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Developing a multi-agent model to study the social formation of design practice

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Abstract: This paper describes a computer simulation based approach to investigating the longitudinal patterns in social emergence of design practice. Legitimation code theory is adopted as the underlying framework to develop the model. The design practices in this model emerge and evolve under the influence of both social structure and knowledge structure. This model simulates a society of designers with different design backgrounds, affiliated to different teams and organizations. Design agents interact with each other and the concepts associated with the different disciplines. Design agents within each discipline are modelled to be attracted towards concepts, i.e., knowledge mode, as well as towards the other design agents, i.e., knower mode, which collectively influence design practice. The force of attraction towards the knower or concepts varies across disciplines. The emergent social pattern is plotted in a two dimensional space defined by the social and knowledge axes. The simulation environment allows studying the longitudinal emergence of design trends resulting from varied initial conditions and what-if scenarios that are difficult to study in the real world. Exemplary results are presented.

Keyword: Common ground, legitimation theory, identity, influence, emergence.

1 Introduction

Design involves multidisciplinary faculties, including technical and social knowhow. The widespread use of the term ‘Design’ across different disciplines often leads to debates over ‘art’ and ‘science’ distinctions. While such debates may never have clear outcomes, a common understanding and acceptance of design typically emerges over time through social processes within a given discipline. Over an extended period of time, society develops mechanisms and processes to recognize and legitimise design practices within its community or discipline. Since this recognition and legitimation of design practice is a longitudinal process and as a consequence is difficult to study empirically, the understanding of social emergence of design practice is currently limited. Therefore, this research adopts a computer simulation based approach to investigate the longitudinal patterns in social emergence of design practice. Agent based studies have evolved as a powerful research method to conduct what-if studies for scenarios that are difficult to study in the real-world, and allow longitudinal studies with greater control of the parameters [1, 2].

This research reported in this paper adopts legitimation code theory [3] as the underlying framework to develop the model. LCT is based on five principal dimensions that include autonomy, density, temporality, specialization and semantics, of which the last two are most developed. According to the specialization principle of legitimation code theory, design practice and recognition within a social group are driven through both the knowledge and knower modes [4], i.e., the design practices emerge and evolve under the influence of the social structure as well as the knowledge structure. This model 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 legitimation code theory, 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 social pattern 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 allows studying the longitudinal emergence of design trends resulting from varied initial conditions such as the number of design agents in the society and level of interdisciplinary interactions. The objective of this research is to investigate questions such as:

How does the design practice emerge over an extended period in a society? How do design trends vary across disciplinary and multidisciplinary communities?

This paper presents the theoretical basis for developing the computational model and provides preliminary simulation results to demonstrate the usefulness of an agent based approach in understanding complex social behaviours that emerge at global level from simpler local interactions.

2 Social emergence of design practice

Design concepts and capabilities such as creativity have been argued to be social constructs [2]. Similarly, Bourdieu [5], Nonaka [6] and others have discussed the social creation and emergence of knowledge in a broader context. In this respect, legitimation code theory provides a useful conceptual framework to study the emergence and acceptance of knowledge in a social-cultural context.

Legitimation code theory is built on the premise that in any society the prevalent practices, beliefs and knowledge are driven towards something and or someone, such that there is an epistemic relation to an object (ER) and a social relation to a subject (SR) [7, 8]. The epistemic relation pulls the agents in the society towards knowledge, i.e., knowledge mode while the social relation pulls the agents towards the socially dominant agents, i.e., knower mode, Figure 1.

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 knowledge code emphasises concepts, while the knower code emphasises design agents. The elite code emphasises both the conceptual and social dispositions, while for the relativist code neither conceptual nor social dispositions are required.

These legitimation codes conceptualise the dominant basis of success in any particular social context. 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, [9] have compared the legitimation codes across different design disciplines including architecture, fashion design and engineering design, Table 1.

