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PRELIMINARY SIMULATIONS OF SCALE AND VALUE OF LEGITIMATION IN DESIGN PRACTICE

Vishal SINGH (1), John GERO (2)
1: Aalto University, Finland; 2: Krasnow Institute for Advanced Study and University of North Carolina at Charlotte, United States of America

ABSTRACT
This paper presents preliminary simulation results on the effects of scale and value of legitimation in design practice. The paper describes a basic simulation model, which adopts legitimation code theory as the underlying conceptual framework. This model simulates a society of design agents with different backgrounds. Based on the given legitimation values of their discipline, agents are attracted towards knowers or knowledge. The force of attraction towards the knower or knowledge varies across disciplines. The emergent design practice is plotted in a two dimensional space defined by the knower and knowledge axes. The effect of scale is studied by changing the number of agents. The effect of value is studied by comparing scenarios where legitimation values of a design agent remain constant throughout the simulations to scenarios where legitimation values increase at a constant rate, as a function of time spent in a multi-disciplinary environment. Preliminary results indicate that both scaling up and changing values can lead to cohesive design practice in multi-disciplinary societies. The underlying assumptions and limitations of the simulation model are discussed.

Keywords: design practice, simulation, research methodology, computational sociology

Contact:
Dr. Vishal Singh
Aalto University
Civil and Structural Engineering
Espoo
00076
Finland
Vishal.Singh@aalto.fi

1 INTRODUCTION

Designing is a rich and multi-faceted activity and is defined differently in different disciplines. For example, some designers consider designing as a methodical, scientific, computable and knowledge driven process while others consider designing as a reflective, intuitive and perception driven process (Papanek, 2001). A common understanding and acceptance of design typically emerges within a social context through social interactions and the legitimation of its practice in that discipline (Maton, 2000; Carvalho, 2010). Legitimation refers to what is considered as acceptable or normative in a society, often understood as some form of implicit code or unwritten 'rules of the game' (Bourdieu, 1983). The legitimation of design practice within a social context emerges over time, making it a longitudinal process (Carvalho, 2010). Therefore, any study of this legitimation of design practice and its emergence in a society requires a longitudinal study, which is difficult and time consuming through empirical methods. Hence, this research adopts a computer simulation based approach (Carley, 1994; Sosa and Gero, 2005) to investigate the longitudinal patterns in social emergence of design practice. The simulation model adopts legitimation code theory (LCT) (Maton, 2000) as the underlying framework, and the validation of the model based on this approach has been discussed in an earlier paper (Singh and Gero, 2013).

LCT describes the development of practice through specialization and semantics as two important dimensions. While LCT has been used to explain legitimation codes with various knowledge and educational contexts, with the exception of Carvalho (2010) and Carvalho et al (2009), there appear to have been no studies in design disciplines applying LCT. According to Carvalho et al, the specialization principle of legitimation code theory describes how the design practice and recognition within a social group are driven through both the knowledge and knower modes (Maton, 2006), i.e., the design practices emerge and evolve under the influence of the social structure as well as the knowledge structure.

Building on Carvalho et al (2009), the simulation model used in this research simulates a society of design agents with different design backgrounds affiliated to different teams and organizations. Design agents interact with each other and the concepts associated with the different disciplines. Following LCT, design agents within each discipline are modelled to be attracted towards concepts, i.e., knowledge mode, as well towards the other design agents, i.e., knower mode, which collectively influence the design practice. The force of attraction towards the knower or concepts varies across disciplines. The emergent design practice is plotted in a two dimensional space defined by a social axis and knowledge axis such that design agents higher up the social axis exert higher knower force while the concepts higher up the knowledge axis exert higher knowledge force.

