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INDEATE 3.0: AN ONTOLOGY BASED, GENERIC DESIGN PROCESS GUIDANCE WEB-TOOL

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Abstract

InDeaTe web-tool addresses the issues of poor incorporation of design methods and tools in design. Initially conceived with a focus on sustainability, it is supported by a comprehensive database of design methods and tools, that are mapped using an ontology developed with ACLODS framework as the basis. This paper discusses the expansion of the ontology and inclusion of multiple design methodologies within the InDeaTe 3.0 web-tool, highlights the salient features of the tool and further discusses its relevance also as a research support, to widen its applicability across domains and criteria.

Keywords: design methodology, ontology, design support system

1. Introduction

Design is an iterative, problem-solving process culminating in 'new and useful', i.e., creative solutions (Sarkar and Chakrabarti, 2011) to meet the needs of the present and the future (Archer, 1965; Jones, 1970; Simon, 1996; Hurst, 1999). Literature reports that a larger number of ideas are generated upon the use of design methods to perform various tasks within design (Lopez-Mesa, 2003); use of design methods therefore could be viewed as a driver for design innovation. Correct use of appropriate design methods and tools positively impact industrial practice (Chakrabarti and Lindemann, 2016); however, its success is determined by selection of appropriate methods (Ritzén and Lindahl, 2001; Ernzer and Birkhofer, 2002). Based on a review of the state-of-the art in this area (Strasser and Grösel, 2004; Sauer et al., 2006; Ponn and Lindemann, 2006), Chakrabarti et al. (2017) stressed the need for an integrated platform to support the design process holistically through appropriate selection and correct use of relevant design methods and tools, and proposed InDeaTe (Innovation Design Database and Template) tool as a possible solution. The tool has a 'design process template' that is prescriptive, and a 'database of design methods and tools' with its contents linked to the steps of the process in the template, tagged the with respect to the dimensions of the ACLODS framework (Kota, 2009; Kota and Chakrabarti, 2014). This ontology allows for filtering of the design methods and tools, with respect to the ACLODS dimensions, of Activity (A), Criteria (C), Life cycle phase (L), etc., for appropriate selection. The tool further supports its proper use through instruction and information, through a computer-based user-interface.

Initially conceptualised to primarily support design of sustainable systems, the tool was evaluated via several case studies on its use to address design of various types of systems - products, services or manufacturing system – in terms of the impact of the tool in supporting improvement of sustainability of the systems re-designed in the cases. The evaluation was based on an assessment of the design concepts developed, with and without the use of the tool, by experts to assess sustainability improvements, and using the feedback on tool collected from the users. These studies were conducted on the two earlier versions of InDeaTe: via design sessions conducted on InDeaTe

v.1.0 by mixed design teams in India and USA (Acharya et al., 2017a; Acharya et al., 2017b; Devadula et al., 2017; Ghadge et al., 2017a, 2017b; Uchil et al., 2017); and later with comparative study of design sessions with and without InDeaTe v.2.0 with 34 engineering students from India at the "Indo-US Dissemination workshop on design of sustainable systems". The key findings from the studies were as follows: (1) *applicability of the tool is wider than only for design for sustainability*; (2) *the users needed further training and improvements in user-interface* than provided in InDeaTe 2.0; and perhaps most significantly (3) *analysis of information in the tool as well as collection of data from its use can both be used to further support design research*. These prompted further development of the tool into its third and web-accessible version (presented in this paper), and the evolution of InDeaTe into a 'generic online process guidance tool' for design of systems across domains and criteria.
This paper reports, therefore, the following advancements, as incorporated in InDeaTe v3.0, with the objective of supporting selection of appropriate methods (and tools) their correct use, as well as how information in the tool can be used for supporting further research:

- ***Improvement in relevance of appropriate methods and tools*** by filtering from the database, and providing a highly relevant list to the user/designer for selection and use during the design process. This is proposed through *extension of the underlying ontological framework* to include System-structure (S) that captures the abstraction in design, and Criteria (C), beyond sustainability, that enable generic, multi-criteria consideration in designing, see Section 2. The web-tool has also been advanced to further support design process by *addition of multiple, widely cited design methodologies* to henceforth allow designers to select the design process methodology they wish to learn or use, beyond the one originally prescribed in the design process template of the tool.
- ***Enhancement of the overall user-experience of the tool*** by further development into a web-based platform with salient support features, e.g. tutorials and demos with self-explanatory videos for training, tracking designer search, collecting their feedback, and so on, see Section 3.
- ***A preliminary analysis of information contained in the methods base of the tool*** to illustrate its possible use in supporting design research, e.g. by trends and gap analysis in research into methods development, see Section 4.

The paper discusses the contributions of this tool in relevant design support space and examines its relevance as a research support.

2. Improvement in relevance: Expanding the ontological framework

Earlier work reported empirical assessment of ACLODS framework to be holistic in describing the various aspects of design across design methodologies (Kota, 2009; Kota and Chakrabarti, 2014). Thus, this ontology has been used to integrate the two major parts of the InDeaTe tool, i.e., the design process methodologies (called the template) and the design database. Since the earlier versions of InDeaTe were focused only on design for sustainability, the design database of these versions was tagged with only some of the dimensions of the ACLODS framework (Kota and Chakrabarti, 2014), namely; Activity (A), Outcome (O), Lifecycle phase (L) and Design stages (D); it considered only the single Criterion (C) of Sustainability, further distinguished with respect to Triple Bottom Line or TBL scope (Elkington, 1997), i.e., society, environment, economy. Since the focus was specifically on designing product, manufacturing system or service systems, these were the only system tags used.

2.1. Research methodology

Through literature review on the comprehensiveness of the 'tagging' available in previous versions, the following gaps were identified and then incorporated:

1. **Activity tag was expanded to include 'Understand'**, beyond GEMS (Generate, Evaluate, Modify, and Select) that are direct design activities. Based on a documented procedure of tagging, a number of methods were found to lie outside the ambit of direct design activities and categorised under the indirect activity of 'understanding', a term used in (Pahl and Beitz, 1996)

2. **Criteria** tag was expanded beyond TBL scope to include; performance, cost, environment, safety, styling, structure (of design), quality, energy consumption, recyclability, efficiency, waste disposal, manufacturability, strength, time, social aspects, market requirements, customer requirements, technical feasibility, compliance with legislation, and price. These tags were already identified and reported by Kota (2009). Further, a 'Generic' tag was used for those that encompass more than one requirement.
3. **Structure**, a tag also earlier reported, had to be expanded to be more generic in application across design stages as this dimension of ACLODS was more applicable in the embodiment stage. Therefore, the tag 'Structure', while retaining its core implications, was replaced by the tag 'System Structure' that included the hierarchical levels of a system, i.e., system, sub-system, elements, features, and relationships, as used in IMoD (Srinivasan and Chakrabarti, 2010) to better capture the systemic abstractions of a design.

A prescriptive document for tagging has been developed using literature review and concurrence across researchers, further discussed in Section 2.2. A database of 152 methods has been tagged first with respect to the ontology; and then with respect to design methodologies using these tags.
Preliminary empirical testing of the reproducibility of the steps and reliability of the procedure has been conducted, by assigning a minimum of two coders on the same task.

2.2. Procedure for tagging

The The 'tagging' procedure used comprises of two steps:

- Step 1: Tag the methods and tools in the database using all the expanded tags - Activity, Criteria, Life cycle phase, Outcomes, Design stage, System-type and System-structure, as in (Table 1).
- Step 2: Tag five representative design methodologies - Pahl and Beitz (1984), Cross (1989), Ulrich and Eppinger (1995), Stanford Design thinking (Rowe, 1987; Faste, 1994) and InDeaTe design template (Chakrabarti et al., 2017) - to methods & tools applicable at each step of the methodology, as in (Table 2).

