InDeaTe—A Computer-Based Platform with a Systematic Design Template and a Database of Methods and Tools

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Abstract InDeaTe—Innovation Design Database and Template—is a knowledge-driven, sustainable design process support tool, aimed at improving sustainability considerations in design. It comprises a design process template that guides 'life cycle thinking' into design by creating intersections of stages of design with life cycle phases at which design activities are directed. The tool also has a design database of sustainability definitions and indicators, and methods and tools, for solving a given design problem by supporting the template. This paper discusses the potential of InDeaTe in supporting design of sustainable products, services and manufacturing systems by retaining its inherent characteristic of exploration and innovation, while offering a multitude of possibilities and routes towards achieving the design goal.

Keywords Eco-design · Sustainability · Enabling technologies and tools · InDeaTe platform

1 Methods in Design

A "methodology" is a system of methods used in an area of study, and can be a set of methods, rules, or ideas, a particular procedure, or set of procedures. It guides the design process along a route towards its goal, be it customer satisfaction,

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improvement of standard of living, or sustainable development. A common thread across methodologies is seeing design as an iterative process divided into stages, during which various activities are performed and decisions are made.

Design methods are systematic techniques to assist in developing solutions to a given design problem. According to Cross, design methods attempt to bring rational procedures into the design process [1]. Large-scale studies [5] reported that, when appropriate methods and tools were used correctly, they had significant impact on industrial practice. However, some literature also reports that design methods were occasionally used in industry [2], and that methods, when casually followed, were not very effective [3]. Only a few methods were widely and systematically used, many with ad hoc modifications, and most abandoned mid-way into the process [4]. Some of the reasons cited [4] for sparse use of design methods in practice are:

- Lack of *time* to learn new methods.
- *Incorrect* selection or use of methods leading to disappointing results.
- Use of methods based on popularity even if these did not *suit* the problem.
- Methods from written sources "unevenly" described with unrealistic examples.
- Descriptions of methods in company manuals hard to understand.
- Large number of methods available, all claiming to be generally valid.

Selection of appropriate methods is the key to their successful use [6, 7]. Various approaches are suggested to aid selection, such as multiple levels of selection [7] and method selection rules [4].

Integrated software tools, as noted in [4], aid successful use of design methods. Not surprisingly, various web-based portals and computer-based tools are developed to support use of design methods in practice, e.g. CiDaD tool [8], Landscape of Methods [9], and web-based portal 'Pinngate' [10]. In CiDaD, a model of methods is used as the representational basis, which includes process description, steps, input, output, and support for the method, along with advantages and disadvantages [8]. Strasser and Grosel [9] developed a Landscape of Methods (LoM) that uses a model of the product development process with the following stages: task clarification, concept design, embodiment design, and detail design. Further, a microcycle (situation analysis, target specification, idea generation, and evaluation) is used to solve problems at each stage. Strasser and Grosel [9] assign appropriate design methods that match the steps of the microcycle. They use a form to collect data about methods that includes name, description, purposes of the method, suitability, nature of outcome, implementation risk, and information on prerequisites, i.e. no. of people, learning effort, software needed, etc. 'Pinngate' [10] contains knowledge bases, learning/teaching environments, design methods and tools.

Further, there are several web-based tools such as EcoIt [16], SimaPro [17], and Sustainable minds [18], for supporting Eco design. However, they do not typically include methods that support synthesis activities. Methods and tools that support synthesis such as mind mapping [19], Idea-Inspire [20] are not seamlessly integrated into a single platform that would have reduced the cognitive burden of shifting across tools during design activities, potentially hindering the natural way of working of designers.

While several such frameworks are reported in literature, a major issue is the lack of empirical verification of the models used in and efficacy of the frameworks in supporting design. The work reported here builds on the learning from existing attempts and observations, in order to develop a support that is built on empirically established models and can be tested for efficacy in supporting sustainable design.

2 Research Objectives

We identify two major requirements for the use of methods in practice:

1. *Selection* of appropriate methods: *context* (design stage, activity etc.) of use of the method and expected *benefits* of using the method should be clear to the user.
2. Appropriate *Use* of the methods selected: it should be clear as to what the *costs* are, i.e. what resources and training are necessary before the methods and tools can be used; and the methods and tools should be *represented* such that it is clear as to what their start and end points are, and how to proceed from start to end.