The simulation environment can be used to study the longitudinal emergence of design practice trends resulting from varied "what if" scenarios. The internal validation of the simulation environment for its suitability to study longitudinal emergence of design practice trends has been carried out by comparing the results from preliminary simulations with empirical patterns observed in comparable scenarios. These validation studies were presented in an earlier paper (Singh and Gero, 2013), where patterns for trends across architectural, engineering design and fashion design societies were compared. The observed emergent patterns in the validation simulations were consistent with the qualitative findings in the empirical studies conducted by Carvalho (2010). Accordingly, in architectural design society the growth was relatively balanced across knowledge and social axes, whereas in engineering design society, the growth was skewed towards knowledge axis, while the growth in fashion design society was skewed towards the social axis. Following the internal validation of the computational model for its consistency and conformity with empirically observed patterns, further results were presented in the same paper (Singh and Gero, 2013) that compared design practice in each of these mono-disciplinary societies against the design practice in a multi-disciplinary society. The current paper builds on those mono-disciplinary and multi-disciplinary comparisons.

Two questions are investigated in this paper:

Q1: Does scale or size of the society have an effect on the emergent design practice resulting from the legitimation codes within the society and if it does how does the effect of scale on emergent design practice vary across mono-disciplinary and multi-disciplinary societies?

Q2: How does the change in values associated with the legitimation codes of different disciplines within a multi-disciplinary society affect the emergent design practice? It is argued that within a multi-disciplinary society, as agents from different disciplinary backgrounds interact with each, they mutually influence each other's values associated with the legitimation codes.

The remainder of this paper presents a brief background of LCT, a brief description of the simulation model, the details of the experiment design, and the simulation results.

2 BACKGROUND

This section discusses the literature on social construction of design, LCT principles and the empirical study using LCT in design, which together provide the conceptual basis for developing the computational model.

2.1 Social emergence of design

Trends, concepts and assessment of design are often viewed as social constructs (Sosa and Gero, 2005; Sternberg, 1999). In discussing the social construction of creativity, an attribute closely associated with design, Sternberg suggests that creativity assessment and related values are negotiated by social groups. This constructivist view of design as a form of assessable expertise is consistent with the social creation and emergence of knowledge in a broader context (Bourdieu, 1983; Nonaka, 1994). For example, in his SECI model, Nonaka describes knowledge creation and assimilation as cyclical processes involving socialization, externalization, combination and internalization of the existing and emergent knowledge. This assimilation and recognition of the emergent knowledge and the concepts involve formalization and legitimation of the tacit knowledge as acceptable and normative. The social legitimation of emergent knowledge and its associated concepts and values are also explained using LCT. LCT provides a conceptual framework to study the emergence and acceptance of knowledge in a social-cultural context, and LCT has been applied to study the legitimation practices across various domains, including design.

According to the specialization principle of LCT, in any society the prevalent practices, beliefs and knowledge are driven towards something and or someone, such that there is an epistemic relation (ER) and a social relation (SR) (Maton, 2006). Figure 1 represents the legitimation codes. The values (+/–) along the X-axis represent the strengths of social relation, and the values (+/–) along the Y-axis represent the strengths of epistemic relation. Each quadrant of the model corresponds to a specific LCT code. The epistemic relation pulls the agents in the society towards knowledge and the social relation pulls the agents towards the socially dominant agents, Figure 1.

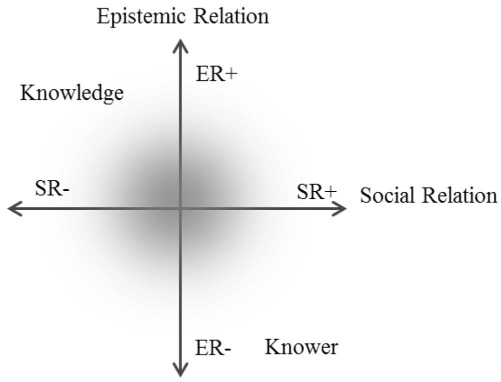

Figure 1. Modes of legitimation of design practice (after Maton 2006)

While there is always a knowledge and knower dimension in any social context, the knowledge or knower dimensions may dominate the other based on the established norms within the context. In design disciplines, even though such debates are common, there is little research in this area. More recently, Carvalho (2010) has compared the legitimation codes across different design disciplines including architecture, fashion design and engineering design, Table 1.

