ZOOMING IN ON PRODUCT-SERVICE SYSTEM ECODESIGNING: A NOVEL ANALYSIS APPROACH AND APPLICATION TO A CASE INVOLVING EXPERIENCED PRACTITIONERS

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ABSTRACT

In this article, we introduce a protocol analysis-based approach to analyze the cognitive characteristics of conceptual ecodesigning of product-service systems (PSSs). We initially present a novel and generic model to represent the lifecycle stages of solutions offered by industry and we contextualize it to PSS based offerings. Based on this representation of the PSS lifecycle stages and that of its architecture, we propose a multi-level coding scheme and a protocol analysis-based approach to analyze the distribution of designers' cognitive effort on the following three dimensions: i) different lifecycle stages, ii) different aspects of PSS architecture and iii) ecodesign activities and environmental issues. We applied this approach to analyze a conceptual PSS ecodesign case, performed in a laboratory setting by a pair of experienced practitioners. The results clearly indicate the evidence of quantitative differences in the distribution of the designers' cognitive effort on the different dimensions of PSS ecodesigning and thus, confirms the applicability and utility of the proposed approach.

Keywords: Product-Service Systems (PSS), Ecodesign, Design cognition, Protocol analysis, Sustainability

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1 INTRODUCTION

Manufacturers are increasingly developing and offering product-service systems (PSSs), which are essentially systems consisting of integrated combinations of tangible products and intangible services (Meier *et al.*, 2010). The focus of future development of such systemic solutions will likely be on the design of the desired behaviour of the system (including that of constituent product and service design objects), which can effectively address the customer needs (Isaksson and Eckert, 2020) with minimal environmental impacts. Such offerings of PSS-based solutions are widely considered to have a high potential to support manufacturing companies in their endeavour to contribute to the societal transition towards a resource-efficient and circular economy (Tukker, 2015).

In recognition of the resource-efficiency potential of the PSS, environmentally conscious (eco)design and environmental sustainability researchers have directed significant focus into PSS design research (Pigosso *et al.*, 2015). Ecodesign is defined as "a systematic approach, which considers environmental aspects in design and development with the aim to reduce adverse environmental impacts throughout the life cycle of a product" (ISO:14006, 2020) or that of a PSS. Several prescriptive methods and tools, as reviewed by (Brambila-Macias, Sakao and Kowalkowski, 2018; Vasantha et al., 2012), have been developed to support the ecodesign of PSSs. However, such design methods and tools generally tend to be prescriptions that rely on theoretical constructs or high-level qualitative descriptions of design processes. To gain a comprehensive understanding of the design activity and effectively support it, robust quantitative knowledge of its underlying micro-scaled cognitive characteristics is essential (Gero and Milovanovic, 2020; Hay *et al.*, 2020).

Since the cognitive nature of PSS designing is hypothesized to be significantly different from traditional product designing (Sakao *et al.*, 2020), potential differences in the cognitive characteristics of PSS and product ecodesigning are also expected. There are a few empirical studies that have provided useful quantitative insights into the cognitive nature of product ecodesign (e.g., Collado-Ruiz and Ostad-Ahmad-Ghorabi, 2010; Vallet *et al.*, 2013). There is still a lack of empirical insights into and availability of approaches to investigate how designers ecodesign PSSs at the cognitive level. Such empirical insights are crucial to improve and support PSS ecodesign practice and pedagogy.

This exploratory study aims to present an approach to analyse the cognitive characteristics of PSS ecodesigning. To operationalize this aim, we investigate the following research questions (RQs):

1. How can the distribution of cognitive effort expended on the different lifecycle stages during PSS ecodesigning be measured?
2. How can the distribution of cognitive effort expended on the different dimensions of the system architecture across the different lifecycle stages during PSS ecodesigning be mapped?
3. How can the cognitive effort expended on analysis and manipulation of potential environmental issues during PSS ecodesigning be measured?