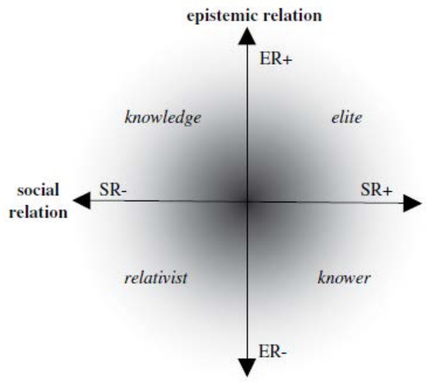


Figure 1 Modes of legitimation of design practice (after [7])

Table 1 Legitimation codes across different design disciplines (based on [9])

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

According to [9], while architecture tends to show greater balance between the knowledge and knower modes, in fashion design the knower mode tends to dominate, while in engineering the knowledge mode tends to dominate.

3 Why computational simulations as the research method?

Though Carvalho et al [9] have shown that the relative contributions of the knowledge mode and the knower mode in legitimation and recognition of design practices vary across the disciplines studied, the understanding still remains subjective and abstract. For example, while [9] have established that legitimation of design practice in fashion is more knower driven than knowledge driven, it is currently difficult to establish how these relative values compare, i.e., whether the relative contributions are linearly related or exponentially. The difficulty in establishing such relationships is further exacerbated because of the socially emergent nature of legitimation mechanisms, which are gradual and longitudinal processes, requiring observations and data collection over an extended period of time. In such a complex longitudinal scenario if the research were to rely entirely on real world observations and case studies, the progress would remain slow and partial because of the time, cost and resources needed to obtain empirical data. Computational simulation test-beds using agent-based models provide a complementary research method and infrastructure that can reduce the time, cost and resource constraints towards generating and testing the promising theories. Building such a research infrastructure, i.e., computational model may be a challenging task but once the initial infrastructure is created, it allows rapid extensions and explorations across different parameters and scenarios of interest.

Hence, this research adopts computational simulations to study the emergent social patterns across different design disciplines for what-if scenarios, based on informed assumptions derived from subjective understanding of the role of knowledge modes and knower modes across the different design disciplines. Since the underlying assumptions in the computational model and parameter values at time t=0 are known in the simulations, the observed causal effects can be stochastically established with high confidence levels. This research is planned bottom-up such that the initial simulations are conducted with as few assumptions and as few parameters as needed to generate and test meaningful hypotheses about the emergent social patterns across different disciplines. The key research questions are listed in Table 2, and the corresponding minimal requirements to enable investigating these questions.

Table 2 Research questions, requirements and parameters

Research questions	Simulation requirements	
	Assumptions	Parameters
How does the emergent social pattern of design recognition vary across disciplines? How does the social pattern in multi-disciplinary design society compare to uni-disciplinary social environment?	Forces between parameters Initial state (starting positions of design agents and concepts)	Design agents with different disciplinary backgrounds A set of concepts associated with different disciplines Demography, i.e., population mix, population size

In order to compare the emergent social patterns resulting from differential knower and knowledge modes across different disciplines, we need to make informed assumptions about the relative knower and knowledge force of attractions across the different disciplines. Once force values are assumed they are kept constant across the different simulations, while the demography of design society is varied such that resulting patterns can be compared. Typically, designers work within teams and organizations, and affiliation to such teams creates a nested structure. These teams may have varied inclinations towards knowledge mode or knower mode and in the process affect the emergent patterns. Further, in order to understand the effects of scale, simulations are conducted with different population sizes, including more concepts and teams.

Once the findings of these simulations are known, additional parameters and assumptions can added to create complex scenarios. The research outcomes are intended to inform future empirical studies by identifying promising and potentially interesting hypotheses.

4 Computational framework

The computational model is implemented in MASON [10], a java based multi-agent system. 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.

Representing each entity as agents gives them agency, which allows design agents, concepts and teams to move within the two dimensional space as per 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 Legitimation Code Theory, 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 social pattern including the knowledge and social dimensions of the design agents, concepts and teams are recorded and can be graphically observed. Following are the key assumptions and considerations in the model:

4.1 Forces of attraction and disciplinary effects

Based on [9], three disciplinary backgrounds are considered to include architecture, fashion design and engineering. Design agents, teams and concepts are assumed to be associated to belong to one of these three disciplines such that the disciplinary background of a design agent determines how much it is influenced by knower mode and knowledge modes. The assumed forces are presented in Table 3.