Table 1. Legitimation codes across different design disciplines (based on Carvalho, 2010)

Discipline	Epistemic relation (Knowledge mode)	Social relation (knower mode)
Architecture	+	+
Fashion design	-+	++
Engineering design	++	-+

According to Carvalho, Table 1, architecture tends to show greater balance between the knowledge and knower modes, in fashion design the knower mode tends to dominate, and in engineering the knowledge mode tends to dominate.

2.2 Value and exchange in multi-disciplinary environments

As described in LCT, in any social context norms emerge in terms of what is valued as meaningful and desirable. At individual levels such value propositions are either acquired or developed through the process of social learning and interactions. As a result, there is greater push in organizations and society in general towards creating multi-disciplinary and multi-cultural environments where actors from different backgrounds interact and learn about each other's values. It is expected that such interactions lead to exchanges of ideas and values through various mechanisms such as imitation and acquisition. Accordingly, in a multidisciplinary design environment, the exchange of values associated with the legitimation practice should influence the emergent design practice. While it is acknowledged that such multi-disciplinary design environments lead to exchange of ideas and values, the emergent design practice over extended period of time is not well understood.

2.3 Computational social simulations

Computational social simulations are an established method to test and generate socially-related hypotheses (Carley, 1994). The key drivers for using a computational simulation approach for studying the design practice emerging from legitimation codes have been presented in Singh & Gero (2013). As stated, these computational social simulations are meant to provide a complementary research method and infrastructure that can reduce the time, cost and resource constraints towards generating and testing the promising theories, especially in scenarios that require longitudinal studies that are difficult to conduct through empirical methods.

3 EXPERIMENT DESIGN

This paper investigates how the scale, i.e., population size, and changes in value of actors in a multi-disciplinary environment influence design practice. A computational model is implemented in MASON (Luke et al, 2005), a java based multi-agent system, with basic assumptions about the design society to be studied. Each entity in the model that needs interaction, i.e., the designers, concepts and teams are implemented as agents within the simulation environment such that there are dynamic connections and forces of attraction between design agents, between design agents and concepts, between concepts, between design agents and teams, and between teams and concepts. Following Carvalho (2010), the three disciplinary backgrounds considered are architecture, fashion design and engineering. Table 2 shows the assumed forces. The assumed values in Table 2 correspond to the qualitative knowledge of their relative values (Carvalho, 2010), as shown in Table 1.

Table 2. Assumed forces of influence across different disciplinary entities

	Entities (E^1 & E^2)	Force=	Discipline conditions
1	E^1= Agent; E^2= Agent	**K**× ($I_R E^1$ × $I_R E^2$) / (distance E^1 and E^2)^2 **K**= constant; I_R= Influence Radius	IF architecture **K**= 100 IF fashion design **K**= 1000 IF engineering **K**= 1
2	E^1= Agent; E^2= Concept		IF architecture **K** = 100 IF fashion design **K** = 1 IF engineering **K** = 1000
3	E^1= Concept; E^2= Concept		IF E^1 and E^2 belong to same discipline **K**= 100 ELSE **K**= 1
4	E^1= Agent; E^2= Team		Same as 1
5	E^1= Team; E^2= Concept		Same as 2
6	E^1= Team; E^2= Team		Same as 1

Forces corresponding to knower modes are highest for fashion disciplines and least for engineering disciplines. For example, constant K in agent-agent (knower) attraction is highest for fashion design agents and least for engineering design agents. Other assumptions are based on similar arguments.
In addition to the basic assumptions about knowledge and knower modes, additional assumptions are superposed in the new simulations about the change in values associated with the legitimation codes across the different disciplines. This follows the bottom-up approach of the research such that the additional parameters are added once the effects of fewer parameters are known from earlier simulations. The additional assumptions and parameters considered in this paper are listed in Table 3. First, in order to understand the effects of scale, simulations are conducted with different population sizes, including more concepts and teams. Second, in order to understand the role of changing values associated the legitimation codes across the different disciplines, an additional parameter of 'change of value' is considered. The 'change of value' is described in terms of the rate at which agents from different disciplines influence each other's legitimation codes. It is assumed that as agents spend more time in a multi-disciplinary environment, their values towards legitimation practices tend to converge. Since agents typically learn from each other, and multi-disciplinary teams are known to develop a shared understanding of design after an extended period working together, this assumption appears plausible. While the authors are not aware of empirical data on value transformation across disciplines, these what-if simulations are expected to provide qualitative insights on the merits of following such a path of enquiry in the future.