For these requirements to be satisfied, a support is needed that: explains the structure of the methods, their key benefits and costs; specifies the context for use of methods within the design process; is easy to use and gives access to a comprehensive set of methods and tools.

A highly usable computer-based repository seems to be an option, as indicated by the recent attempts in literature. Therefore, the key objective of this research is to develop a computer-based platform on which a comprehensive set of design methods and tools can be integrated using a uniform representation of aspects such as structure, context, benefits and costs, so that these methods and tools can be identified, selected and used within a relevant context, in concurrence with sustainability as the primary motivation.

3 InDeaTe Design Tool: A Template and a Database

To fulfil the objective, a computer-based tool called InDeaTe (Innovation Design Database and Template) is developed, and tested for supporting sustainable design innovation. It has two modules: a design process *template* (Sects. 3.1 and 3.2), and a linked *database* (Sect. 3.4) with sustainability definitions, indicators, methods and tools for supporting design of sustainable systems.

The InDeaTe template is a generic representation across design processes and is distinct from any particular design process, since it does not constrain but provides direction and guidelines for the use of a number of design processes. It guides the designer by contextualizing information on definitions, indicators, methods and tools in the database so that appropriate information from the database can be used in the right context within the process followed. The InDeaTe template is based on an empirically tested, holistic framework called ACLODS, for product life-cycle development [11]. ACLODS is an integration of the dimensions of Activities, Criteria, Life-cycle phases, Outcomes, Design Stages and Structures. Built on analyses of an extensive range of design methodologies, ACLODS argues that the above dimensions are essential for developing the lifecycle of a design; it is not the design but its life cycle that impacts the environment and in turn sustainability. The InDeaTe template steers the design process through an iterative set of Activities (A) in each Design stage (D), for all Life cycle phases (L), by creating intersections for design Outcomes (O) with various aspects of sustainability as Criteria (C). The resulting design developed is the Structure (S). ACLODS provides a generic ontology for design that is used as the basis for the template and the information in the database. Note that InDeaTe is a template for a generic design process which can be governed by any criteria (and not only or necessarily sustainability); however, it is tested in this work for design of sustainable systems. The InDeaTe database currently provides a comprehensive, expandable, and editable knowledge-base of: (i) sustainability definitions and indicators that are intended to help designers clarify, for designing sustainable systems, as to "what to design for?", and (ii) design methods and tools that aid the designer in "how to design?." The database of sustainability definitions help clarify the design task at hand from the sustainability perspective, while the database of sustainability indicators prompt suitable sustainability considerations in the design.

The InDeaTe tool, which integrates the template and the database, is a knowledge-driven design process support. It is meant to be a comprehensive yet generic tool to support innovation across domains of product, manufacturing and service systems. This tool is envisioned to be a web-based, open-source support, with a growing repository of information in its database that can be used alongside the broadly encompassing process template. The tool has three main features:

(i) **Provide knowledge** of design and design processes: this is intended to be achieved using a tutorial with which to train the user in the template, database and their use. It acquaints the user with the ACLODS dimensions that are used to uniformly represent the knowledge made available, i.e., sustainability definitions and indicators, and design methods and tools, with respect to the context for appropriate use and selection of methods during design.

(ii) **Provide support** to the design process by helping users: clarify the design task with pertinent information from its sustainability definitions and indicators database, filtered using the ACLODS dimensions; and perform various design activities, considering all life cycle phases at every design stage.

(iii) **Helps create documents** that: capture the rationale of the design process with its sustainability considerations, methods and tools used, and outcomes and decisions, empowering the users to reflect on their process and to learn from the repository of design routes previously used; and also capture real-time use of methods and tools to offer feedback on its usability and usefulness, thereby providing validation of the tool.

The InDeaTe tool is intended to support design as a whole—from problem identification, solution seeking and selection, through detailing, to development of documents—i.e. elements that are critical to a professional design approach.

3.1 Description of ACLODS

Through analyses of literature and empirical studies of the design process [10], the dimensions of ACLODS (below) encompassed those used in existing design methodologies and those observed in earlier empirical studies [11, 12].