Each design method and tool in the database, and each step of the five design methodologies are tagged with one or more tags from the ACLODS dimensions: Activities, Criteria, Lifecycle Phases, Outcomes, Design Stages, System, and System Structure.

Table 1. InDeaTe v3.0 design methods and tools database

METHODS & TOOLS	*ACTIVITIES*	*CRITERIA*	*LC PHASES*	*OUTCOMES*	*DESIGN STAGES*	*SYSTEM - TYPE*	*SYSTEM-STRUCTURE*
6-3-5; Brainstorming	G	Gen	Gen	Req, Sol	Conceptual Design	Pr, Sr, Mf	System
Activity Network	U	Time, Cost, Price	Gen	Req	Task Clarification	Sr, Mf	Sy, Ss, Rs, El
Analytical Model for Material Handling Systems	E	Performance, Quality, Safety, Efficiency, Strength, Energy Consumption	Gen	Sol	Conceptual Design, Embodiment Design	Mf	Sy, Ss, Rs, El, Fe

Table 2. InDeaTe v3.0 design process tagged to database

PROCESS STEPS	*ACTIVITY*	*CRITERIA*	*LC PHASES*	*OUTCOMES*	*DESIGN STAGES*	*SYSTEM-TYPE*	*SYSTEM-STRUCTURE*
Step 1- 3 :	*Indirect design activities*				Task Clarification	Pr, Sr, Mf	Sy
Step 4 : *Find the important issues*	E, M	Gen	Gen	Req, Sol	Task Clarification	Pr, Sr, Mf	Sy
Step 5 : *Decide on a list of requirements*	S	Gen	Gen	Req, Sol	Conceptual Design	Pr, Sr, Mf	Sy
Step 6 : *Develop ideas to satisfy requirements*	U, G	Gen	Gen	Req, Sol	Conceptual Design	Pr, Sr, Mf	Sy, Ss
Step 7 : *Select the most promising*	U, E, S	Gen	Gen	Sol	Conceptual Design	Pr, Sr, Mf	Sy, Ss
Step 8 : *Integrate these ideas*	G, M, S	Gen	Gen	Sol	Conceptual Design	Pr, Sr, Mf	Sy, Ss, Rs
Step 9 : *Select the most promising*	E, M, S	Gen	Gen	Sol	Conceptual Design	Pr, Sr, Mf	Sy, Ss, Rs
Step 10 : *Develop variant configurations*	G, M, S	Gen	Gen	Sol	Embodiment Design	Pr, Sr, Mf	Sy, Ss, Rs, El
Step 11 : *Select the most promising solution*	E, S	Gen	Gen	Sol	Embodiment Design	Pr, Sr, Mf	Sy, Ss, Rs, El
Step 12 : *Integrate into solution embodiments*	G, E, M, S	Gen	Gen	Sol	Embodiment Design	Pr, Sr, Mf	Sy, Ss, Rs, El, Fe
Step 13 : *Select the most promising embodiment*	E, M, S	Gen	Gen	Sol	Embodiment Design	Pr, Sr, Mf	Sy, Ss, Rs, El, Fe

Tables 1 and 2 exemplify the result of expanding the ontological framework for InDeaTe 3.0: (Req: Requirement; Sol: Solution; Pr: Product; Sr: Service; Mf: Manufacturing System; Sy: system; Ss: Sub-system; Rs: Relationships; El: Elements; Fe: Feature; G: Generate; E: Evaluate; M: Modify; S: Select; U: Understand; Gen: Generic)

2.2.1. ***Activity tags****: refer to the activities performed that the particular design method contributes to in the design process, from among: Understand, Generate, Evaluate, Modify and Select.*

- Example: 'Brainstorming' (Wilson, 2013) involves the 'generation' of a list of ideas by a group of participants. Therefore, this method should be tagged with 'Generate' as its Activity tag. (Brainstorming like every method may involve the 'understanding' of the problem statement or the method, etc., but the major design activity that it relates to is considered for the tagging.)
- Example: 'Buzz Reports' (Kumar, 2013) are a way of collecting information from various sources, keeping updated, and discussing the impacts of the findings on the project. This is a form of research allowing an 'understanding' of the problem space and drawing insights. Therefore, this method is tagged with 'Understand'.