Following the findings in [9], 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. On the other hand, forces corresponding to knowledge mode are highest for engineering design agents and least for fashion design agents. Accordingly, constant **E** in agent-concept (knowledge) attraction is highest for engineering design agents and least for fashion design agents. Similarly, other forces and constants are assumed using similar arguments.

Table 3 Assumed values for knowledge and knower attraction forces

	Entities	Force	Discipline conditions
1	Agent (A^1)- Agent (A^2)	Constant **K** × (InfluenceRadius A^1 × InfluenceRadius A^2) / (Square of social distance between A^1 and A^2)	For design agents IF discipline is architecture **K**= 100 IF discipline is fashion design **K**= 1000 IF discipline is engineering **K**= 1
2	Agent (A^1)- Concept (C^1)	Constant **E** × (InfluenceRadius A^1 × InfluenceRadius C^1) / (Square of distance between A^1 and C^1)	For design agents IF discipline is architecture **E** = 100 IF discipline is fashion design **E** = 1 IF discipline is engineering **E** = 1000
3	Concept (C^1)-Concept (C^2)	Constant **D** × (InfluenceRadius C^1 × InfluenceRadius C^2) / (Square of distance between C^1 and C^2)	IF C^1 and C^2 belong to same discipline **D**= 100 ELSE **D**= 1
4	Agent (A^1)- Team (T^1)	Constant **K** (Similar to 1)	Same as 1
5	Team (T^1)- Concept (C^1)	Constant **E** (Similar to 2)	Same as 2
6	Team (T^1)-Team (T^2)	Constant **K** (Similar to 1)	Same as 1

4.2 Starting conditions

At the start 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 dimension and knowledge dimension. The initial scenario across all the entities, i.e., where the different agents, concepts and teams start from may influence the emergent social pattern. However, since the focus of the study reported in this paper is the effects of disciplinary backgrounds and not the initial conditions, in all the simulations the starting conditions remain the same.

4.3 Analyzing the outcomes

Given that there are limited prior studies to benchmark the findings, this research poses challenges in analyzing the outcomes. Hence, visual representations of emergent patterns across different scenarios provide useful preliminary comparison across different cases. Developing the model requires iterations to calibrate the assumptions.

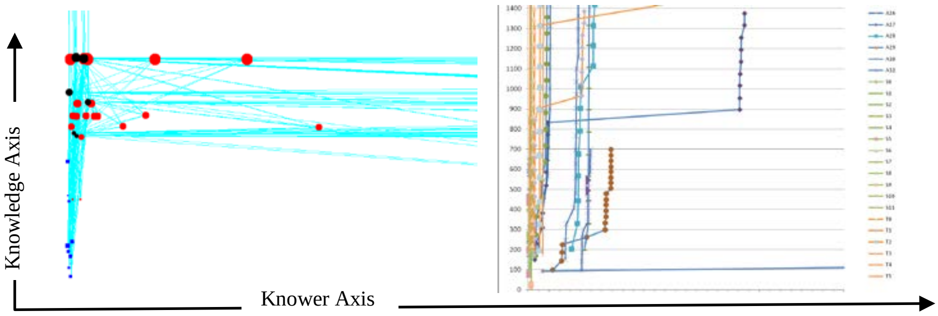
5 Simulation results and discussion

The first set of simulations was conducted to compare the effects of disciplinary backgrounds. A summary of the conducted simulations is presented in Table 4.

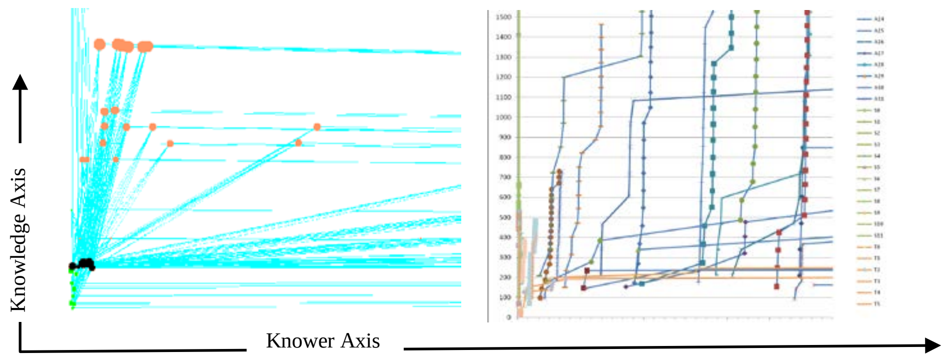
Table 4 Simulations conducted to compare patters across different disciplines with population of 32, 6 teams and 12 concepts

