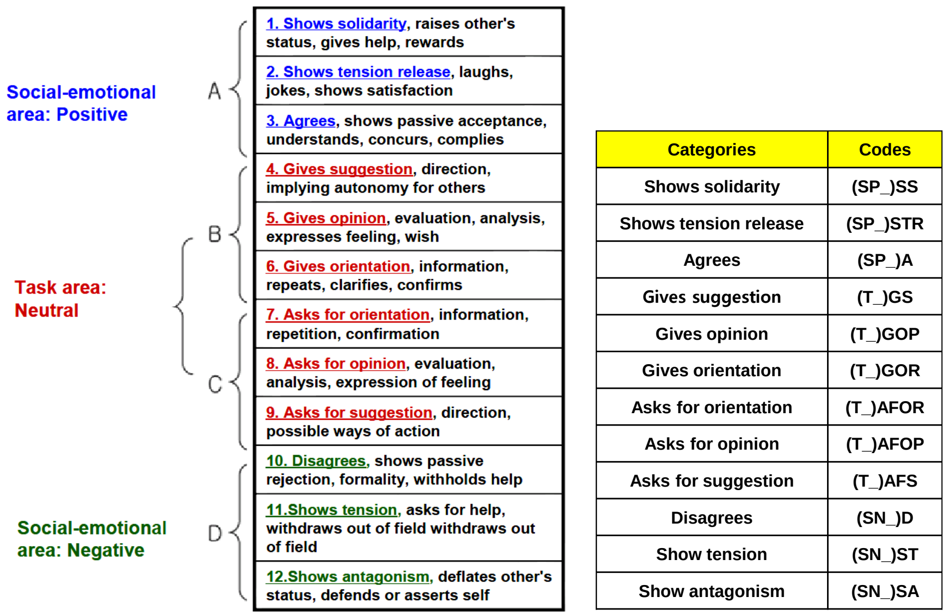


Figure 2 Interaction Process Analysis coding scheme (Bales, 1950)

4 PSS DESIGN EXPERIMENT

4.1 PSS Design Teams

Two design teams were composed to conduct PSS design sessions. The personal creativity modes (Wilde, 1999) and backgrounds of each designer were considered to form the design teams. The team 1 consisted of three female industrial design researchers who had somewhat different personal creativity modes. On the other hand, the team 2 was composed of one female industrial design researcher, one female graduate student majoring in interaction science and one male graduate student majoring in mechanical engineering. The personal creativity modes of members of the second team were very similar to each other. The personal creativity modes of two design team members are given in Figure 3. As can be seen in Figure 3, in the case of the team 2, the members had a strong aspect of intuition in a perception domain and a feeling-oriented trait, in particular teamwork creativity, in a judgment domain in common.

(a) Team 1 *(b) Team 2*

Figure 3 Personal creativity modes of design team members

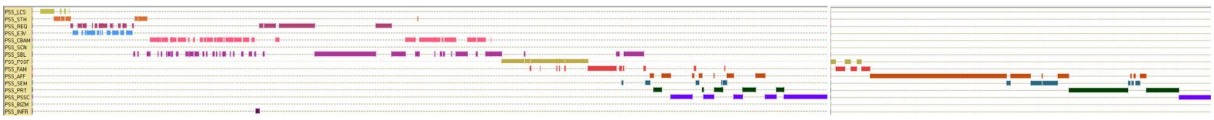
4.2 PSS Design Task

The members of two design teams firstly determined together a target product with which they could start for their conceptual PSS design. The selected target product was a public phone. In Korea, only a small number of people have used public phones since most of people possessed portable smart phones. Thus, each design team decided to explore any novel PSS ideas around a public phone. Each design team conducted PSS design sessions twice. Once they finished their first PSS design session, it was found that their work on conceiving product elements was not sufficient. Therefore, each team was asked to conduct another PSS design session from the phase of PSS function modeling. During their design tasks, they used various PSS design support software tools such as the life-cycle step analysis, service blueprint, PSS function-based design and PSS concept generation systems. In addition, they also used a general design support software tool such as SketchBook Pro for their sketching. Their entire activities and talk were recorded via small microphones and video cameras, and the screens were also recorded via the Camtasia software. The members of both design teams were well aware of PSS design process which was described in the sections of 2.1 and 2.2.