To address these research questions, we initially present a generic lifecycle representation that can be used to analyse the distribution of designers' cognitive effort on the analysis and manipulation of potential environmental issues across the different lifecycle stages of a PSS solution during its conceptual ecodesigning (see Section 2). Such a model is deemed to be essential, as the lifecycle activities of PSSs are considered to be significantly different and more complex than that of products (Abramovici *et al.*, 2010). The currently available representation of lifecycle is mainly product-centric and thus is not suitable to analyse the lifecycle activities of a PSS. Based on this lifecycle model and the prescribed architecture of the PSS, we present a protocol analysis (Ericsson and Simon, 1993; van Someren *et al.*, 1994) based approach to analyse the cognitive characteristics of conceptual PSS ecodesigning, which includes a novel coding scheme. This approach of analysis is then applied to a sample of protocol data extracted from a conceptual PSS ecodesign session by experienced practitioners (described in Section 3). The results of this analysis are then presented (see Section 4). Finally, the responses to the research questions, their implications and limitations, a brief review of related works and future research directions are discussed before concluding the study (see Section 5).

2 PROPOSED REPRESENTATION OF SOLUTION LIFECYCLE STAGES

The currently available representation of the product lifecycle stages begins with raw material extraction, followed by product design, manufacturing, distribution and use (including reuse, maintenance, repair, remanufacturing, refurbishing and upgrading), before ending with the final disposal of the product after end of life treatment (ISO:14006, 2020). Since the goal of the PSS is to provide systemic solutions that can fulfil customer needs, the system that is designed to deliver the solution can include used products as a part of its content along with services. Also, if the products or components of a PSS offering do not reach their full service lives in one use, they can be remanufactured or reused as a part of the contents of another offering (for an example, see Sundin, Lindahl and Ijomah, 2009). This suggests that the lifecycle of a PSS solution does not necessarily have to either begin with raw material extraction or end with product disposal, as represented by the extant model of lifecycle stages.

Although the classic model of the lifecycle is suitable for the product-centric view, it cannot effectively represent the more complex lifecycle activities of the PSS. This issue of compatibility is reflected by the challenges faced during the definition of a functional unit for the PSS with the traditional product-centric lifecycle view (Kjaer *et al.*, 2018). Even though there are several frameworks for PSS lifecycle development and management, most of them tend to be linear (Song *et al.*, 2015), to neglect the constituent service-oriented intangible aspects and not accommodate the flows of resources and information that are peculiar to a PSS.

Therefore, an alternative generic representation of the solution-oriented lifecycle stages is proposed as follows. In this representation, the lifetime of the solution is decoupled from the lifetime of its constituent product or other components that enable the solution. Instead, it is based on the time required to develop the solution, address the targeted customer needs, and subsequently recirculate the resources used, and information produced that can support the development of other solutions, in line with Vandermerwe (1993). This representation does not include a dedicated stage for either raw material extraction or disposal. Rather, it includes a representation of a source and a sink for resources (RSS), which is essentially the environment. The resources are either extracted from the source or processed and emitted to the sink by the system throughout the lifecycle (partly based on Joung *et al.*, 2013). Lifecycle of a solution refers to the series of interconnected stages through which the solution passes through during its lifetime. It can be categorized into three cyclical stages (as illustrated in Figure 1): i) solution development, ii) solution deployment and iii) solution retirement.

