A systematic review of research methods and sources of information in product design (supplementary material)

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Abstract

This document complements the preprint paper entitled *A systematic review of research methods and sources of information in product design* that is the result of the PID 038 of the University of Valladolid (Proyectos de Innovación Docente). This document integrates a brief abstract of each of the papers that have been analysed in the project. The document is shorted by journal revised (Design Studies, International Journal of Design, Research in Engineering Design and Research in Engineering Design) and cites are shorted in alphabetic order. Each description includes the aim of paper and contribution the strategy of inquire and the sources of information. Details about the method followed and the conclusions of the study can be found in the mentioned preprint.

The paper has been submitted to the journal "Research on Engineering Design" and the preprint is available at (Escudero Mancebo et al., 2021)

Contents

DESIGN STUDIES

(Comi et al., 2019)

The paper explores how architects and engineers mobilize visual objects to coordinate their professional visions around a design issue. Authors define the concept of shared professional vision, and their research involved direct observation of design work carried out in an architectural studio in the UK. As sources of information, they used direct observations of design meetings between architects and their consultants, recording the sessions, and collecting the drawing and other technical documents used to exchange information.

(Goucher-Lambert & Cagan, 2019)

The paper explores the potential of using an untrained crowd workforce to generate stimuli for trained designers. It has two main aims: the first one, is to test whether it is feasible to obtain inspirational stimuli from an untrained workforce using crowdsourcing, and the second, to check the effectiveness and impact of varying distances of crowdsourced inspirational stimuli during design concept generation using a human subject experiment. It employs a methodology fully quantitative with subjective ratings and uses a control group and conditions that change among

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experimental groups, that are composed by designers who perform solutions (sketches) that are self-evaluated using formularies and evaluated by experts as well.

(Hanrahan et al., 2019)
The paper presents a case study of a six-month paper prototype deployment that was materialized collaborative interactions in care retirement community. It shows how the interactive, paper prototype provided critical guidance in how realistic their imagined practice would be. The continuous, in-situ design activity was particularly valuable for their system. The prototype took the form of a magnetic whiteboard, for which the authors designed various widgets, markers, and artifacts with participants, which they could use to express and support their activity or idea. As sources of information, they made meetings and interviews with participants, conducted focus groups, and prepared a kickoff workshop, leading design discussion around a template, suggesting or responding to activities on the board. Based on observations and discussions with participants, they made several changes to their procedure, over the course of the deployment.

(Hyysalo et al., 2019)
The paper details how democratized design contributes to the configuration of spaces and services of a public library, the Helsinki Central Library. It proposes a methodology for developing this and employs therefore a qualitative case study in which methods of democratized design are applied. As sources of information, the authors used field notes and synthesis documents from the observations of the meetings and workshops, which were reviewed with other authors during the analysis stage. They also made interviews with the project team members and the consultant, and with the participant staff and participants in meetings and workshops.

(Khalaj & Pedgley, 2019)
The aim of the paper is to investigate how can users' product impressions be systematically compared with designers' product expressions, to reveal and help alleviate discontinuities between intended and realized semantics. Authors propose a method for identifying such semantic discontinuities. The diverse impression data from users demanded the development of a substantive new qualitative semantic data analysis technique, a semantic network clustering. The information retrieved from interviews with designer is transformed into statements and likert scale values, and. Product appraisal and interviews with users are converted into semantic networks.

(Mathias et al., 2019)
The paper introduces Hybrid Prototyping as a way to couple different prototyping methods. A simulation-based study was conducted into the coupling of low-cost 3D printing and LEGO, developing an experiment with fourteen participants. Following a preliminary investigation, the results were implemented in a lookslike prototype for a video game controller. The iterative case study helps to illustrate the potential benefits of coupling building blocks and low-cost 3D printing across multiple iterations of the design. The findings mean that increases in prototyping iterations can be made due to reduced time and material costs, accelerating the product development process.

(McDonald & Michela, 2019)
In the paper the authors inquire into the moral goods that are significant for design studio instructors, by examining how they talk about the way critiques fit into the studio as a social practice. The research is performed by using in-depth interviews with six studio instructors, which talk about their backgrounds and common class procedures, and offer general comments on the critique as an instructional interaction. As sources of information, the authors conducted three interviews with each participant, which were audio recorded, and also class observations, which were video recorded.

