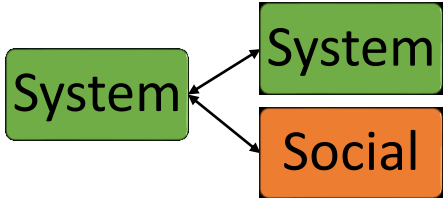
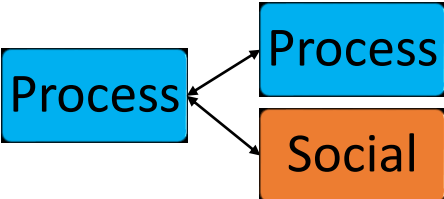
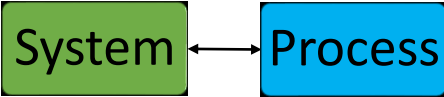
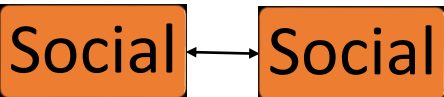
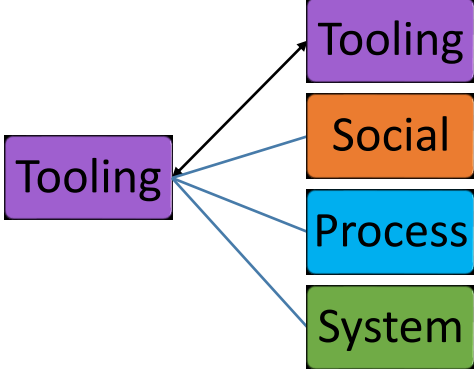


Online Resource 3 Supplement data table for Table 7 in main article. This table contains the references with their corresponding identified generalized complexity challenge