Activities are performed during the design process; the definitions of the activities used in InDeaTe are taken from the Integrated Model of designing [13], as follows:

1. Generate (G): involves bringing for the first time an outcome into a problem solving episode. Can be generating requirements (Gr), or generating solutions (Gs). Note that requirements and solutions are **Outcomes** of a design.
2. Evaluate (E): involves checking the worth of an outcome, individually or in comparison to other alternatives. Can apply to requirements (Er) or solutions (Es).
3. Modify (M): involves changing the outcome to make it better. Can be for modifying requirements (Mr) or solutions (Ms).
4. Select (S): involves selecting whether to accept or reject an outcome. This can be for selecting requirements (Sr) or solutions (Ss).

Criteria are considerations for a design. For design for sustainability, the key criterion is sustainability, which can be described using the Triple-Bottom Line (TBL), i.e. sustainability dimensions of the environment, society and economy. Examples of criteria for social sustainability might be good living condition or high level of education; that for economic sustainability might be high standard of living or high per capita income; and that for environmental sustainability might be low carbon footprint or low depletion of resources. Criteria might be represented using appropriate Indicators.

Life cycle phases of a design are the contributors to the sustainability of the system being designed. The phases consist of processes, where each process impacts the ecology, economy and society, influencing their sustainability, as follows:

1. Materials (Mat): This phase involves the processes with which the materials used in the system are made (e.g. from soil in the earth to steel for use).
2. Manufacturing (Mfg): This phase involves the processes with which the objects in the system are made (e.g. from steel to shaft/bolts and their assembly).
3. Distribution and Storage (Dist): This phase involves the processes with which the objects used in the system are transported and stored at the interface of other processes (e.g. from factory to warehouse, from warehouse to sales points, from sales points to user locations, from user locations to End of Life units, etc.).
4. Use (Use): This phase involves the processes with which the system designed is used, maintained and repaired during use e.g. installation, maintenance, etc.
5. After Use (AUse): This involves the processes with which the system is treated during the end of its life (e.g. disposal, reuse of parts, recycling of materials etc.).

Outcomes of design are either requirements or solutions. Requirements are what need to be satisfied or achieved and can be needs, demands or wishes. Solutions are as to how the requirements could be fulfilled, at different levels of abstraction from concept to embodiment. These outcomes emerge and co-evolve through the stages of design. Outcomes are in turn impressed upon by the criteria. For example, the 'low Environmental Impact' criterion may give rise to the solution-outcome 'use of recyclable material' or the requirement-outcome 'reduce carbon footprint', which in turn may lead to the solution-outcome 're-use of component'. Thus, it is important that the requirements be clarified and outcomes vetted frequently during the design process.

Design stages are four broad temporal divisions within the design process, as prescribed in most design methodologies. Each stage has well-defined deliverables that act as input for the next stage. Outcomes, as requirements or solutions, emerge and evolve during these stages, at various levels of abstraction. However, ***in reality, design is not a linear process***; the starts and ends of design stages overlap. The designer is encouraged to move fluidly among stages, with the overall intent to move forward.

Structure of a design are the entities that the designer conceptualizes and embodies during the design process. In products and manufacturing systems, structure is often recognized, typically at the embodiment stage, as physical objects: sub-assemblies, parts, features and their relationships. Empirical studies further reveal that an abstract structure exists even at the conceptual stage. Service systems may appear intangible as a whole, but can still be detailed for implementation and tested for effectiveness.

3.2 InDeaTe Template

The InDeaTe platform supports the designer to define the design system using various criteria e.g. functionality, cost and sustainability. The InDeaTe template provides a generic overview of the design process, see Fig. 1. It represents the junctures of problem-finding and solution-seeking as explicit intersections of the dimensions of *stage*, *activity* and *lifecycle* phase of the design. The other three dimensions of ACLODS are implicit. At any of these intersections, one explores *outcomes* against various *criteria*, within various levels of the *structure* of the system being designed.