Table 3. Research questions, assumptions and parameters

Research questions		Simulation requirements	
		Assumptions	Parameters
Q1	Does the scale of the society affect the emergent design practice across different design societies?	A society with design agents and teams with different disciplinary backgrounds A set of concepts associated with different disciplines	Population size
Q2	How does the emergent design practice in multi-disciplinary design society change if the design agents acquire each other's values associated with the legitimation practice?	Design agents are assumed to incrementally acquire values associated with other disciplines as they interact with each other in a multi-disciplinary society. This is modeled as a 'rate of change on value', implemented as a constant % change in force, occurring at a given interval.	Constant change in force (R) Constant frequency (N), i.e., number of simulation cycles after which values change

At the commencement of the simulation, i.e., at t=0, all the entities in the simulation environment including design agents, concepts and teams start with a pre-defined position the two dimensional space, defined by their social and knowledge dimensions. The initial scenario across all the entities, i.e., where the different agents, concepts and teams start from may influence the emergent design practice.
Design agents, concepts and teams move within a two dimensional space based on their interactions with other design agents, concepts and teams. Each entity has an influence radius such the force of attraction between any two agents is directly proportional to their influence radius. Following the two modes in LCT, the two dimensional space is defined by orthogonal axis with epistemic (knowledge) mode along the ordinate while the social (knower) mode is represented along the abscissa. As the interactions take place, the emergent design practice including the knowledge and social dimensions of the design agents, concepts and teams are recorded and can be graphically presented. For simulation cases where agent's values change during the simulations, the forces of influence change over time.

3.1 Details of simulation scenarios

Two sets of experiments were conducted to investigate the questions of scale and value, Table 4. The first set of simulations was conducted with different population sizes for each social composition, i.e, mono-disciplinary design societies and multi-disciplinary design society. The second set of simulations was conducted with multi-disciplinary design societies only, with two cases. In case 1, the design agents retained their original legitimation values throughout the simulations. In case 2, design agents incrementally acquired legitimation values associated with other disciplines.

Table 4. Experiment design

Research question	Cases to compare	
Q1 (Scale)	Mono-disciplinary/Multi-disciplinary design society Number of design agents= 32 Number of concepts= 12 Number of teams= 6	Mono-disciplinary/Multi-disciplinary design society Number of design agents= 256 Number of concepts= 96 Number of teams= 48
Q2 (Value)	Multi-disciplinary design society Value= constant as per Table 2	Multi-disciplinary design society Value= changes at a constant rate, R= 20%, N= 5, as per Table 3

4 SIMULATION RESULTS AND DISCUSSION

The simulation results are analyzed qualitatively because the assumed values are chosen on relative terms, and there is no empirical data to benchmark the assumed values. Accordingly, the graphical visualization of the emergent design practice plays an important role in studying the effects of scale and change of values in design practice.

4.1 Effects of scale

Figure 2 shows snapshots from simulations with multi-disciplinary society, for each social composition, i.e, architectural society, fashion society, engineering society and the multi-disciplinary society. Figures 2(a) and 2(b) show snapshots from simulations with 32 agents and 256 agents respectively. The emergent design practice with 256 design agents show similarities to the patterns observed with 32 design agents. Despite the change in scale or size of the population, in each case, distinct layers are created along the knowledge axis. Some design agents form a leadership pack while the others become followers. Similarly, irrespective of the scale, segregation across disciplinary backgrounds is observed in a multi-disciplinary society.