2.2.2. ***Criteria tags****: refer to the specific 'criterion' that the particular design method takes into account when being performed. Some methods may not specifically limit themselves to particular criteria, in which case they will be tagged 'Generic'. When a particular method is tagged 'Generic', no other tag from the Criteria category needs to be assigned to the method.*

- Example: 'Brainstorming' (Wilson, 2013) being an idea generation method, limited to no specific criteria for which it is to be performed, has the 'Generic' tag.
- Example: 'Program Evaluation Review Technique - PERT Chart ' (Cook, 1966; Brennan, 1968) is a method primarily employed for scheduling of tasks in a given project. The only criterion that this method deals with is 'Time', and is hence tagged with 'Time'.

2.2.3. ***Lifecycle Phase tags****: refer to the 'Lifecycle phase' that the design method particularly deals with. For methods that are not linked to any specific lifecycle phase, the 'Generic' tag is used.*

- Example: As 'Brainstorming' (Wilson, 2013) is not linked to a lifecycle phase, it is given the 'Generic' tag.
- Example: 'Assembly Chart' (Tompkins et al., 2010) method enlists the ways parts should be assembled during manufacturing, dealing in the 'Production' phase of the lifecycle; it is tagged 'Production'.

2.2.4. ***Outcomes tags****: refer to the 'Outcome' of the design method. The outcome may be in the form of Requirements or Solutions of the given problem, and is tagged accordingly. Some methods may be used for obtaining either or both of these, in which case both tags are to be used.*

- Example: 'Objectives Tree Method' (Cross, 1989) helps understand the problem and define requirements. As its outcome is a comprehensive set of Requirements, the method is tagged 'Requirements'.
- Example: 'Root Cause Method' (Wilson et al., 1993) is used to identify faults or problems in a given system, which may lead redefinition of the requirements, or to newer solution ideas. It is therefore tagged with both 'Requirements' and 'Solutions'.

2.2.5. ***Design Stage tags****: refer to the 'Design stage' where the design method is best employed.*

- Example: 'Brainstorming' (Wilson, 2013) is used to generate ideas based on the requirements of the problem statement, and is hence most aptly used in the 'Conceptual Design' stage.
- Example: 'Objectives Tree Method' (Cross, 1989) is used to enunciate the requirements of the problem, and is better suited for in the Task Clarification stage; it is therefore tagged 'Task Clarification'.

2.2.6. ***System Structure tags****: refer to the systemic levels for which the design method can be used.*

- Example: 'Buzz Reports' (Kumar, 2013) only deals with the highest-level information collection about the overall system, but does not by itself go into the analysis of the specific parts and assemblies of the system designed. It is tagged at the highest-level, 'System'.

- Example: 'Concept Prototyping' (Kumar, 2013) involves understanding the system, its sub-assemblies, parts and features to varying levels of detail. This method is assigned all the System Structure tags.

*2.2.7. **System-type tags**: refer to the system or problem-type (product, process or service) for which the design method is most suitable. Some methods are Generic, suiting all three problem types.*

- Example: 'Brainstorming' (Wilson, 2013) is not specific to a particular kind of problem type and is hence assigned all three tags: Product, Service, and Manufacturing system.
- Example: 'SERVQUAL' (Parasuraman et al., 1988) is a method for capturing customer expectations and perceptions of a service along five dimensions representing service quality; it thus refers particularly to the problem type: Service. This method is therefore tagged 'Service' for System/problem type.

2.3. Inter-coder reliability test of the ontological tagging

As a preliminary evaluation of the tagging procedure, an inter-coder reliability test was conducted, with results as follows:

- Percentage agreement for each tag - Activity: 80%; Criteria: 93.33%; Lifecycle phase: 88.89%; Outcome: 83.33%; System: 84.44%; System Structure: 88%;
- Minimum agreement for a given method: 80% (least was for - Value Engineering and QFD);
- Maximum agreement for a given method: 97.78% (most were for methods - Critical Thinking and Morphological Analysis).