(McKinnon & Sade, 2019)
The paper aims to contribute to the continuing discussion about the development of design research artifacts by presenting an in-depth analysis into the creation of a set of artefacts created to explore the home environment. As sources of information, the authors collected artifacts that included user opinions, which were reviewed in workshops with expert opinions.

(Reimlinger et al., 2019)
The aim of the paper is to evaluate the usage of design guidelines by novice and expert designers when designing a product. The authors use a qualitative analysis, looking for patterns in the ways the engineers approached the design, and quantitative, employing statistical analysis to look for significant correlations between variables. As

sources of information, the authors used interviews, to ask participants about the personal views about the benefits obtained by using the design guidelines, and eye tracking, to capture sequence charts and dwell time.

(Roy & Warren, 2019)
The paper studies card-based design tools making a review and analysis of 155 card decks for designers. The authors discuss how card-based design tools are supposed to work, what users think about them, and whether they are effective as aids to designing. As a starting point, they used the Deckaholic (2014) website, their own collection of card decks used in teaching and the online reviews by Miemis (2012) and others. Finally, they completed the inventory via a systematic literature and internet search.

(Self, 2019)
The paper studies how stakeholder expertise influences design interpretation derived from intent communication through conceptual design representations. Findings are discussed in terms implications for understanding the role and use of sketches in the communication of intent during conceptual design ideation. It uses qualitative analysis of eye-tracking maps and quantitative analysis of participants' responses in a card-sorting exercise. As sources of information, the authors recruited three stakeholder groups often present within a process of new product development (designer, manager, engineer), and examined their response to four sketch representations of design intent (idea sketch, study sketch, usability sketch, memory sketch). They obtained results from eye-tracking data for gaze point fixations and pupil dilation and from self-report card-sorting exercises.

(Van der Linden et al., 2019b)
The aim of the paper is to analyse the knowledge about the user experience the architects manage during their projects. As sources of information, the authors used the integration in three companies of architecture and collect data through observations documented in field notes, several documents as briefing papers, meeting reports, drawings or models, and in-depth interviews audiotaped and transcribed, most with architects and some with partnering firms or clients. The mix of ethnographic techniques used balanced what architects say with how they act, allowing meaning to be co-constructed in dialogue with participants.

INTERNATIONAL JOURNAL OF DESIGN

(Barati et al., 2019)
Thepaper studies the understanding of a new smart material by potential users and proposes a specific methodology for this aim. The authors use the material under study in prototypes developed in design challenges and collect expert opinions, of designers and scientists, in interviews about the challenge results. They also made an ethnography analysis where designers are observed during prototyping.

(Daalhuizen et al., 2019)
The aim of the paper is to defend a methodology for product design, Architecture for Design Doing (ADD)- that is consistent and flexible, user-centered, and aimed at learning and continuous development. With no data collection, the authors used a case study for the application of the framework with the Philips Customer Decision Journey (CDJ) methodology, which includes a step named 'iterate in which stakeholders' that contribute to evaluate the different drafts in workshops.

(Van der Linden et al., 2019a)
The aim of the paper is to study the application scenario-based design in architecture domains. The authors use proof of concept as methodology conducting test workshops in two architecture firms involved in designing residential care projects and discussing the findings with an expert panel. As sources of information, the authors used observation notes drawn during the workshops and audio recorded and summarized experts feedback.

(Feijs & Toeters, 2018)
The aim of the paper is to integrate the processes of generating new patterns by using tools called 'cellular automata' with the fashion design processes. It describes how the coding process is integrated with the fashion design, with many iterations in the coding phase and multi-disciplinary cooperation in the overlapping weaving, design, and construction phases. The authors have realized a small collection based on findings of the paper.

(Genç et al., 2018)

The aim of the paper is to propose five recommendations for designing fashionable wearables with computational materials. The authors follow a research through design approach, with a method that involved a design workshop, the analysis of the workshop outcome, and semi structured interviews with international experts. As sources of information the authors collected products: they first reviewed the results from the design workshop and examined videos of the presentations and sketches for the projects.

(Q. Li & Luximon, 2018)
The aim of the paper is to study a given aspect in the specific domain such elder people usability of mobile technology usability (perception and behaviour) for designer to build specialized interfaces. The authors made a quantitative experiment, a descriptive analysis conducted on user characteristics, technology features, usage behaviour, and user perceptions, and evaluated the the correlations between different variables of these four aspects, performing a Spearman correlation analysis. They employed a multiple regression analysis to ascertain factors of user characteristics and technology features associated with older adults' post-adoption behaviour. The authors also developed a qualitative phenomenological study, reporting comments retrieved in interviews about the day live interaction with technology.