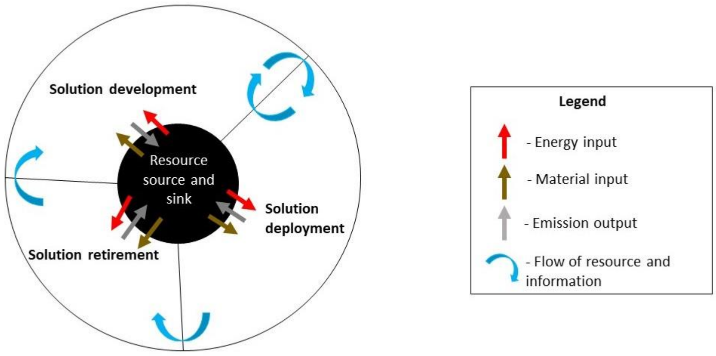

Figure 1. Representation of solution-oriented lifecycle stages

Solution development refers to the stage in which the system contents and the channels required to deliver the solutions are developed. In the PSS context, the contents can include tangible products and intangible services, while the channel can include a network of companies and the infrastructure (Mont, 2002) required to transfer, amplify and control the contents (Sakao and Shimomura, 2007). While this stage can include the main activities of the manufacturing stage of the traditional product lifecycle such as material procurement and processing, design and fabrication of new products and adaptation of existing products, it is also extended by the design of potential services, business models and the delivery channels (Schweitzer and Aurich, 2010).

The solution deployment stage for the PSS includes the use of the constituent products, execution of pre-designed services and multiple cycles of reuse of serviced products. The information gathered in the solution deployment stage can be circulated back into the development stage (illustrated in Figure 1) to further modify the solution to be offered. These activities together address the needs of and deliver the intended value to the customers. The solution retirement stage represents the stage at which the solution is withdrawn. It involves the restoration and recirculation of the resources used and information developed in the lifecycle of the current solution into another through activities such as information transfer, product takeback, remanufacturing, recycling and related transportation (based on BSI, 2018).

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It can also include the safe disposal of remanent resources to the RSS (including material, products, or components) that cannot be further recovered. Further, PSSs are expected to constantly interact with the RSS in each of the three stages, as the system might need to extract material (e.g., raw material and consumables) and energy (e.g., power) from the environment and also generate emissions (e.g., greenhouse gases) in all of the three stages. The overall goal of PSS ecodesigning is to minimize environmental impacts. Based on the view of design as a cognitive process of iterative exploration of problem and solution spaces (Hay *et al.*, 2017), during ecodesign we expect designers to analyse (the problem space) and manipulate (the solution space) the interactions between the solution and the physical environment to reduce potential impacts. Here, such interactions are broadly referred to as environmental issues, which include the material and energy input and emissions output.

3 ANALYSIS OF CONCEPTUAL PSS ECODESIGNING

3.1 Description of the research method and source data

Protocol analysis is a widely used method for the analysis of verbal thought sequences that are extracted from think-aloud protocols, which are considered as valid sources of data on cognition (Ericsson and Simon, 1993; van Someren *et al.*, 1994). This method has been adapted and widely utilized in design research across multiple domains (Gero and Mc Neill, 1998; Gero and Milovanovic, 2020; Hay et al., 2017). The protocol data for this study is extracted from a conceptual PSS ecodesign session carried out in a laboratory setting. The cohort of this study included a pair of experienced practitioners from a multi-national manufacturing company based in Sweden. These practitioners had an average work experience of nine years between them in multiple domains such as product development, ecodesign, service and marketing development. They were given the task of conceptually redesigning an existing coffee machine and related services to increase its resource efficiency and to reduce its environmental impacts. This sample data is part of a larger data set used in a previous study (Neramballi *et al.*, 2018), and the readers can access the detailed design brief from the same study.

3.2 Proposed multi-level coding scheme and research process

Designers tend to approach design problems on multiple levels. The following coding scheme is proposed to analyse PSS ecodesigning on the following three levels: design effort expended on i) different lifecycle stages, ii) different aspects of the PSS architecture and iii) ecodesign activities and environmental issues. The first level of the coding scheme is based on the proposed representation of solution-oriented lifecycle stages described in Section 2. The different codes attributed to the different lifecycle stages of the PSS and the qualifying lifecycle activities within each stage that can potentially be influenced by the designers are presented in Table 1.