Even though the evaluation was not a comprehensive in assessing the reproducibility of the tags and the tagging process, it offered adequate support for further the development of the tool.

3. Enhancement of the overall user-experience of the current version of the tool

Beyond the incorporation of the expanded tagging discussed above, development of version 3.0 addresses the empirically identified requirement to support tool users with adequate learning material to ensure correct use of relevant methods. Overall, InDeaTe version 3.0 has the following salient features;

1. Demo and tutorial of the web-tool: Each step of the InDeaTe web-tool is supported with tutorials for ease of use and navigation of the interface. A demo of the tool is also provided to explain the functionality and features of the tool.
2. Self-explanatory videos of method (or tool): Each method or tool in the database has been provided with a description. The description has an explanatory text in form of a description, the procedure of using the method, an "input-output" diagram, key-benefits of the method and references. This is supplemented by short videos, case-studies and examples, enabling correct use of that method. Time required for use of a method, if available, is also provided.
3. Collecting user feedback: Each page has a feedback button made available to (i) collect real-time feedback on the use of the method, and (ii) gather other information about is-sues faced or concerns of the user. Based on the feedback, collected real time during the use of the tool, a star-rating system was developed to aid the designer in appropriate selection of relevant method already filtered as per the desired methodology or tags chosen.
4. Star-rating of each method (or tool): Each method or tool in the database is provided with star-ratings on five attributes - Understanding, Relevance, Effectiveness, Ease of use and Time required – These attributes were identified predominantly from feedback and corroborated with literature (Ernzer and Birkhofer, 2002; Lopez-Mesa, 2003)
5. Tracking design path and search: As design is iterative, InDeaTe 3.0 provides the flexibility of moving across design steps, back and forth, and tracks this to help designer edit the project. It also tracks the designer's search and changes in selection of tags used in filtering the methods and tools. This is shown in the process-line bar at the top of each webpage where the current design step is highlighted. This feature helps create a design document for later reference.

6. Add-feature for new or unlisted methods (and tools): The database of the web-tool currently has 152 methods and tools from multiple domains and system-types, and is designed to grow. Therefore, it has an 'add new method or tool' feature, using which users can contribute new methods and tools by providing information with respect to the seven tags, source, relevance, etc. This is then verified by the web-tool admin for accuracy be-fore being allowed online.

The UI of the web-tool has also been updated for easier software programming and user-experience.

4. Analyses of tagging and database of InDeaTe 3.0

In concurrence to the exercise of developing InDeaTe 3.0, further studies have been undertaken to investigate the relevance of the tool and its potential impact. A study of the extended ontological tagging of the design methods and tools database and a review-based study of the tool with similar support, have been undertaken to investigate the trends and assess the potential contributions of the tool.

4.1. Analysis of trends in the ontological tagging

The database of InDeaTe 3.0 supports 152 design methods and tools, tagged using 7 primary tags, corresponding to the dimensions of ACLODS and system-type. Each of these primary tags are further sub-divided into a number of sub-tags, for example, the Activity Tag houses Generate (G), Evaluate (E), Modify(M), Select(S) and Understand(U) tags. In totality, 45 tags are available and some methods have multiple tags, within the ambit of a primary tag, i.e., a method may support different activities and maybe tagged G,E and M, as represented in the figures.

As an exemplar of the kind of research support that could be provided by information contained in InDeaTe (when its database becomes representative of the literature available on design methods and tools), the methods and tools available in its current database were studied with respect to the ontological tags to carry out an illustrative study for prevalent trends, see Figures (1a-f). The observed trends, which are only illustrative and limited by the current methods and tools available in the tool database, are further discussed below.