The Template explains the **Design Stages**—*Task Clarification, Conceptual Design, Embodiment Design and Detail Design*; and **Life cycle phases** of the system designed—*Materials, Manufacturing, Distribution and Storage, Use and After-use*. It promotes lifecycle thinking for improving sustainability by encouraging exploration of design outcomes across lifecycle phases that are contextualized within the design process. The template guides the designer to perform iterative **Activities** of design, i.e., *Generate, Evaluate, Modify, Select*; at each design stage considering all **Lifecycle** phases, from material to after-use; this is represented as intersections. Activities are performed keeping in mind the **Criteria,** and **Outcomes** emerge as requirements or solutions. Solution-outcomes evolve into conceptual (solution)-**structures** and finally Embodiment Structures before resulting into a complete and detailed design.

Exploration at each stage is supported by information from the database. Sustainability definitions linked to indicators act as criteria to drive formation of requirements. The database supports design by providing methods applicable for

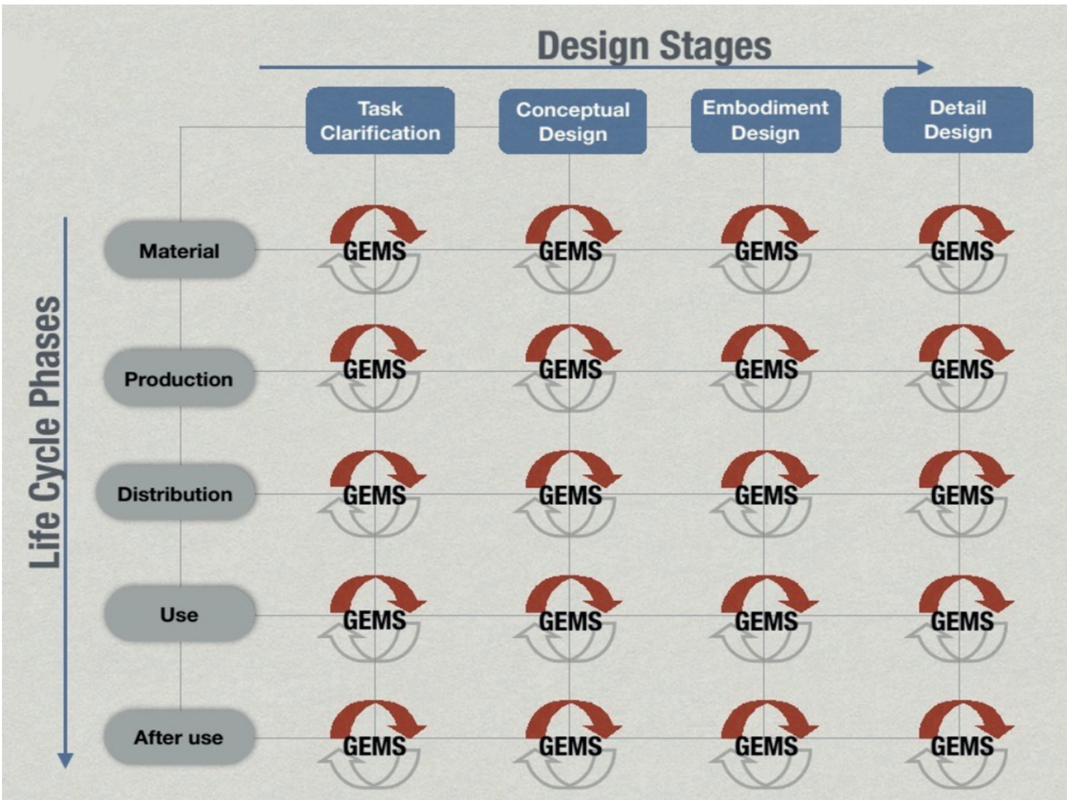

Fig. 1 The InDeaTe design process template

use at each intersection. The process focuses on the whole lifecycle of the system designed, to improve e.g. 3 pillars of sustainability where impact is significant and change is feasible.

3.3 Steps of the InDeaTe Design Process

The steps recommended to be followed during the design process are as follows:

Task Clarification (TC): *During this process, a well-defined list of requirements should be formulated. Ideas for solving the problem may arise and are to be noted down for further use, but solving the problem should not begin.*

1. Select System Boundary: Analyze the problem brief to ask these questions: What is allowed to be changed? What is not allowed?
2. Analyze current situation to identify issues (*Generate Requirement*): What are the current systems in this area? What are their life cycles? Where in these life cycles are major issues (sustainability and otherwise)? Materials? Manufacturing? Etc.
3. Using the tool/database to select Sustainability Definitions and Indicators to be used in the process: What is the guiding definition of sustainability used in this work? What are the guiding principles being followed? What are the indicators that would be used to operationalize these?
4. Evaluate the issues to find the important ones to address (*Evaluate/Modify Requirements*): How important is each issue? Can the issue be refined? What requirements can be used to represent each issue? (*Generate Requirement*)
5. Decide on a list of requirements and their relative importance for use the subsequent stages (*Select Requirement*): What requirements are really important to keep? How important are these relative to one another? Can these be quantified?