Table 1. Coding for solution-oriented lifecycle stages

Lifecycle stage	Qualifiers - Lifecycle activities	Code
Multiple stages	- Activities that are not limited to one lifecycle stage	1
Solution development	- Business model design - Product and service design - Material procurement and processing - Product fabrication/adaptation - Filling/packaging/distribution	2
Solution deployment	- Logistics - Instalment - Product use - Service execution (spare or consumable supply/repair/maintenance) - Product reuse	3
Solution retirement	- Remanufacture - Recycle - Logistics (takeback) - Waste management	4

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Initially, the collected protocol data was transcribed and then broken down into smaller units termed as segments by following the segmentation approach suggested by Gero and Mc Neill (1998). The following rules for the application of the first-level coding scheme on the segmented data, were followed. If, in a segment, the designers address any of the qualifying lifecycle activities belonging to a specific lifecycle stage category, then the corresponding code detailed in Table 1 is assigned to that segment. The second level of the coding scheme is based on the PSS architecture from an earlier work (Nerambali *et al.*, 2019). During PSS ecodesign, designers are expected to distribute their cognitive effort on the product and service design objects and the interactions between them. Each segment of the protocol data is assigned a specific code to measure this distribution, based on the following reasoning: a segment is coded as "P" if the designers address only the product design object, "S" if they address only the service design object and "I" if they address the interactions between the product and service design objects.
During conceptual PSS ecodesigning, designers are also expected to distribute their cognitive effort on two different types of ecodesign activities to minimize the overall environmental impacts: analysis and manipulation of the interactions between the solution being designed and RSS across its different lifecycle stages (partly based on Vallet *et al.*, 2013). As described in Section 2, such interactions are further categorized under the following environmental issues: material and energy input to the system from the RSS and emission output from the system to the RSS. The following third level of coding scheme is applied to capture the distribution of designers' cognitive effort on such activities and issues. A segment is assigned the code "M" or "En" (for material or energy input, respectively), "Em" (for emission output) or "C" (for more than one type of issue), either under the activity of "analysis" or "manipulation", depending on whether in a segment the designers are either analysing or manipulating such environmental issues, respectively. Each segment is given one code from each of the three levels of the coding scheme. The segments that do not address any of the qualifiers of the three levels of the coding scheme are considered as noise and coded as "O". Note that a segment coded as noise for one level of the coding scheme can receive a valid code from another level. Illustrations of the application of the three levels of the coding scheme on an example of a segmented protocol dataset are presented in Table 2.

Table 2. Illustrations of the application of the multi-level coding scheme

Examples of segments	**Coding scheme - Level 1**	**Coding scheme - Level 2**	**Coding scheme - Level 3**	
			Analysis	Manipulation
"I mean if we are thinking about the resource deficiency of the overall offering, we could highlight the big contributors."	1	O	C	O
"We could have a paper filter if that is more resource efficient."	2	P	O	M
"I think we should look at energy required for maintenance during the use phase."	3	S	En	O
"How can we effectively schedule the product takeback/replacement service towards end of life? This is needed to limit logistics that can contribute to reduced emissions."	4	I	O	Em

The distributions of the cognitive effort of the designers on the different lifecycle stages, on the different aspects of the PSS architecture and the analysis or manipulation of environmental issues are measured by quantifying the occurrences of the respective codes within the respective coding schemes. Also, a correspondence analysis (Gero and Milovanovic, 2020) is performed to map the distribution of the cognitive effort expended on the different aspects of the PSS system architecture across the different stages of the solution lifecycle.

3.3 Description of the data analysis

Two coders and a third arbitrator analysed and segmented the protocol data into 693 segments. Subsequently, the above described multi-level coding scheme was applied to the segmented data. Cohen's Kappa was not used, as inter-coder reliability was measured by comparing the coding agreement

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of each of the two coders with the arbitrated codes. Each coder's agreement with the arbitrator for each of the three levels of the coding scheme was measured and found to be satisfactory, with over 70%.

4 RESULTS

4.1 Distribution of cognitive effort on the different lifecycle stages

The results of the analysis indicate that the majority of the distribution of the design effort expended by the designers on the different lifecycle stages was on *solution development* (56%) and a significant portion of the rest on *solution deployment* (40%). The design effort on *multiple stages* (2%) and the *solution retirement* stage (2%) were minimal. The cumulative occurrences of the design effort on the different lifecycle stages are presented in Figure 2.