4.2. Key findings and inferences from the study of trends in the ontological tagging

- 'Evaluate' activity is the best supported amongst all the methods, possibly reflecting the key goal for developing design methods and tools. This is followed by 'Generate' activity, perceived as the creative aspect of design. These trends agree with the common notion of design as a "creative, goal-oriented" process.
- 'Understand' activity is also found to be well supported, but this is an 'indirect' design activity that may support; however, well worth as it might be, there is hardly any empirical studies on its impact on the quality of the Outcome of the design process.
- 'Task Clarification stage' amongst all the Design stages, and 'Requirements' amongst the Outcomes are the most frequent. Requirements are the main outcome of the Task Clarification stage and perhaps these trends are indicative of the same.
- The 'Generic' tag is the most prevalent within the Life cycle phases tag. This possibly indicates that current methods support the Life cycle thinking process in a general sense rather than by targeting its individual phases. This indicates a lack of methods for supporting specific phases.
- It is also observed that 'Material extraction' phase and 'After-use' phase are poorly supported, while both are important considerations from the environmental perspective.
- 'System' is the level of the system-structure most frequently considered by the methods in the database; there is a fair distribution of methods for sub-system, relationships and elements, although very few for features. One possible reason for this is that methods often do not specify as to what aspect of a system these target, indicating a lack and a need for better specification of the systemic level of use of the tools and a possible lack of system-level-specific tools.