Deliverables from TC:

- A (qualitative) list of requirements, some indication of their relative importance;
- Some ideas of how to solve the design problem, noted down for further use.

Steps in Conceptual Design (CD): *During this process requirements will become more refined, more specific to individual sub-systems or parts, and more quantified. Use these to refine the list of requirements and importance.*

6. Generate alternative ideas to satisfy each major requirement (*Generate Solution*): How to satisfy this requirement? What are the other ways it can be satisfied?
7. Evaluate these ideas to select the most promising ones (*Evaluate/Modify Solution*): which of these ideas are feasible? Which ones will have a greater effect?

8. Integrate these ideas to generate alternative solution principles (*Generate/Modify Solution*): What possible combinations of these ideas can be complete solutions to the problem? Are there additional elements needed to put these together?
9. Evaluate these alternatives to select the most promising solution principle (*Evaluate/Select Solution*): Which of the combinations best satisfy the requirements? Which of these is the most feasible?

Deliverables from CD:

- A more concrete list of requirements;
- A list of alternative solution-principles that could satisfy the requirements;
- An evaluation of these principles for their ability to satisfy the requirements;
- The solution-principle selected as the most promising for further development.

Steps in Embodiment Design (ED): *During this process, requirements will become even more refined, more specific to individual sub-systems or parts, and even more quantified. Use these to refine the list of requirements and importance.*

10. Develop alternative, concrete configurations of the sub-systems/parts for the solution principle chosen in CD (*Generate Solution*): How can each subsystem of the solution principle be embodied? What are the other ways it can be embodied?
11. Evaluate and select among these alternatives based on their suitability (*Evaluate/Select Solution*): Will the alternatives satisfy the (refined list of) requirements?
    Can these be tested via calculation, virtual simulation or physical simulation?
12. Integrate these to generate alternative solution-embodiments (*Generate/Modify Solution*): Which embodiments of these concepts can be developed into complete configurations? Are additional elements needed to put these together?
13. Evaluate these alternatives to select the most promising solution-embodiment (*Evaluate/Select Solution*): Which of the combinations best satisfy the requirements? Which of these is the most feasible?

Deliverables from ED:

- A more concrete list of requirements;
- Alternative, feasible configurations for use to embody the solution principle;
- An evaluation of these configurations for their ability to satisfy the requirements;
- The configuration selected as the most promising for further development.

Detail Design (DD) stage typically requires a large amount of domain-specific information, and therefore is left out from this generic recommendation.

3.4 The InDeaTe Database

The database is organized in an easy-to-use structure. It aims to provide a holistic overview of design routes that could be charted by using methods and tools for selected sustainability definitions and indicators representing the problem. The database is classified using the type of design and domains. It allows exchange of information between the *design task* and the *design process*. These two elements: task and process are supported respectively by the 'definition and indicator' database, and 'methods and tools' database. InDeaTe not only enables creation of new routes but also aids in following established routes, e.g. those proposed by certain design methodologies.

3.5 What to Design For?

There are many definitions of sustainability, for varied contexts, dimensions and domains. Also, there are various indicators of sustainability; work is in progress to connect these two. Using indicators for a given definition, the designer specifies the intent of the design to be sustainable. The definition and indicators database in InDeaTe supports specification of sustainability requirements for a design problem. Each definition and indicator is categorized by TBL and ACLODS [12].

3.6 How to Design: Analysis of Design Methods to Support Design

To reiterate, a design process begins with task clarification for the design problem, moves to solution seeking at the conceptual stage, and solution refinement at the embodiment and detailed stages. Methods available in the database for each stage of the design process, and the know-how for using these, aid the designer. The Design Methods database in InDeaTe platform is based on a simple, input-steps-output representation along with its structure, benefits and requirements. Further, each method is linked to case studies on where and how it was used, with its benefits and costs.