Figure 2. Cumulative cognitive effort expended on the different lifecycle stages of the PSS solution

Quantitative analysis of the data supporting the figure and the qualitative analysis of the figure itself reveals that designers spent the majority of their effort on the *solution deployment* stage until the middle of the design session, after which their focus shifted to the *solution development* stage. By the end of the design session, it is evident that designers had expended the highest effort on the *solution development* stage, closely followed by *solution deployment*. Also, linear approximations of the cumulative occurrences of design effort on the different lifecycle stages revealed that both the *solution development* and *deployment* stages constantly received the designers' focus with relatively high coefficients of determination of 0.9855 and 0.9570, respectively.

4.2 Distribution of cognitive effort on the different aspects of PSS architecture

The designers expended the majority of their effort on the *product* design object, which accounted for 73% of the total distribution, while the *service* design object received the least focus with 3% of the total share. *Interactions* between the product and service design objects received the remaining 24% of the total share of the design effort. Linear approximations of the cumulative occurrences of the designers' effort on the three aspects of the PSS architecture revealed that the designers only focused on the *product* design object at a constant rate throughout the design session (the only aspect of the PSS architecture to receive a coefficient of determination value above 0.95, with 0.9909).

4.3 Distribution of cognitive effort on ecodesign activities and environmental issues

Results from the first level of the analysis revealed that the designers spent the majority of their effort on the ecodesign activity of *analysis*, as it received 57% of the total share of cognitive effort; the rest was expended on the ecodesign activity *manipulation*. The relatively high coefficients of determinations of the linear approximations of the cumulative occurrences of the effort on the two activities revealed that both *analysis* (0.9864) and *manipulation* (0.9777) were focused on by the designers at a constant rate.

Results from the second level of analysis revealed that the designers expended almost half of the total share of their cognitive effort on the environmental issue *material input* (46%), closely followed by *multiple measures* (36%) and subsequently, by *energy input* (17%). The environmental issue *emissions output* received the least share of the designers' cognitive effort, with just 1% of the total share. Note that designers may have addressed any of the three discrete interactions (*material* and *energy input* and *emission output*) in combination, under the category *multiple measures*. Linear approximations of the cumulative occurrences of

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the environmental issues revealed that the categories *multiple measures* and *material input* were constantly focused on throughout the design session, as their linear approximations received relatively high values of coefficient of determination (0.9944 and 0.9654, respectively).

4.4 Results of the correspondence analysis

To map the distribution of the cognitive effort expended by the designers on the different aspects of the PSS architecture across the different stages of the solution-oriented lifecycle, a correspondence analysis was carried out, and the results are illustrated in Figure 3.