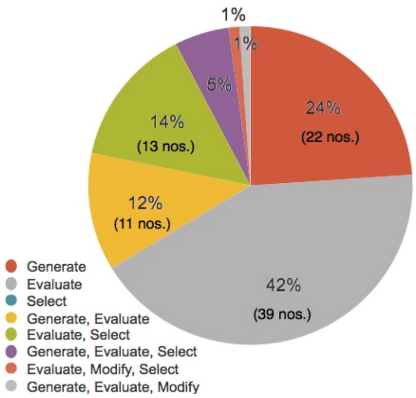

Fig. 1a Activity (direct) tags

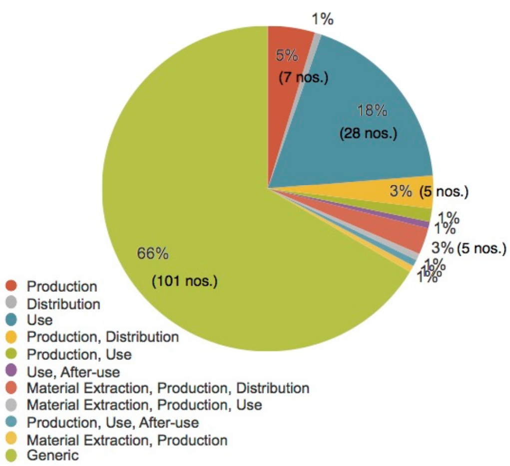

Fig. 1b Lifecycle phase tags

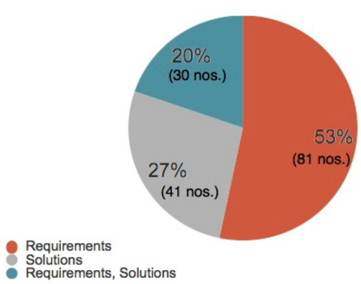

Fig. 1c Outcome tags

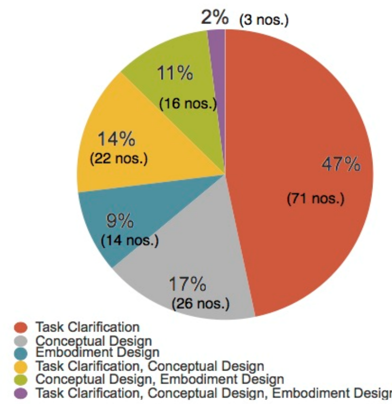

Fig. 1d Design stage tags

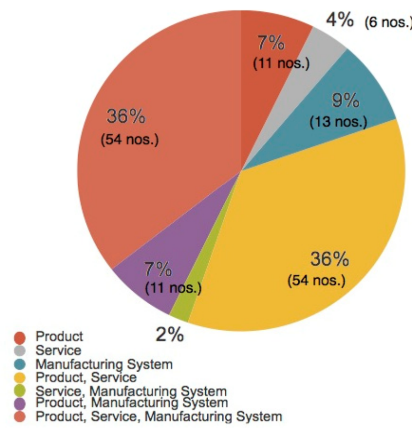

Fig. 1e System type tags

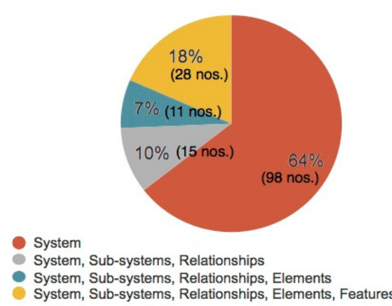

Fig. 1f System-Structure tags

Figure 1. Distribution of tags in InDeaTe methods and tools database

5. Analysis of InDeaTe in comparison with other design methods support

5.1. Comparative analysis of InDeaTe with other such tools

To evaluate the positioning of InDeaTe 3.0 as a web-based design tool for supporting training appropriate selection and use of design methods, a comparative literature-based study was conducted.

InDeaTe 3.0 (Chakrabarti et al., 2017) with its current offerings was evaluated against 9 other web-based, design methods support, namely, the Design Exchange (Roschuni et al., 2011; Roschuni et al., 2015), Amsterdam mediaLAB Design Method Toolkit (MediaLAB Amsterdam, 2016), IDEO Designkit (Kelley et al., 2013), WikID by Industrial Design Engineering at TU Delft (Vroom and Horváth, 2014), Korea University Design Method Toolkit (KIID, 2014), Google Design Sprint Kit (Banfield et al., 2015), Design and Emotion Society Library (McDonagh et al., 2004), Usability.gov (Leavitt and Shneiderman, 2006) and Usability Body of Knowledge (Usability Professionals' Association, 2005). These were compared with respect to seven criteria, as given in (Table 3), namely, area of application - generic or specific, type of support - database or toolkit, platform of application - web-based or otherwise, number of design methods documented, underlying design methodology or process, Ontological classification (number of tags), information provided and paid or unpaid access to the information.

Table 3. Comparison of InDeaTe v3.0 with other supports

CRITERIA	**InDeaTe** (Chakrabarti, et.al, 2017)	**Design Exchange** (Roschuni & Agogino, 2011)	**Designkit by IDEO**	**WikID by TU Delft**	**MediaLab Amsterdam Toolkit**	**Korea University Design Method Toolkit**	**Google Design Sprint Kit**	**Design and Emotion Society Library**	**Usability.gov database**	**Usability Body of Knowledge database**
Area of application	Generic *(considering just the methods database),*	Generic	Human-centered Design	Generic	Agile team-based projects	Driving innovation in organizations	Usability and testing	Emotional experience in the design profession	Usability and User experience	Usability and User experience
Tool / Database	Toolkit	Toolkit	Toolkit	Toolkit	Toolkit	Toolkit	Toolkit	Database	Database	Database
Platform of application	Web-based application	Web-based application	Web-based application	Web-based application	Limited information on the website, have to purchase flash cards	Web-based application	Web-based application	Web-based application	Web-based application	Web-based application
No. of design methods documented	152	284	61	42	57	87	27	70	53	65
Underlying Design Methodology/ process	InDeaTe design process template, availability / addition of more methodologies	A five-step process: "Research -> Analyse -> Ideate -> Build -> Communicate"	Inspiration -> Ideation -> Implementation	Categorized but no specific design methodology mentioned	A five-step process: Know User -> Define Intentions -> Frame Insightes -> Ideation and Concepts -> Prototype and Test	A five-step process: Definition -> Research -> Analysis -> Synthesis -> Realization	A five-step process (inspired by IDEO): Understand -> Sketch -> Decide -> Prototype -> Validate		No underlying methodology	No underlying Methodology
Ontological Classification of methods & tools (No. of tags)	45 tags based on 7 primary tags (the dimensions of ACLODS & system-type)	29 themes categorised with respect to the five-step process; each further attributed with variants	3	7	7	5	5	6	8	7
Information provided	Description & procedure; Input/ output diagram; key-benefits; case-studies, examples, videos and references; time required; rated with respect to Understanding, Relevance, Effectiveness and Ease of use	Overview, Instructions, Resources, When to use, Benefits, Limitations, Skills, Video example, Time, Tools, No. of people, Tags	Time, level of difficulty, materials needed, participants, steps to be followed	Description, references	When, why, tasks, output, references	Input, output, What it does, How it works, Case-study	Description, directions, prerequisites, time	Description	Description, Examples, Case-studies	Description, procedure, references
Paid/unpaid access to the information	Unpaid	Unpaid	Unpaid access to limited information	Unpaid	Unpaid access to limited information	Unpaid	Unpaid	Pay, become a member and use	Unpaid	Unpaid