(Park-Lee & Person, 2018)
The aim of the paper is to analyze different ways to manage briefing in the designer-client relation adapting to sales, pursuing an inductive thematic analysis. The authors develop an analysis of the different experiences of industrial design consultants perfits to build a classification of frequent adapted practices. As sources of information, the authors make interviews with experts, two rounds of semi-structured interviews with a total of 28 interviews along with briefing and sales related documents from 19 industrial design consultants in Finland, and collect documents: the briefings of the professionals.

(Pedgley et al., 2018)
The first aim of the paper is to study a given aspect in the specific domain such as the use of surfaces with imperfections in product design: ways to be imperfect, lifecycle analysis etc. It also proposes a design guideline, since the paper culminates in a visual guide to embracing material surface imperfections in design practice. The authors developed a qualitative study in which a classification of material surface imperfections was proposed, different designing teams made proposals with imperfect materials, and the results were classified in terms of the type of imperfection and annotated with sensorials properties and material meaning. As sources of information, the authors collected prototypes, created during concept design projects, and made observation of these products for annotating properties and checking the completeness of the imperfection categories.

(Roesler et al., 2019)
The aim of the paper is to design a process of the Anesthesia Medication Template, co-designed between physicians and designers, in order to improve in medication handling safety. The authors developed a quantitative field empirical study, along 4 years, employing practice-centered design with iterative prototypes, using quantitative field evaluation by expert practitioners in simulation studies and in the work setting.

(Selvefors et al., 2018)
The aims of the paper are to study a given aspect in the specific domain, since it analyzes the importance of appliances for economizing energy when using electric domestic devices, and to propose a guideline for effective appliance design. The authors developed a qualitative phenomenological study, performing a field study during two weeks with three test groups to evaluate three common types of kitchen appliances. As sources of information, they collected the data on the participants' reported use and perception of the appliances through online surveys, and they also conducted round-up semi-structured interviews in the participants' homes at the end of the study to explore the participants' experiences of using the appliances in more detail.

(Takahashi et al., 2018)
The aim of the paper is to provide five design recommendations for designing fashionable wearables with computational materials along with the strategies that designers can follow for applying them. The authors followed a research through design approach, a method which involved a design workshop, the analysis of the workshop outcome, and semistructured interviews with international experts.

(Tsai & Hoven, 2018)
The aim of the paper is to create a suitable method of inquiry into the way materials can enrich dialogues about remembered experiences derived from human traces left on cherished possessions, and to investigate how the

accumulation of human traces on objects influences people's remembering and usage. The authors adopted a constructive design research approach, adapting design probe method. As sources of information, they collected expert opinions in order to design the Memory Probes, and developed a field study along two weeks with seven participants to interact with these research artifacts.

(Vegt et al., 2019)
The aim of the paper is to study the use of games in brainstorming sessions. The authors developed a quantitative empirical study quasi-experiment, with comparison between conditions and correlation between variables. As sources of information, they used expert opinions, made observations and questionnaires, and collected products.

JOURNAL OF ENGINEERING DESIGN

(Abi Akle et al., 2019)
The paper is about Design Space Exploration (DSE), one embodiment of Design by Shopping (DbS) used during conceptual design and detailed design phases, which allow designers to sample thousands of design points iteratively, explore the design space, gain knowledge about the problems and make design decision. Observing that information visualisation is an indispensable element for the practice of DSE, the aim of the paper is to find a graph better suited to decide about quality and to gain greater understanding, proposing the scatter plot matrix (SPM). The authors conducted a controlled experiment using quantitative and qualitative variables, with 42 participants who were in final year of a MSc in Computer Aided Engineering and Product Development, that adopted a between-subject approach. For the analysis of data, the authors applied different statistical tests. As sources of information, they used multiple choice questionnaires and a web platform that permits eye tracking and video recordings for monitoring the participants while designing.

(B. Chen et al., 2019)
In the paper the authors propose a methodology for going from functional requirements to design parameters in the framework of Axiomatic Design. They develop a case study, a friction testing machine, and use a proof of concept to validate it. As sources of information, they use the input for the algorithm retrieved from the case study understood by the computer.