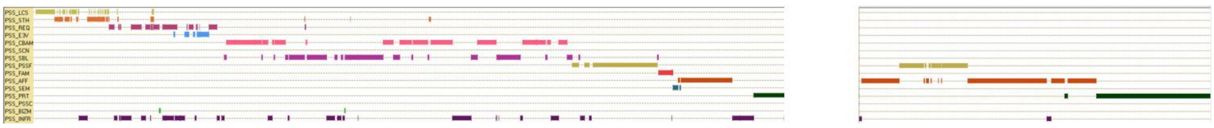
5 PROTOCOL ANALYSIS – RESULTS AND DISCUSSIONS

5.1 PSS Design Process

The protocol data obtained from the PSS design sessions of two design teams were analyzed by two experienced design researchers based on the coding scheme proposed in the section of 2.2. The InterACT software was utilized for the protocol analysis. Figure 4 shows the protocol analysis results of two PSS team design processes. The total times were 7 hours 35 minutes for the team 1 and 6 hours 53 minutes for the team 2 respectively when combining the first and second PSS design sessions. Since both design teams conducted the conceptual PSS design tasks, the subclass of PSSP was not considered for the protocol analysis. In addition, the subclass of TAP was not considered either because both design teams made a decision on the target product together.



(a) Team 1

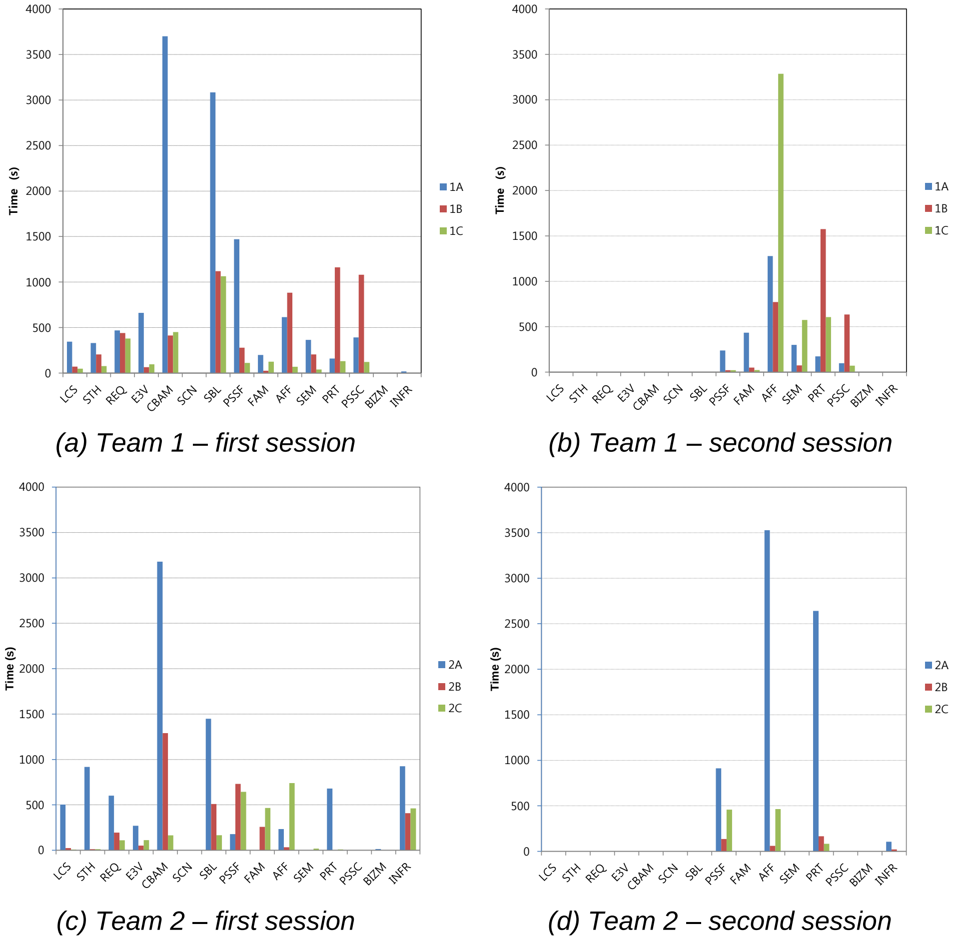


(b) Team 2

Figure 4 PSS design process protocol data coding results of two design teams

As can be seen in Figure 4, more iteration among PSS design activity subclasses is observed in the case of team 1. For instance, it can be observed that the iterations between REQ and E3V and between CBAM and SBL in the case of team 1 were much more than those in the case of team 2 at an early PSS design period of the first session. In addition, the team 1 conducted much iteration among AFF, SEM, PRT and PSSC at a final period of the first PSS design session. In the second PSS design session, the iteration patterns among PSSF, FAM, AFF and PRT were also observed. On the other hand, the team 2 did not conduct PSS design task in an iterative way overall. At a beginning period of its first session, some iterative pattern between LCS and STH was observed, but other design activities were done in more focused way. The similar focused patterns were also found in the second session. In other words, it seemed that the team 2 finished one design activity and shifted to other design activity during the PSS design session. Meanwhile, team 2 conducted much more INFR activity than team 1, which may be due to the feeling oriented trait of its members.