5.2. Key findings from the comparative study

- Out of the ten supports, only three toolkits - InDeaTe 3.0, the Design Exchange and Wiki ID - address a generic area of application while the rest were developed to support specific goals.
- Though all toolkits and databases are available on the web, the MediaLab toolkit is only partially web-supported and has other additional material which has been acquired and bought offline for use.
- All but one of the toolkits, i.e., 6 out of 7, are grounded in some underlying design methodology or process; whereas all supports have ontologically based classification. The rest 3 supports are databases and have no underlying design methodology.
- InDeaTe and the Design Exchange have a larger number of tags, 45 and 29 in number respectively; and provide a broader spectrum of information beyond description, procedure or directions and references.
- Two key differences between InDeaTe and other supports have been inferred, are as follows:

1. The ontological tagging of InDeaTe is potentially richer compared to that of the other supports as it covers an array of dimensions beyond design stage and activity, which is the primary classification basis for the other supports.
2. While the other supports primarily provide methods and tools information in their databases, InDeaTe also provides a choice from a number of established design methodologies that can be used to guide the design process.

6. Summary, conclusions and future work

InDeaTe 3.0 is a theoretically-grounded, empirically-based tool for design of various types of systems. It is intended to support designers in appropriate selection and correct use of design methods by providing relevant information from the database, filtered with respect to an extended ontological tagging, on an enhanced user-interface with several salient features designed for these purposes. The tool also supports users to follow the design process methodology of their choice and provides the relevant methods and tools data tagged with respect to that methodology.

Currently, the tool supports product and service design system-types well, with 119 and 117 methods and tools tagged respectively. However, there is scope for improvement of the database of methods and tools for manufacturing systems design. The tool database also reflects all the dimensions of designs as empirically enlisted in the ACLODS framework; and supports all design stages (D), activities (A) and Outcomes (O), individually and in concurrence. However, there are not adequate methods and tools to support individual Life cycle phases (L) and Criteria (C), nor to address specific levels of a System (S). The tool has a number of more advanced features in comparison to the other available support, as it provides both instructive as well as explorative information at the perusal of the designer. Also, the enhanced user-interface offers self-learn and use features with intuitive navigation and support. Overall, InDeaTe v3.0 has promise to become a 'generic design process guidance tool' as it supports the design process across several dimensions of design and various design methodologies. Currently, evaluation of the web-tool is in progress by allowing open-access for use, contributions and real-time feedback.

The Design Exchange toolkit (Roschuni and Agogino, 2011), housing over 284 methods, is a potential benchmark to analyse InDeaTe for comprehensiveness of methods as well as the tagging ontology. Further improvements in tagging, in the information provided on the methods and tools using feedback from users, growth of the database with more methods and tools from literature as well as through user contribution entail future work, based on evaluation in progress. Also, development of this tool as a potential research support that allows the study and understanding of the distribution of methods, their selection and use, and their aid in development of refined/tailored design processes, methods and tools, is a probable future direction.

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