(Belkadi et al., 2019)
The paper describes a software platform for monitoring the design of experiments. By using a case study, the authors compare performance metrics with respect a reference model.

(Benavides & Lara-Rapp, 2019)
The aim of the paper is to develop a theoretical framework whose results indicate that minimising the number and the strength of all dependences as much as possible is a necessary and sufficient condition for robustness and value. This result leads to the definition of the Ideal Output, the one with the weakest and the lowest number of dependences. Thus, it is a fundamental result of the paper that, when seeking robustness, all dependences are important and all of them must be the target of the designers' labour. For this research, the authors use mathematical formulation including axioms, theorems, colloraries and principles. The formulation is confronted with a real case study.

(R. Chen et al., 2019)
The study proposes a novel integrated physical architecture generation and evaluation method. When various functional architectures are input, various types of ranked physical architectures can be obtained. The objective of this method is to identify and rank all feasible physical architectures to assist designers inmaking decisions. The authors show how the algorithm selects the best option among a set of them, and use technical documents for describing the results.

(Graeff et al., 2019)
The paper shows the importance of including biologists in design teams. The authors make a quantitative analysis based on an experiment that compares results of two different groups of designers and on a survey submitted to experts. In this experiment, students must solve problems and the outcomes are quantified to be compared with statistical methods. The authors also collect questionnaires in the survey.

(Morkos et al., 2019)

The aim of the paper is to study a given aspect in the specific domain such as the impact of requirement elicitation on the quality of the final project. The study results on proposing a guideline on how to elicit requirements. The authors developed a case study in which teams of students present weekly reports with the requirements of a given project. Requirements are classified and quantified for correlating them with the final scores of the projects. As sources of information, the authors therefore collect documents with the requirements, that are quantified and correlated with final grades. Grades are assigned by professors and peer evaluation.

(Ozer & Cebeci, 2019)
This paper uses both qualitative and quantitative criteria to compare k-means and fuzzy c-means clustering algorithms to analyse big data to offer customised and personalised online products and services with appealing features. In this way, the firms can increase the relevance and appeal of an online service and can increase customer satisfaction. As sources of information, the authors conducted a questionnaire survey with two hundred fourteen potential online shoppers at a major US university, and apply different measures on clustering algorithms (compactness, separation, prediction of the intention, prediction of online shopping usage ...), to discriminate if one method is better than another.

(Saravanan & Jerald, 2019)
The paper proposes a methodology to predict variations in assembly and integrate to it geometric tolerance design, The authors show how the method is applied to a case study to "demonstrate" the working of the proposed approach. There is no specific empirical design. The "demo" shows how a set of parameters work with the new approach suggested.

(Sung et al., 2019)
The aim of the paper is to study a given aspect in the specific domain such as the influence of sketching instruction on students' design cognition within elementary science classrooms. As sources of information, the authors made three observations of sketching instructions from fourth-grade elementary science classrooms with two different sketching strategies and one control group, recording video and audio and collecting sketching outcomes.

(Valverde et al., 2019)
The paper explores mechanical push-buttons' haptic profiles, from both available literature and observation of experimental measurements, leading to an identification of a high number of usable haptic parameters. The authors made experiments, providing prototypes with distinguishable feedbacks. They measured their haptic profile and translated them into unique engineering parameters, including new metrics to address feedback resilience in suboptimal actuations.

(Wlazlak et al., 2019)
The paper investigates the design and use of visual representations to support communication between an R&D team and geographically distributed suppliers. The empirical materials were collected through an exploratory, in-depth case study of an NPD project. As sources of information, researchers collected data from multiple sources, including interviews, observation of numerous R&D team meetings, observation of meetings between the R&D team and representatives from the distributed manufacturing site, a workshop and company documents.

RESEARCH IN ENGINEERING DESIGN

(Behera et al., 2019)
The aim of the paper is to propose a new approach to integrating and managing design definitions (shape models, product documentation), and design structures (bills of materials, assembly mating structures and function structures) which preserves the heterogeneity of different design definitions while allowing necessary relationships to be defined between them by making use of lattice theory and qualitative data analysis software tools. The authors presented two separate case studies and analysed their design definition documents as a starting point to establish a proof of concept that permits illustrating the benefits of the new approach.