The times spent by three individual members of each team were shown in Figure 5. In the case of the first PSS design session of team 1, the member 1A spent most times during its PSS design session overall. More specifically, the member 1A led sub-design activities in the early design phases such as E3V, CBAM, SBL and PSSF. The member 1B led sub-design activities in the later design phases such as AFF, PRT and PSSC, and made some contributions in REQ, CBAM and SBL. In addition, the member 1C made some contributions in the sub-design activities of REQ, CBAM and SBL in terms of the working time. On the other hand, in the second PSS design session, the participation of the member 1C increased significantly, especially, in the sub-activities of AFF and SEM. The member 1A led PSSF and FAM, and the member 1B made some contribution in AFF and led PRT and PSSC, which is similar to the case of the first session. In the first session of team 2, the member 2A spent most times overall, and in particular, in the sub-design activities of LCS, STH, REQ, E3V, CBAM, SBL and PRT. The member 2B made some contributions on the activities of CBAM and SBL, and led the activity of PSSF. The member 2C made some contributions on the activity of PSSF, and led the activities of AFM and AFF. However, in the second session, the member 2A's dominance was significantly high in all sub-activities of PSSF, AFF and PRT.



(a) Team 1 – first session *(b) Team 1 – second session*

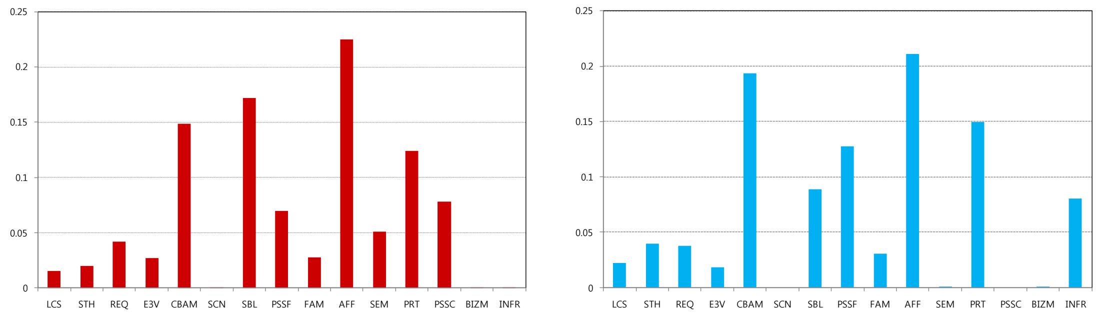
(c) Team 2 – first session *(d) Team 2 – second session*

Figure 5 Times spent by members for each sub-design activities of PSS design processes