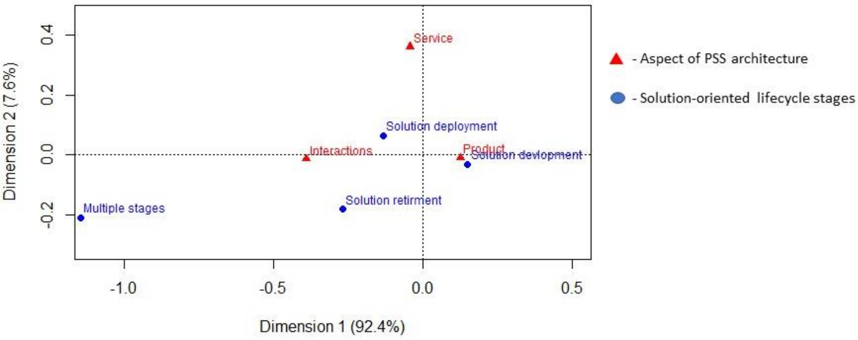

Figure 3. Correspondence analysis of PSS architecture and lifecycle stages

The results of the analysis cover the entire range of data variance. Dimension 1 on the horizontal axis explains the majority of the data variance (92.4%), while Dimension 2 on the vertical axis explains the rest of the variance (7.6%). Together these dimensions represent 100% of the information in the residual. The cognitive effort on the *product* as a design object appears to correspond the most to s*olution development* as a lifecycle stage in relation to the correspondence between the effort on other aspects of the PSS architecture and the different lifecycle stages. This suggests that the designers chose to focus mainly on the *product* design object during *solution development* despite the availability of an extended design space (in terms of the *service* design object and the *interactions* between the two) and lifecycle perspective.

5 DISCUSSIONS AND CONCLUSIONS

5.1 Answers to research questions

The RQs (stated in Section 1) are answered as follows: To answer RQ1 (*How to measure the distribution of cognitive effort expended on the different lifecycle stages during PSS ecodesigning?*), a set of three stages that is suitable to describe the lifecycle of PSSs was presented (in Section 2). A multi-level coding scheme was then introduced based on the proposed representation of the lifecycle stages and the PSS architecture (in Section 3).

This coding scheme was applied to the protocol analysis of an example PSS ecodesign session. The application of this scheme revealed the following clear differences in the distribution of the designers' effort expended on the different lifecycle stages (as described in Section 4.1): *solution development* (56%), *deployment* (40%) and *retirement* (2%). Until the middle of the session, substantial portions of the designers' effort were expended on *solution deployment* (e.g., aspects such as product use and product-oriented service execution were addressed substantially) in addition to the dominant focus on *solution development.* However, the *retirement* stage received substantially less effort compared to the other two stages.

RQ2 (*How to map the distribution of cognitive effort expended on the different dimensions of the system architecture across the different lifecycle stages during PSS ecodesigning?*) is answered as follows: by combining the level of coding scheme for the PSS architecture with that for the lifecycle stages, correspondence analysis was shown to be useful to qualitatively illustrate the correspondences between the two levels of analysis of PSS ecodesigning (as shown in Section 4.4). The results from the analysis suggest a strong correspondence between the *solution development* stage and *product* design object (see Figure 3). It was also revealed (in Section 4.2) that the *product* design object received almost three fourths of the total share of the designers' cognitive effort and was the only aspect of PSS architecture to have been focused on at a constant rate throughout the design session.

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Three categories were introduced to answer RQ3 (*How can the cognitive effort expended on analysis and manipulation of potential environmental issues during PSS ecodesigning be measured?*): *material input*, *energy input*, and *emission output* to the sink (as explained in Section 2). Its application to the PSS design session showed the following effort expended: *material input* (46%), *energy input* (17%), *emission output* (1%) and *multiple measures* (36%). This type of distribution is useful to indicate the relative degrees of effort from the environmental viewpoint, although such a distribution depends on the environmental characteristics of specific solutions (e.g., designing a system with energy-using products will require effort on the energy input). Further, designers seemed to focus on *analysis* and *manipulation* of these environmental issues throughout the design session at a constant rate.

5.2 Research implications and limitations

The results of the analysis indicated how the designers distributed their cognitive effort between the different stages of the lifecycle across the time dimension. More specifically, the designers appeared to expend most of their effort on solution deployment stage until the middle of the design session, before focusing on the solution development stage until the end (see Figure 2). Further, the designers seemed to focus their cognitive effort on both analysis (exploring the problem space) and manipulation (exploring the solution space) of environmental issues at a constant rate throughout the design session (Section 4.3). These findings are possibly in line with past works that frame designing as a cognitive process involving the iterative exploration of problem and solution spaces (Hay *et al.*, 2017). Although, this type of cognitive process was reported to be observed in a previous case of conceptual PSS designing (Dewberry *et al.*, 2013), until now, it has not been observed in the case of conceptual PSS ecodesigning. Furthermore, this type of episodic analysis of cognitive effort across the time dimension is common practice in protocol analysis-based design cognition research (Gero and Mc Neill, 1998). But until now it has not been applied in the context of PSS ecodesign.