(De Lessio et al., 2019)
The aim of the paper is to research on planning systems, because they directly impact how design and development processes develop and can provide a new insight into coordination problems and associated inefficiencies. The authors developed a survey tool to evaluate a planning system from the perspective of its stakeholders. The survey results are analysed using the Multiple Domain Matrix (MDM) methodology for ideas and suggestions for improvement. The approach is developed and demonstrated through a case study in a company that develops

advanced electroclinic scientific instruments. In addition to surveys, the authors collected products and made interviews and individual sessions with workers as sources of information.

(Franceschini & Maisano, 2019)
The aim of the paper is to present, in a relatively simple way, a novel approach to these questions: How can the degree of concordance of designer rankings be measured? Which aggregation model provides the most coherent solution, for a given set of designer rankings? and To what extent is the collective ranking influenced by the aggregation model in use? The authors introduce a case study concerning the design of an automatic pallet stretch-wrapping machine, which accompany the theoretical description of the proposed methodology, involving a team of designers in an important company based in north-western Italy. They presented a quantitative experiment with a preference profile provided by ten design engineers, for four design concepts, and employing the Kendall's coefficient of concordance W, or by other similar multi-rater coefficients of agreement, as well as interpreting Arrow's theorem, deployed in the context of engineering design.

(Garcia et al., 2019)
The aim of the paper is to present a set of metrics supporting the negotiation of expectations among stakeholders, which could facilitate the definition of a common set of requirements and constraints satisfying all the stakeholders. The authors analyse the case of a joint-venture of two ship owners who have decided to build a large offshore construction vessel.

(Gralla et al., 2019)
The aim of this paper is to research how to decompose complex problems. The authors analyse the way variables are grouped into subproblems, the process of decomposition, and whether small teams use similar decomposition patterns. As sources of information, they studied the activities of five design teams engaged in a half-day design session.

(Gyory et al., 2019)
The aim of the paper is to study a given aspect in the specific domain, such us the impact of management on enhancing performance of design teams. The authors compare the performance of different groups of students operating under different team work conditions. From the outcomes of the team work, they computed a set of measurements that score the quality of the designs, taken from the proposed design and from the transcriptions of audio recordings.

(Jagtap, 2019)
The aim of the paper is to make a revision of concepts related with design and poverty in state of art publications. As sources of information, the author collects documents (papers in the state of art publications).

(Martinec et al., 2019)
The aim of the paper is to propose a methodology for product design and/or development, specifically for modelling the micro-scale process patterns which can be identified during team conceptual design activities, developing a state-transition model that has been used to empirically investigate the patterns of design operations during activities of ideation and concept review.
The empirical part of the research has been conducted in the form of a verbal protocol analysis study).
As sources of information the authors used (i) workshops (experiment sessions with four teams -12 participants-, composed of mechanical engineering students selected from a final year product design and development course), (ii) simultaneous verbalisation (a verbal protocol analysis study), (iii) video recordings (recorded experiment sessions), and (iv) other such as whiteboard and sheets of paper, coding schemes (the recorded team conversations have been transcribed and parsed into coded segments), and proportion matrices averaged per teams to summarise the data.

(Menold et al., 2019)
The aim of the paper is to study the effects of a structured prototyping framework on several design attributes.
Three groups of students (groups A and B received instruction in the PFX framework, while group C did not) follow different methodologies for developing prototypes that are evaluated and compared.
The final designs from each group were assessed by two independent human raters. Five assessments/metrics subjective scores are judged: (1) a user satisfaction scale, (2) a user-perceived value scale, (3) an effectiveness scale, (4) the critical print count ratio, and (5) the critical part count ratio.

(Ogura et al., 2019)
The aim of the paper is to study a given aspect in the specific domain such as shortening of products developing durations. The paper presents an analytical framework for optimally allocating resources to shorten the lead time of product development projects having a time-varying dependency structure.
The authors build their theoretical framework on a linear system model of product development processes, in which system integration and local development teams exchange information asynchronously and periodically. Utilizing a convexity result from the matrix theory, the paper shows that the optimal resource allocation can be efficiently found by solving a convex optimization problem. The authors provide illustrative examples (by using a case study) to demonstrate the proposed framework, and the conclusions are supported in measurements taken in the aforementioned case study (an automotive appearance design).