The above patterns of times spent by each member could be attributed to their levels of knowledge and expertise on the specific sub-design activities of the PSS design process. For instance, in the first session of team 1, the member 1A had more previous experiences on the PSS design and could lead overall PSS design process in the early stage. In addition, she had known the context-based activity modeling and service blueprint very well, and therefore considerable times spent in the activities of CBAM and SBL were shown. In the case of the member 1B, she had been specialized in the affordance-based design and concept generation with a lot of sketches, and therefore she led the activities of AFF, PRT and PSSC in the later stage. On the other hand, in the second session, it seems that the member 1C took a leading role in the sub-activities of AFF and SEM based on her sufficient knowledge on those activities. In the case of the members of 1A and 1B, they still took similar roles in the second PSS design session, too.

Similarly, in the first session of team 2, the member 2A had more overall knowledge and previous experiences on the PSS design than the members 2B and 2C, and thus she led the sub-design activities in the early stage mostly. The members 2B and 2C started to spend considerable times from the sub-activities of PSSF while the participation of the member 2A was very low. In particular, the sub-activities of FAM and AFF were mostly conducted by the member 2C. In addition, the member 2A came back and conducted the sub-activity of PRT mostly, which could be due to her background as the industrial designer. However, in the second session, the member 2A took a leading role for every sub-activity based on the materials on which team 2 had worked.

Meanwhile, the ratios of times spent for each sub-design activity with respect to the total time of the PSS design sessions of two design teams were given in Figure 6. As can be seen in Figure 6, each team spent most times in the sub-activity of AFF – 22.5% and 21.5%, respectively. In the case of team 1, the sub-activities of SBL, CBAM and PRT were those in which the members spent much time in sequence. On the other hand, in team 2, the sub-activities of CBAM, PRT and PSSF were those in which the members spent much time in sequence.



(a) Team 1 *(b) Team 2*

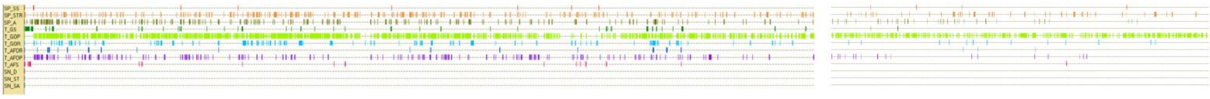
Figure 6 Ratios of time spent for each sub-activity versus total time during PSS design processes

5.2 Team Interactions

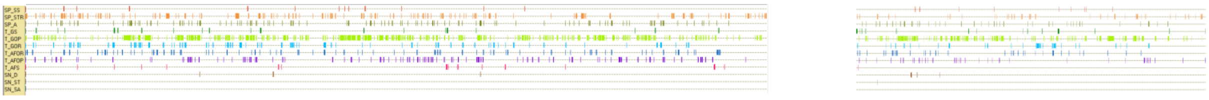
The interaction patterns in two design teams were also analyzed by using the IPA coding scheme. Figure 7 shows the IPA protocol data coding results of each team during their first and second PSS design sessions. As can be seen in Figure 7, when comparing the interactions between team 1 and team 2 in the case of the first PSS design session, more dense interactions were observed in the case of team 1 than team 2, overall. In particular, steadily dense interactions in the category of “gives opinion” (T_GOP) were observed in team 1 throughout the entire design session, but those in team 2 were much less and some dense interactions in T_GOP were occurred intermittently. Besides, many interactions in “agrees” (SP_A) and “asks for opinion” (T_AFOP) were occurred at the beginning period of the design session of team 1. It can imply that the members of team 1 did more vigorous interactions while they tried to understand the given PSS design problem by asking for opinions, giving opinions and agreeing. However, in the case of team 2, such vigorous interactions were not observed at the beginning period. It seemed that the members of team 2 were less interactive while they analyzed the design problem at the beginning period. In the case of the second PSS design session, more frequent and dense interactions on T_GOP were observed in the case of team 1 than team 2. In particular, in team 2, more interactions in the categories of T_AFOR and T_AFOP were observed than team 1.