However, a sign of one potential effect of scaling-up is observed, which needs further investigation. This distinction is more evident in Figure 3, which plots the average movement of each agent across 30 simulation runs. In each of the design societies there are a few outlier design agents who grow across both knowledge and knower axes. Such outliers may be a result of the biased initial positions of those agents at the start of the simulation. Nonetheless, in a small population size, the number of these outliers is too low to have any significant impact on the emergent design practice. Whereas, when the population size increases, the absolute number of these outliers may increase to a critical mass beyond which they may influence the design practice. Accordingly, it can be observed that the patterns of growth in larger population size (256 agents) are more bi-directional than the patterns of growth in smaller population size (32 agents).

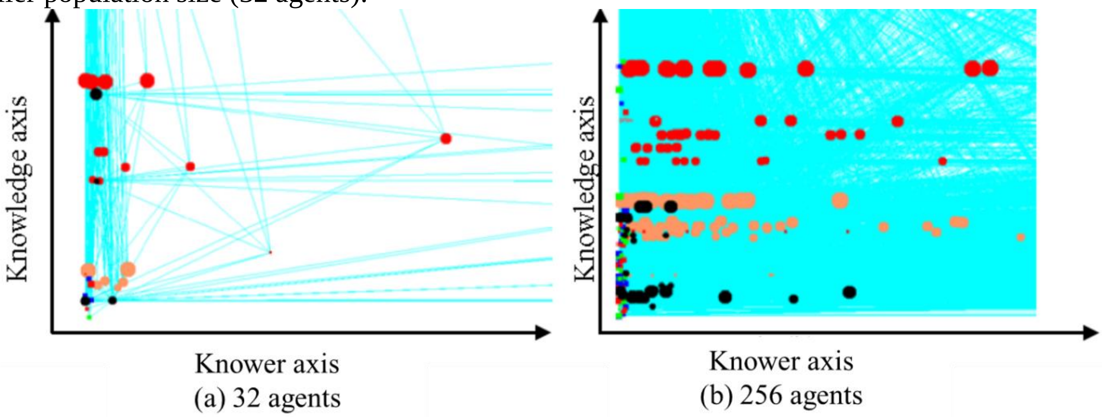

Figure 2. Comparing effects of scale, Multi-disciplinary society (simulations snapshot)