(Piccolo et al., 2019)
The aim of the paper is to create a bridge between the social perspective on the design process and the technical perspective, i.e. an intersecting design theory about modularity and iterations with network science to model process structure and organisational structure. Thus, the paper shows that iterations increase when the number of participants increases and when external suppliers are involved, and are lower in presence of integrative activities.
The quantitative empirical study consists of: (i) an exploratory analysis of the case dataset to visualise and understand how the design process unfolds over time, showing its iterativeness, and (ii) the use of a rigorous statistical approach of hypothesis testing to test six hypotheses on what influences on design process iterations.
The qualitative case study provides the data set (a log of the 3559 documents produced during the design process of biomass power plant for electrical power generation) used to investigate the aforementioned six hypotheses.

(Saliminamin et al., 2019)
The aim of the paper is to study a given aspect in the specific domain: clarify the performance of R&D designers when involved in design task for the ideation of the next generation of a technical system.
Three experts received the list with the whole set of generated ideas as emerged from the transcripts. They ranked each idea according to the metrics presented in Sect. 3 of the paper.

(Santolaya et al., 2019)
This work aims at projecting more sustainable products by the application of a methodology which assesses impacts not only from an environmental point of view but also from a socio-economic perspective and includes a redesign phase integrating sustainability strategies consistent with the initial product design specifications.
Authors present two case study in which they compare alternative re-design proposals by using a set of metrics that permit to assess and compare sustainability of alternative designs.

(Tahera et al., 2019)
The aim of the paper is to study the relationship between testing and design process.
The paper combines insights from literature study with findings from three empirical studies of testing.
As sources of information there were: (i) collecting documents (various issues in the literature relating to testing in engineering design and development), and (ii) interviews (semi-structured interviews performed in three different companies, i.e. three case studies).

(Wood & Mattson, 2019)
The aim of the paper is to propose a methodology for product design and/or development, specifically the results obtained in this study can help design teams plan their own ethnographic activities to increase the likelihood of collecting information that is useful for making product design decisions based on the conditions. As sources of information the authors used: interviews, observations, diary (field reports: at the end of each day, the researchers would write a detailed description of the activities of that day), photographs, video recordings, and audio recordings.

(Yang et al., 2019)
The aim of the paper is to propose a methodology for product design and/or development, specifically to propose three principles (modularity, community and strength) that rationalize the part consolidation candidate detection (PCCD) process with regard to the maximum number and the priority of parts to be consolidated, in a complex product design.
It has been developed a modularity-based PCCD (MPCCD) framework which is featured by the need for module division and community detection as well as two PCCD algorithms [strength-based numerical PCCD (NPCCD)

and community-based PCCD (CPCCD)]. Two case studies of a throttle pedal and an octocopter are presented to demonstrate the effectiveness of the proposed CPCCD algorithm and the MPCCD framework, respectively. Additionally, a sensitivity test is conducted for understanding better the robustness of the proposed algorithms.

(Yunpeng Li et al., 2019)
The aim of the paper is to propose a methodology for product design and/or development, specifically to derive the optimal product form design which satisfies multiple affective responses (MARs) simultaneously.
A Mixed empirical study is employed: design analysis is first used to identify design variables and MARs; a multi-objective optimization (MOO) model that involves maximizing MARs is constructed; an improved version of the strength Pareto evolutionary algorithm (SPEA2) is applied to solve this MOO model. After that, the Choquet fuzzy integral is employed to determine the optimal design from the Pareto solutions in accordance with the consumer preference. As sources of information the authors used questionnaires.

(Yongfeng Li et al., 2019)
The aim of the paper is to propose a methodology for product design and/or development, specifically to investigate how engineers and data scientists can effectively collaborate in a mixed team for new product development with data-driven features; additionally, the paper focuses on the concept development stage for smart products. Therefore, an integrated process model is explored by revisiting the traditional new product development process model as well as the knowledge discovery and data mining process model.
A case study of the development of an application-specific unmanned aircraft system is used to examine the proposed model. It has been carried out by university researchers and staff. In particular, authors analyze interaction between engineers and data-scientist groups.
Authors rate (three values scale) the flows of information by leveraging four attributes proposed by Krovi et al. (2003) to analyse the evolution of the inter group interaction throw time.

(Zhang & Thomson, 2019)
The goal of this paper is to study the development processes of complex products from a knowledge perspective.
A mixed empirical study is employed: the paper introduces an agent-based model that simulates the learning and application of knowledge during product development.
The agent-based model was developed by using AnyLogic, a simulation software that supports multiple modelling paradigms, namely discrete event and agent based. This model used product and development process data from a case study consisting of the development of a hydroelectric generator at GE Hydro.

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