The counts of each IPA category of individual members of each team are graphically shown in Figure 8. As shown in Figure 8(a) and (c), in the case of team 1, the member 1 showed much more counts than others for all IPA categories in the first session. Since the members 2 and 3 had the introvert traits on the personal creativity modes, their participations could be less than that of the member 1. On the other hand, all members of team 2 showed similar numbers of counts for all IPA categories in the first session. In the second session, the design teams were asked to additionally conduct the design activities to produce more detailed product elements. Therefore, as can be seen in Figure 8(b) and (d), the members of 1B and 2A having expertise on the sub-activities of AFF and PRT seemed to show more interactions, in particular, in GOP.

To more closely analyze the differences in the team interaction patterns of two teams, the normalization process was applied via dividing each IPA count of the member by the total IPA count of the member. In Figure 9, the converted normalized ratios of each member's IPA counts are shown in the first and second design sessions. As can be seen in Figure 9, the degree of similarity in the interaction patterns among members in the case of team 2 is higher than that in the case of team 1. In other words, the members of team 2 show similar interaction behaviors while the interaction behaviors among the members of team 1 are slightly different. This difference could be attributed to the degrees of similarity in the personal creativity modes among the team members due to social nature of team interaction.

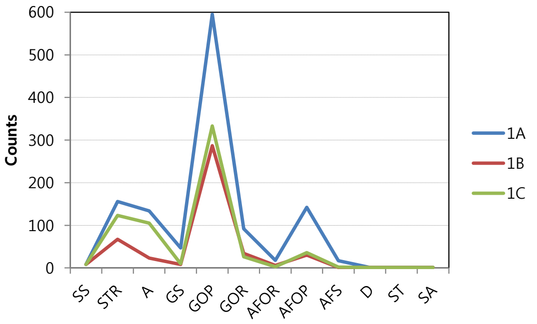


(a) Team 1

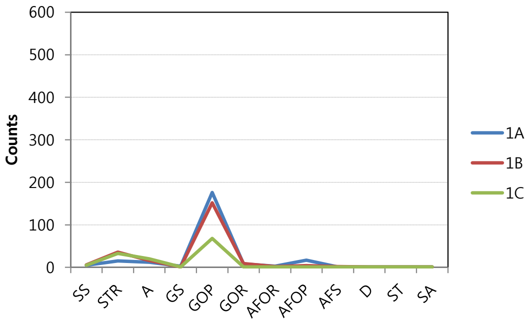


(b) Team 2

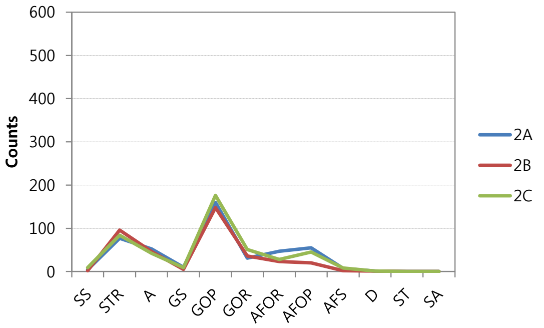
Figure 7 IPA protocol data coding results of two design teams