Viewpoints' relationships	Challenge		References
	1	Alignment of the system and social viewpoints	DSM AND KNOWLEDGE [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] <i>Change propagation: DSM AND KNOWLEDGE</i> [31] [18] MODEL [32] [33] [34][35] [36] [37] [38] [39] [40] [41] [42] [43] [44] [45] [46] [47] [48] [49] [50][51] [52] [53] [54] [55] [56] [57] [58] PROCESS [59] [60] [61] [62] [63] [64] [65] [66] [67] [68] [69] [70] [71] [72] [73] <i>consistency of information, horizontal integration</i> [74], missing clarity of system elements and interactions between them and environment [75], failure to capture interconnectivity and collaboration aspects in SoS [76], [77]. PRODUCT [78] [79] [80] [81], <i>forward and backward integration of engineering information</i> [82], <i>consistency, reuse and explicit to tacit</i> [83], <i>communication about the system effectively</i> [84], [85], [86], [87], with regards to product data [88], projects errors are reproduced, lessons learned not documented, not able to find solutions to defects, poor knowledge management [89], [90], large diagrams difficult to understand [91], [144], connection between the information models of disciplines [92], product models [93], understanding across disciplines [94], TOOL due to heterogeneity and uncertainty [95], traceability issues from the information of the system [96], <i>traceability of project data to be accessed during different tasks</i> [97], <i>consequences of separation of concerns are less opportunity of correct by construction design and inability to perform cross-domain optimizations. The price to pay is decreased predictability and costly redesign cycles.</i> [98], assure consistency of the development [99], <i>challenge to find common concepts to handle integration of concerns at the interfaces of the different disciplines on project and team level. Still the degree of abstraction of data integration leaves much room for details about how to connect or combine the heterogeneous data sources. Plus there are problems with change management, high-costs of reuse.</i> [100]
	2	Alignment of the process and social viewpoints	DSM AND KNOWLEDGE [2] [101] [9] [10] [11] [12] [14] [15] [16] [18] [19] [27] <i>Change propagation:</i> [31] [18] MODEL [36] [37] [42] [43] [45] [46] [47] [48] [50] [53] [54] [57] [102] PROCESS [59] [60] [61] [62] [63] [64] [103] [65][104] [66] [67] [105] [106] [68] [107] [108] [109] [110] [71] [111] [74][72] [72] [73] [112] [75] <i>two types of methods need to be understood: methods for the system design and methods for the support and coordination of the development tasks</i> [77] PRODUCT [80] <i>missing process comprehension</i> [81], [82], <i>design decision and communication during process</i> [84], [85], [86], <i>best practices not formalized</i> [89], [90], [113], [144], required flexibility and lack of documentation of process [92], efficient cooperation across disciplines [94], TOOL integrate product and manufacturing [95], traceability issues to get insights from process and results [96], <i>a comprehensive understanding of the processes and methods in cross domains affairs is an issue</i> [99], <i>challenge to properly track changes and their propagation, which causes misconceptions of project's status</i>
	3	Align the process and the system viewpoints	DSM AND KNOWLEDGE [8] [12] [14] [15] [18] [19] [21] [25] MODEL [33] [36] [38] [47] [53] PROCESS [59] [60] [61] [64] [103] [66] [67] [68] [111] [74] [72] [112] [75] [77] PRODUCT [84]<i>align product data with workflow</i> [88], transferring knowledge from engineering design, to prototyping to production (PLM) challenges [94]
	4	Management of the social viewpoint (Human factors)	DSM AND KNOWLEDGE [2] [5] [8] [9] [11] [126] [127] [128] [129] [130] [28] [29] MODEL [32] [37] [40] [42] [43] [45] [46] [49] [53][55] [57] [102] [58] PROCESS [63] [64] [65] [66] [67] [68] [107] [69][71] [74] (natural attraction to couple design, wanting to work on solution fast) [73] considerations of scheduling, costs of change, time, etc. + non considered human behavior under time pressure [112], skills and knowledge of engineers [75], to coordinate the multiple team efforts. Manage organization reluctance to invest [76], <i>cooperation</i> [77] PRODUCT [115] [81] [84] [86], <i>varying experience, implicit/explicit information</i> [87], resources overload (using non-planned resources), management problems, responsibilities not defined, bureaucracy [89], <i>communication and coordination</i> [117], [144] TOOL <i>Varying needs/demands from tool users (direct and indirect)</i> [120], <i>the tasks to handle integration of concerns at the interfaces of different engineering disciplines and to add or generate the common semantic concepts are normally executed by experts who are familiar with at least two related tools</i> [100], <i>many developments of tool integration require deep knowledge and understanding of the metamodels of the tools, plus programming skills</i> [121], difficult to find someone that understands two domains and mastery of modelling transformation languages [124]
	5	Alignment of the tooling viewpoint with the system, process, and social viewpoints	DSM AND KNOWLEDGE [11][12] [16] [18] [22] [24] [27] [30] MODEL [32] [33] [36] [37] [114] [39] [40] [41] [42] [43] [44] [45] [46] [47] [54] [55] [57] [102] PROCESS [59] [60] [64] [68] [69] [110] [74] [75] [77] PRODUCT [115] [80] [81] [82] [84] [116]<i>PDM</i> [88], cloud computing [117], interoperability [90], TOOL lack of modern tool integration and deployment platforms, seamless integration of end-to-end tool chains [95], tool integration, model transformation analysis, knowledge management, project management [118], <i>Relationship designer-tool: providing information for accomplishing a task, suggesting error solutions, general assist to users</i> [96], <i>interoperability among the tools, to be able to reuse data from the various environments as well as guaranteeing consistency</i> [97], <i>loose coupling between engineering tools can lead to inconsistencies and errors</i> [119], technical details have been covered but high-level issues and contexts are treated indifferently, the issue is having an overall understanding what tool integration is, facilitate discussions, trade-offs and identify weaknesses. Different “dimensions” of tool integration, namely Control, Data, Platform, Presentation and Process Integration. [120] , <i>more comprehension of the tools in cross domains affairs is needed</i> [99], <i>exchanging data between disciplines and different engineering groups needs to be done manually, as parts of the common data model are simply missing in some tools</i> [100], <i>the challenge is that there is a price to pay for the flexibility and interoperability which is normally affecting performance (increase execution time) compared to native facilities of the tools</i> [121], applying a tool chain can impose great hardship on a development team, as to ensure that an arrangement of tools qualify the established developed culture, processes and standards [122], <i>check well formedness and healthiness of designs as prelude for co-simulation</i> [123], <i>making engineering tools from multiple disciplines interoperate</i> [124], <i>models of physical and computing process</i> [125]

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