The design process is realized by using the methods and tools, upon selection and supports a variety of tasks, e.g. ideation and evaluation, at various design stages, for various lifecycle phases. The listing of appropriate design methods and their selection for a particular design activity in a particular design stage is enabled by the following:

(1) Each method or tool is categorized using ACLODS: For e.g., Brain storming method is tagged with generation (activity) of requirements and solutions

particularly in task clarification and conceptual design stages, with generic TBL scope, for all life cycle phases.

(2) Each method and tool is described to help understand its objective, inputs, steps, outcomes, benefits and costs; so as to align it with the objectives of appropriate use and selection for a given context.

4 Case Studies

Six case studies were conducted so far to test the efficacy of the InDeaTe tool. Each study is on one of the 3 types of problems: product, service or manufacturing system, in two countries, India and the USA, by mixed student teams, to improve existing solutions to real problems, with and without InDeaTe and were compared. The observations were the following: (1) In the 4 cases in which problems were solved without InDeaTe, methods were used only 6 times. Designers followed their own processes using collective knowledge; (2) In CS2, although designers used some methods, participants from non-design backgrounds had to struggle to apply these methods; (3) In the 6 cases that used InDeaTe, methods were used 26 times. Each case study has been discussed in detail as papers [21–26].

5 Discussion

Landscape of methods by Strasser and Grosel [9] has a general product development process along with a microcycle of activities; they have a situation questionnaire to help designers select methods. The InDeaTe database structures methods using the four stages prescribed by [17]. Similar to the use of micro cycle in [9], InDeaTe follows the GEMS cycle [13]. Lindemann [14, 15] developed CiDaD, a web-based portal and tool, using a model of methods [8]. The design methods database in InDeaTe is based on a simple, input-steps-output representation along with its structure, benefits and requirements, as proposed in literature [14, 15]. Further, each method is linked to case studies on where and how it was used, with associated benefits and costs. However, none of these tools [CiDaD, Landscape of Methods] considered the life cycle phases of the product within the design stages that assigns methods for sustainable design, nor did they include empirical testing. These are the novel aspects of the InDeaTe tool. The database is reasonably comprehensive (36 sustainability definitions, 379 sustainability indicators, and 158 methods). We argue that keeping as many tools and methods as possible is important, since it gives a wider set of options to choose from.

6 Summary, Conclusions and Future Work

Although design methods can have significant impact on designing [5], there is skepticism towards their use in industry. This grew out of two key requirements: selection of appropriate methods for the design context, and appropriate use of the methods selected.

To address these, with sustainability as the focus, a computer-based tool InDeaTe is developed; it uses a design template made of design stages, life cycle phases and their intersections with GEMS activities. The template is based on the empirically validated ACLODS framework. The tool has a database that contains: sustainability definitions, sustainability indicators, and design methods and tools. The methods have been represented with information similar to those from literature.

The InDeaTe tool has been tested with six case studies [21–26]. It was found that, though methods were used, in cases that did not use the InDeaTe tool, the frequency of use was far less than when InDeaTe was used. Further, participants in the studies felt that use of InDeaTe helped them carry out design with better focus on sustainability.

More case studies, however, need to be conducted to assess its benefits conclusively. Eventually the tool should be made capable of empirically capturing the methods used more often or found to be efficient from the feedback received, and in turn support quick and easy selection of appropriate methods.