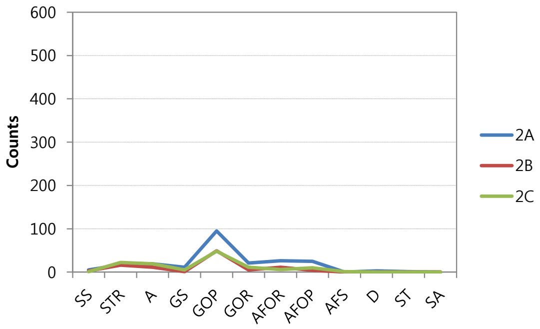
(a) Team 1 – First session



(b) Team 1 – Second session



(c) Team 2 – First session

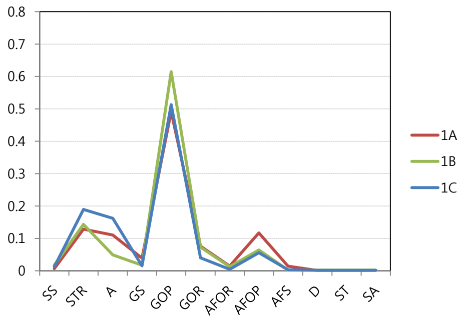


(d) Team 2 – Second session

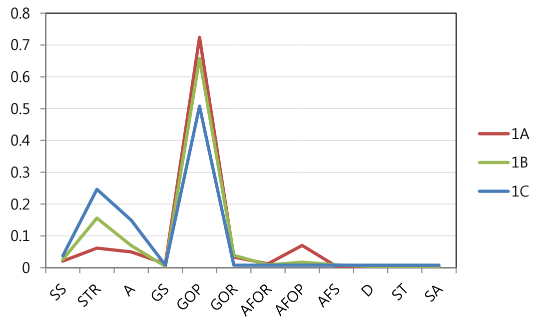
Figure 8 Counts of IPA categories of two design teams

5.3 PSS Design Results

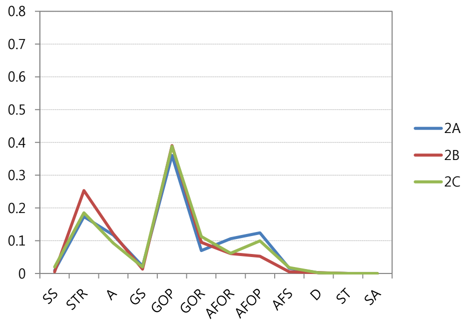
The critical product elements resulted from the PSS design sessions of two design teams was conceived. The sample sketches of the critical product elements realizing their PSS concepts are given in Figure 10. The PSS concept which was generated from team 1 was the "One-day mobile" PSS. When people cannot use their cellular phones, for instance, in the case of failure, maintenance, and etc., they can visit the public phone booth in which the automatic renting machine is located and rent the cellular phone with payments. Then, after finishing the use of rented cellular phone, they can return them into another automatic renting machine in a different pubic booth. In the case of team 2, they came up with the "Coin exchange and deposit" PSS via the public telephone. Whenever people need to change their bills into coins or people need to deposit coins into their membership cards, they can use the coin exchange/deposit machine which is renovated from the public phone.



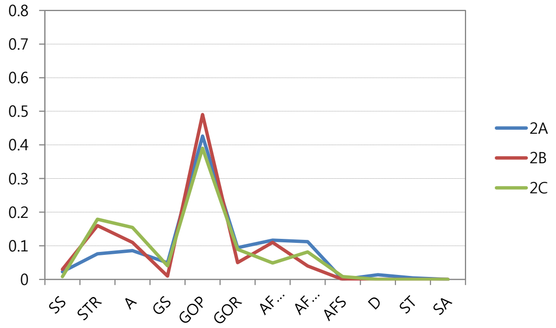
(a) Team 1 – First session



(b) Team 1 – Second session



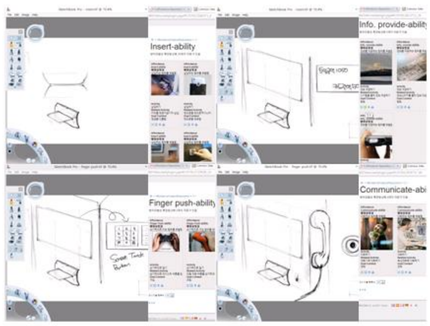
(c) Team 2 – First session



(d) Team 2 – Second session

Figure 9 Converted normalized ratios of IPA categories of two design teams

(a) Team 1



(b) Team 2

Figure 10 Sample sketches of critical product elements of PSS concepts of two design teams

6 CONCLUSIVE REMARKS AND FUTURE WORK

In this paper, the characteristics of design activities and team interactions were investigated with the protocol analysis on PSS design processes. The detailed coding scheme of design activities of PSS design process based on the specific methods was proposed, and the IPA coding scheme was adopted for the protocol analysis. For the case study, two design teams were formed based on personal creativity modes and backgrounds of the members. From the results of protocol analysis, the patterns of design activities during the PSS design process could be identified. It was demonstrated that each member took leading roles for different design activities in the PSS design process based on their knowledge and expertise on them. In addition, the team interaction behaviors could depend on the traits of personal creativity modes of the team members due to their social nature. Therefore, it could be necessary to form interdisciplinary design teams whose members have sufficient knowledge to appropriately cover all design activities without any difficulties. In addition, the members having diverse personal creativity modes might be necessary to induce substantial interactions among them, and as a result, rich discussions on various issues during the PSS design process could be possible.