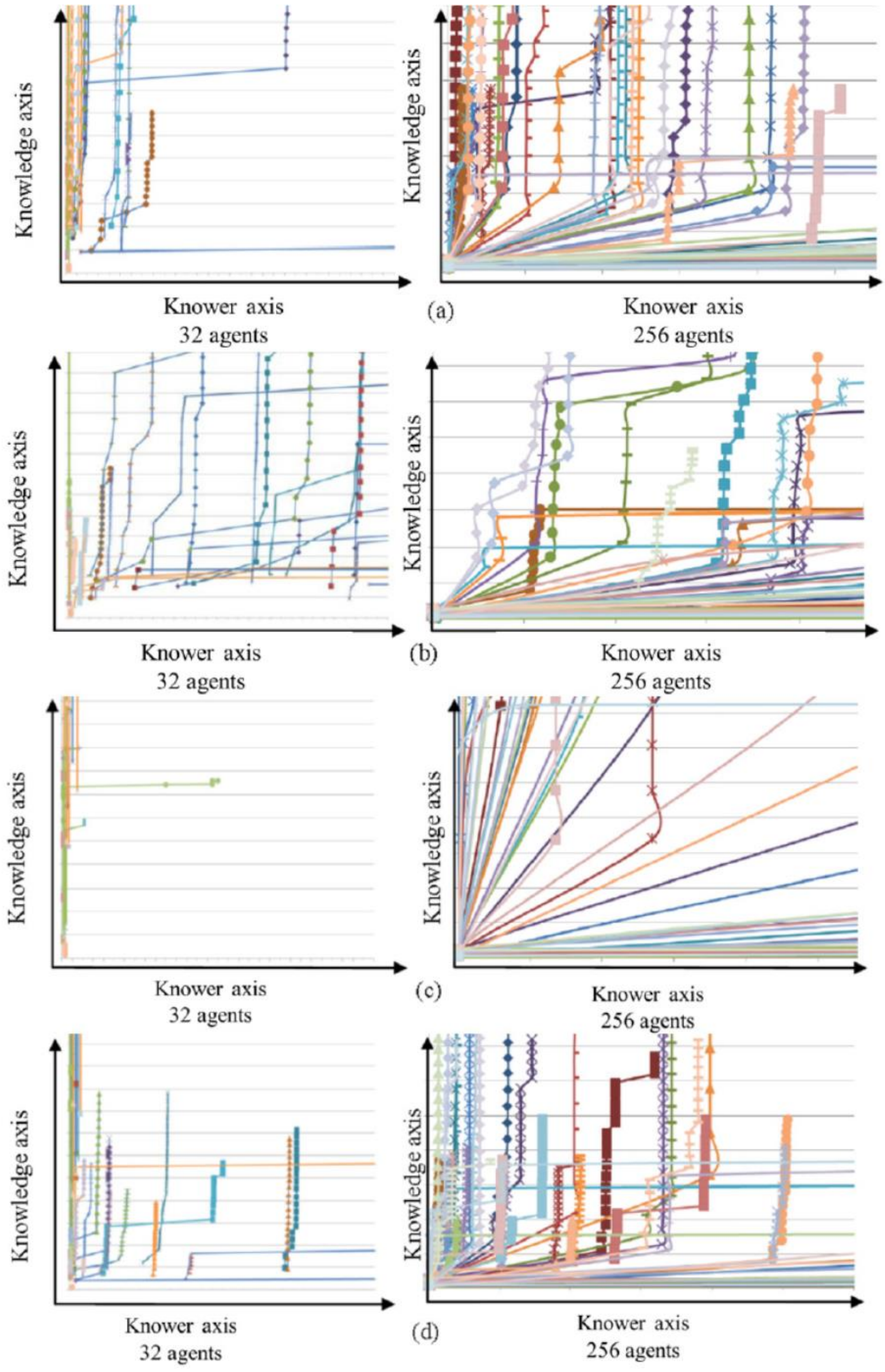

Figure 3. Comparing effects of scale (a) architecture society (b) fashion society (c) engineering society (d) multi-disciplinary society (average of 30 simulations)

Thus, while it appears that scale may not have direct effect on the legitimation practice in a given design society, it is likely that as the population size scales-up, a critical mass of outliers is created who might have an influence on the overall legitimation practice. Therefore, it might be useful to investigate whether there is a threshold tipping point beyond which the critical mass of outliers has an effect on the overall legitimation practice.

4.2 Effects of value change

Figure 4(a) shows a snapshot from simulations where values associated with legitimation codes remain constant. Figure 4(b) shows a snapshot from simulations where values associated with legitimation codes converge with time for agents from different disciplinary backgrounds. As expected, the gap between the design agents from different disciplinary backgrounds begins to narrow. However, where the values do not converge, the gap between the design agents across different disciplines continues to widen. Accordingly, a more uniform growth is observed in multi-disciplinary societies where values of the design agents from different backgrounds change with time. Figure 5 shows the average movement of each agent across 30 simulation runs.