During PSS design, products and services are prescribed to be designed and integrated simultaneously from a systems perspective (Meier *et al.*, 2010). Such a simultaneous consideration of the service design object is expected to extend the design space and thus to present more opportunities for designers to comprehensively minimize environmental impacts during multiple stages of the PSS lifecycle (Aurich *et al.*, 2006) during its ecodesign. Although the laboratory setting of our study facilitated the extension of the design space by allowing the designers to simultaneously consider the product and service design object, the results quantitatively indicated the prevalence of a product-centric mindset. The designers seemed to expend almost three fourths of the total share of their effort on the product design object. Furthermore, the product design object was the only aspect of the PSS architecture that was focused on at a constant rate throughout the design session. In contrast, the service design object and interactions between the design objects received minimal effort and inconsistent focus (Section 4.2). The correspondence analysis also indicated a relatively strong association between the effort expended on the product design object in the solution development phase, in contrast to the correspondence between other aspects of the PSS architecture and lifecycle stages (Section 4.4). These results indicate that the designers might have been fixated (Crilly and Cardoso, 2017) on the existing product design object, potentially hindering the effective utilization of the extended design space.

These insights point towards the need for domain specific prescriptive PSS design support for the designers to effectively redesign existing products to PSSs. However, since the results are derived from a small cohort of experienced practitioners, these insights are not generalizable. Further, the generalizability of the results is potentially restricted by the inherent limitations of the laboratory setting and the characteristics of the design task (Cash *et al.*, 2013). Yet, it highlighted the potential applicability of the proposed scheme of analysis to quantitatively investigate this issue of relevance to manufacturers providing PSSs at present. Further verification of this approach is necessary through its application to more design sessions with a larger cohort size.

5.3 Brief review of related works

In comparison to existing related works, our paper provides the following contributions: we present a generic approach and add empirical insights to the analysis of micro-scaled cognitive activities of PSS ecodesigning, which little literature has addressed thus far; compare with protocol analysis of product ecodesigning (Vallet *et al.*, 2013) and that of PSS designing (Bertoni 2013). Micro-scaled cognitive activities of product or PSS ecodesigning is under researched compared with a large number of

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publications with higher levels of analyses of product ecodesigning (as reviewed by Ramani *et al.*, 2010) and of PSS ecodesigning (as reviewed by Vasantha, Roy and Corney, 2015), and hence comprehensive knowledge for the respective domains of ecodesigning is currently lacking. The missing knowledge is needed to give recommendations to industry and for the development of pedagogy based on scientific evidence. Although Sakao, Gero and Mizuyama (2020) recently proposed a protocol analysis based method to analyse the cognitive characteristics of conceptual PSS designing, the work presented in this paper has a different focus, as the approach presented here can be used to analyse PSS designing from the environmental viewpoint.

5.4 Conclusions and future research directions

To conclude, in this paper, we present a concrete approach to analyse the micro-scaled cognitive characteristics of conceptual PSS ecodesigning. In this approach, we adopted the widely used method of protocol analysis to analyse the distribution of designers' cognitive effort on the following three levels of PSS ecodesigning: on different lifecycle stages, aspects of PSS architecture and ecodesign measures. The entire approach using these three aspects in combination is newly introduced by this paper. Through its application to a design session by experienced practitioners in a manufacturing company, this approach of analysis is shown to be effective in characterizing and measuring designers' cognitive activities. This piece of work enables us to conduct interesting future research. Additional verification of this approach with more design sessions will be carried out immediately by the authors. Comparisons of conceptual PSS ecodesign sessions by experienced practitioners, with and without the use of a specific design support (e.g., use of a high-level PSS design schema by Sakao and Neramballi, 2020), will be performed to demonstrate the usefulness of this approach (building upon (Neramballi *et al.*, 2019) as well as to enhance the understanding of PSS ecodesigning. Such research will provide useful insights for the effective development of design support.

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