References

1. Cross, N.: Engineering Design Methods—Strategies for Product Design, 3rd edn. Wiley, New York (2000)
2. Grabowski, H., Geiger, K.: Neue Wege zur Produktentwicklung. Raabe Verlag, Stuttgart (1997)
3. Furnham, A.: The brainstorming myth. Bus. Strategy Rev. **11**(4), 21–28 (2000)
4. Lopez-Mesa, B.: Selection and use of engineering design methods using creative problem solving. Licentiate thesis, Lulea University of Technology, ISSN 1402-1757 (2003)
5. Chakrabarti, A., Lindemann, U.: Impact of Design Research on Industrial Practice. Springer, London (2016)
6. Ritzén, S., Lindahl, M.: Selection and implementation-key activities to successful use of EcoDesign tools. In: Proceedings of EcoDesign 2001, Tokyo, pp. 174–179 (2001)
7. Ernzer, M., Birkhofer, H.: Selecting methods for life cycle design based on the needs of a company. In DS 30: Proceedings of DESIGN 2002, the 7th International Design Conference, Dubrovnik (2002)
8. Ponn, J., Lindemann, U.: CiDaD—a method portal for product development. In DS 36: Proc. of DESIGN 2006, 9th International Design Conf, Dubrovnik (2006)
9. Strasser, C., Grösel, B.: A landscape of methods—a practical approach to support method use in industry. In DS 32: Proceedings of DESIGN 2004, the 8th International Design Conference, Dubrovnik, Croatia (2004)

10. Sauer, T., Degenstein, T., Chahadi, Y., Birkhofer, H.: A web-based information portal for the early stages of design. In DS 36: Proceedings DESIGN 2006, 9th International Design Conference, Dubrovnik, Croatia (2006)
11. Kota, S.: An interactive support for developing environment friendly product life cycles. Ph.D. thesis, Indian Institute of Science, Bangalore (2009)
12. Kota, S., Chakrabarti, A.: ACLODS: a holistic framework for product lifecycle design. Int. J. Prod. Dev. **19**(1/2/3) (2014)
13. Srinivasan, V., Chakrabarti, A.: An integrated model of designing. ASME JCISE **10**(3), Sept 2010
14. Lindemann, U.: Flexible adaptation of methods within the design process. In DS 30: Proceedings of DESIGN 2002, 7th International Design Conference, Dubrovnik (2002)
15. Lindemann, U.: Methods are networks of methods. In DS 31: Proceedings of ICED 03, 14th International Conference on Engineering Design, Stockholm (2003)
16. www.pre.nl/eco-it/
17. https://www.pre-sustainability.com/Simapro/
18. www.sustainableminds.com/
19. www.mindmapping.com/
20. Chakrabarti, A., Sarkar, P., Leelavathamma, B., Nataraju, B.S.: A functional representation for aiding biomimetic and artificial inspiration of new ideas. AIEDAM **19**(2), 113–132 (2005)
21. Acharya, S., Ghadge, K., Uchil, P., Flynn, C.D., Johnson, A.J., Squier, M.N., Yang, Y., Yang, X., Davidson, C.I., Ameta, G., Rachuri, S., Chakrabarti, A.: Supporting sustainable service-system design: a case study on green-roof design with InDeaTe template and tool at syracuse, New York. In: Proceedings of ICoRD 2017
22. Acharya, S., Ghadge, K., Langfitt, Q.M., Pezeshki, C., Ameta, G., Rachuri, S., Chakrabarti, A.: Supporting sustainable product design: a case study with InDeaTe tool and template at Washington State University, Pullman, WA, in Proceedings of ICoRD 2017
23. Devadula, S., Ghadge, K., Vishwanathan, S., Chan, S.H., Langfitt, Q.M., Dornfeld, D., Gupta, A., Rachuri, S., Ameta, G., Chakrabarti, A.: Supporting social innovation: application of InDeate tool for sustainable service design—case study of community workshop. In: ICoRD 2017
24. Ghadge, K., Vishwanathan, S., Devadula, S., Langfitt, Q.M., Chan, S.H., Patel, A., Ameta, G., Gupta, A., Rachuri, S., Chakrabarti, A.: Application of InDeaTe design toolbox for designing sustainable products—case study of a natural water cooler. In: ICoRD 2017
25. Ghadge, K., Vishwanathan, S., Devadula, S., Langfitt, Q.M., Chan, S.H., Ratnakar, G.K., Ameta, G., Gupta, A., Rachuri, S., Chakrabarti, A.: Application of InDeaTe design toolbox for designing sustainable manufacturing systems—case study of a micro-hydel turbine. In: ICoRD 2017
26. Uchil, P., Ghadge, K., Acharya, S., Bhinge, R., Robinson, S., Dornfeld, D., Rachuri, S., Ameta, G., Chakrabarti, A.: Supporting manufacturing system design: a case study on application of InDeaTe design tool for a smart manufacturing system design. In: ICoRD 2017