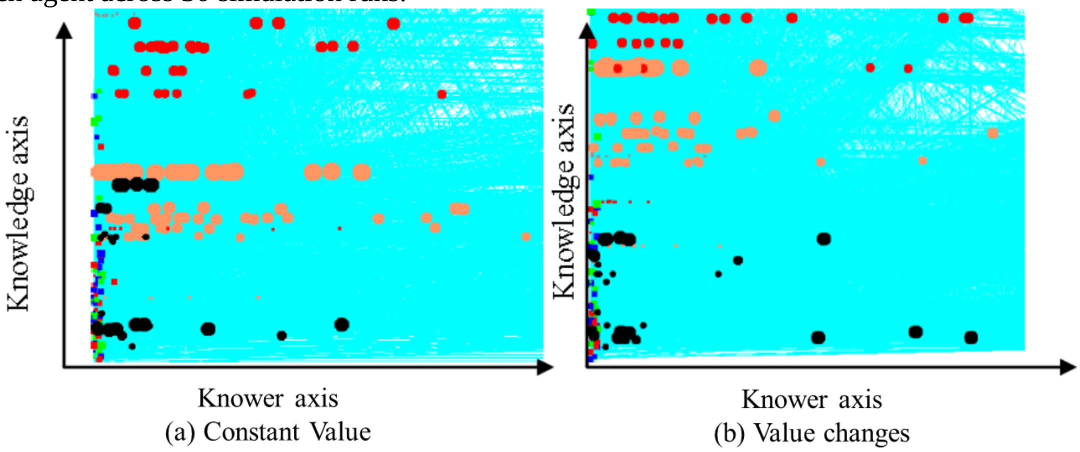

Figure 4. Comparing effects of value in a multi-disciplinary society (a) value remains constant (b) value changes at a constant rate (simulation snapshot)

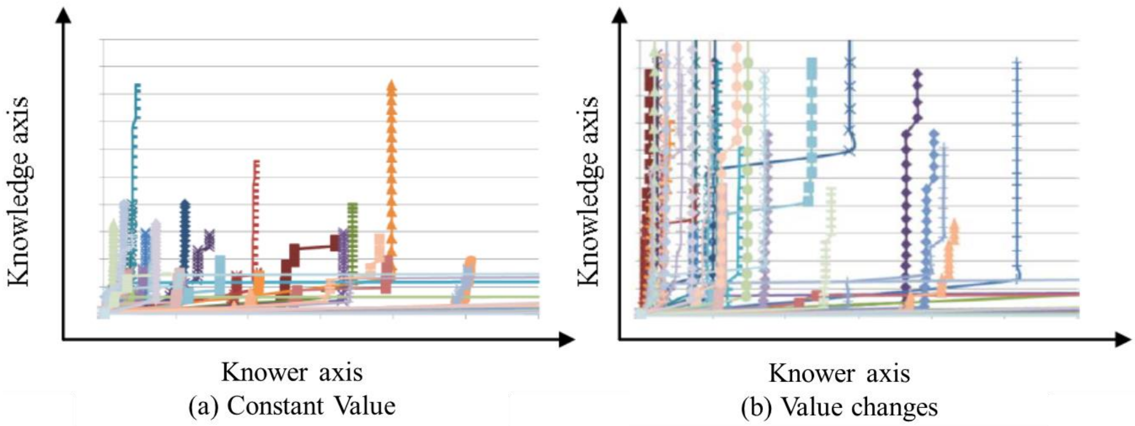

Figure 5. Comparing effects of value in a multi-disciplinary society (a) value remains constant (b) value changes at a constant rate (averaged over 30 simulations)

The longitudinal effects of change in value are observed more explicitly in Figure 6, which plots the pattern of design practice along the knower axis. As observed in the second case, Figure 6(b), when the values change the direction of growth change such that their paths cross each other, unlike the first case, Figure 6(a), where the gap between the agents continues to increase. This cross-over of paths due to change of values can have significant effects on exchange of ideas and co-creation of knowledge. However, this conceptual interpretation is beyond the scope of these simulations. Even though change of value was given in these simulations, these patterns emphasize the positive structural effect and the role of converging values in a multi-disciplinary society.

While this simplified assumption of constant rate of change in values and constant frequency of change is too simple to fully model the development of design practice, it provides a starting point to conduct preliminary what-if studies. Again, following the bottom-up approach, once the patterns from these simulations have been observed, additional assumptions can be superposed. For example, this preliminary investigation should lead to questions such as: How does the rate of change of value influence the emergent design practice? What if there is a limit to the extent of change in value for an agent?