Future work can characterize PSS design processes in real industrial fields such as design consulting and manufacturing firms. In addition, the correlations between the characteristics of design activities and team interactions and PSS design quality will be studied to establish the strategy to effectively guide the PSS design process.

ACKNOWLEDGMENTS

This work was supported by the Industrial Strategic Technology Development Program funded by the Ministry of Trade, Industry & Energy (MI, Korea).

REFERENCES

Aurich, J. C., Fuchs, C., and Wagenknecht, C. (2006) Life Cycle Oriented Design of Technical Product-Service Systems. *Journal of Cleaner Production*, Vol. 14, pp. 1480–1494.

Bales, R. F., (1950) *Interaction Process Analysis: A Method for the Study of Small Groups*, Cambridge, MA: Addison-Wesley Press.

Cho, C. K., Kim, Y. S., and Lee, W. J. (2010) Economical, Ecological and Experience Values for Product-Service Systems. *Int'l Conf. on Design and Emotion*, Chicago.

Gero, J. S., and Neill, T. M. (1998) An approach to the analysis of design protocols. *Design Studies*, Vol. 19, pp. 21-61.

Goedkoop, M. J., van Halen, C. J. G., te Riele, H. R. M., and Rommens, P. J. M. (1999) Product Service Systems: Ecological and Economic Basics. *Report for Dutch Ministries of Environment (VROM) and Economic Affairs (EZ)*.

Kim, Y. S., Maeng, J. W., and Lee, S. W. (2010). Product-Service Systems Design with Functions and Activities: Methodological Framework and Case Studies, *Int'l Conf. on Design and Emotion*, Chicago.

Matzen, D. and McAloone, T. C. (2006) A Tool for Conceptualising in PSS Development. *Design for X, Beiträge zum 17. Symposium. Lehrstuhl für Konstruktionstechnik*, Technische Universität Erlangen, pp. 131–140.

Matzen, D. and McAloone, T. C. (2008) From Product to Service Orientation in the Maritime Equipment Industry – a case study. *41st CIRP Conf. on Manufacturing Systems*, Tokyo.

Maussang, N., Sakao, T., Zwolinski, P. and Brissaud, D. (2007) A Model For Designing Product-Service Systems Using Functional Analysis and Agent Based Model. *Int'l. Conf. on Engineering Design*, Paris.

Mont, O. (2002) Clarifying the Concept of Product-Service System. *Journal of Cleaner Production*, Vol. 10, pp. 237–245.

Mont, O. (2004) *Product-Service Systems: Panacea or Myth*?, Ph.D. Dissertation, Lund University.

Morelli, N. (2003) Product-service systems, a perspective shift for designers: A case study: the design of a telecentre. *Design Studies*, Vol. 24, no. 1, pp. 73–99.

Sakao, T., and Shimomura, Y. (2007) Service Engineering: a Novel Engineering Discipline for Producers to Increase Value Combining Service and Product. *Journal of Cleaner Production*, Vol. 15, pp. 590–604.

Sakato, T., Paulsson, S., and Mizuyama, H. (2011) Inside a PSS Design Process: Insights Thorough Protocol Analysis. *Int'l. Conf. on Engineering Design*, Copenhagen.

Shostack, G.L. (1982) How to Design a Service. *European Journal of Marketing*, Vol. 16, No. 1, pp. 49-63.

van Halen, C. J. G., Vezzoli, C., and Wimmer, R. (2005) *Methodology for Product-Service System Innovation*, Royal Van Gorcum, Netherlands.

Wilde, D. J. (1999) Design Team Role. *ASME Int'l. Conf. Design Theory and Methodology*, Las Vegas.