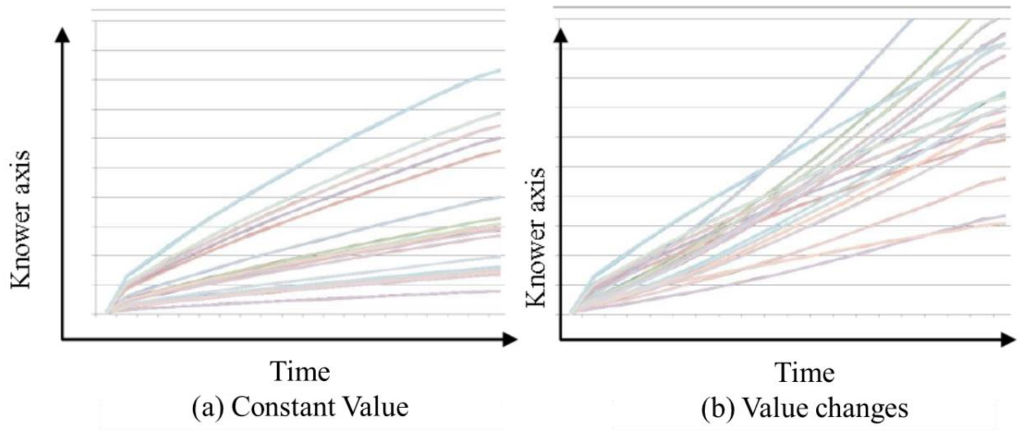

Figure 6. Plotting temporal effects of value along the knower axis (a) value remains constant (b) value changes at a constant rate (averaged over 30 simulations)

4.3 Implications for design practice

The simulation results presented in this paper compare the effects of scale and value in design legitimation practice. As expected, change in value of design agents in a multi-disciplinary society creates a more cohesive society. Hence, multi-disciplinary design environments that support mechanisms for learning and acquiring new values are desirable. However, at the same time, it is observed that even if the agents are able to constantly change their values, it takes time for the effects of change in value to have an observable effect. That is, despite the converging value, which was given in these simulations, the segregation between disciplines continues in the initial period, before the convergence and crossing of paths is observed. How long does it take for observable effect to emerge and for re-orientation of the legitimation values of individuals to occur, depends on the rate of change of value, and hence, on the mechanisms that lead to the change of value in the first place. These very preliminary results indicate that the design society has to invest in the mechanisms that lead to the exchange of values, with the expectation, that once a desirable level of value exchange is achieved, it will propel further interactions and exchange through the convergence of legitimation practices.

While the effects of value were evident and consistent with the expectations, the effects of scale need further analysis. The implications of scale on design practice have conflicting views to consider. In practice, typically multi-disciplinary teams are small, and it is believed that such small teams will have greater interaction opportunities that would support value exchange and acquisition. While small population size may be critical in fostering the change of values in the first place, these simulation results indicate that on scaling-up in a multi-disciplinary society, even the outliers can form a critical mass to influence other actors. What strategy should be chosen in such a scenario? These contradictions indicate the need to consider different phases of influence corresponding to the interactions needed before and after the change of values. Smaller, cohesive groups may trigger change of values but larger groups may be desirable to exploit the benefits of the changing value. These preliminary findings indicate future research directions and paths of enquiry, that can help understand the relationships between value and scale that have not been studied together in this paper.

5 CONCLUSION

This paper presents simulation results on the effects of scale and value in legitimation practice within design societies. The change in value is implemented such that it simulates a scenario where the values of design agents towards legitimation practices tend to converge as they spend more time in a multi-disciplinary environment. Preliminary simulation results indicate that scaling-up may lead to greater uniformity in the emergent design practice, and a possibility that the number of outliers reaches a critical mass large enough to influence the overall pattern of legitimation practice within the society. Simulations with change of values indicate that it takes time for the effects of value change to be observable, but once the effects take place, they promote convergence and cross-over of growth patterns.

The limitations and simplified assumptions of the computational model limit generality in interpreting the results. The model currently assumes that the design legitimation values of agents change if agents are in a multi-disciplinary environment. Rather than making this overarching assumption, in future simulations it is planned to model the mechanisms through which such learning and acquisition of new values takes place. In such a simulation environment the change of values will be dependent on each agent's social interactions with other agents such that the rate of change of values for each agent could be different.

The approach of using computational simulations to study social phenomena (computational social science) provides a foundation to explore design behaviors and scales that are either too difficult or may not be possible to study experimentally with individuals and teams.

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