Case	Distribution/ Demography
1	All design agents, teams and concepts associated with architecture
2	All design agents, teams and concepts associated with fashion design
3	All design agents, teams and concepts associated with engineering design
4	Mixed population with equal distribution of architecture, fashion design and engineering design agents, teams and concepts

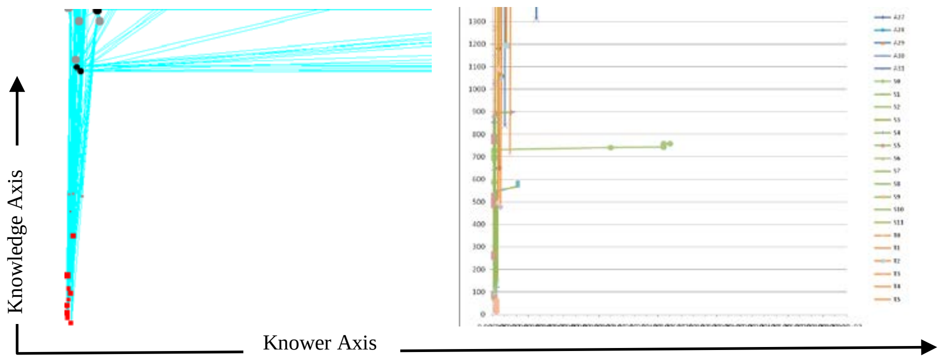
For each simulation case, 30 simulation runs were conducted. A snapshot of the typically emergent social pattern for the different cases is presented on the left hand side of Figure 2, while the plot on the right hand side of Figure 2 shows a pattern created by averaging the results from 30 simulation runs for each case.



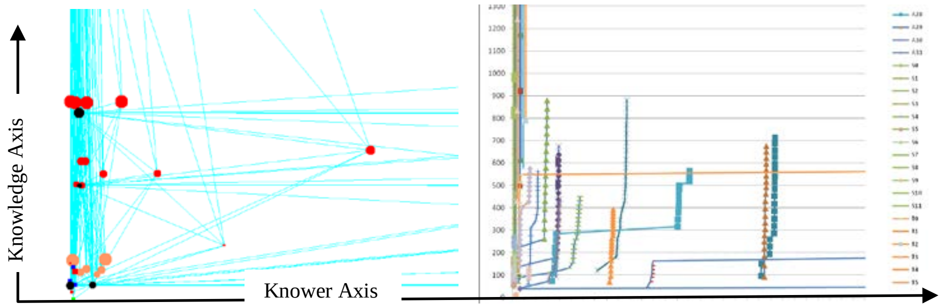
Case 1: Only architecture design agents



Case 2: Only fashion design agents



Case 3: Only engineering design agents



Case 4: Multidisciplinary society with architecture, fashion and engineering design agents

Figure 2 Emergent social patterns across different simulation cases for cases in Table 4

As seen in the first three cases of Figure 2, the computational model simulates distinct patters of social emergence of design practice across different disciplines. A society with only architectural design agents (red), teams (black) and concepts (blue) grows towards the knowledge dimension but there is increasing pull for design agents towards the knower (social) dimension once higher levels of knowledge dimension is achieved. The knowledge leaders in the architectural design society also grow along the knower dimension, becoming attractors for other agents to follow them through the knower mode.

Though this pattern appears to be the result of assuming balanced knowledge and knower forces for architectural design agents, unlike the observed pattern, it was expected that the architectural design agents, teams and concepts would move at approximately diagonally across the two axes.

A society comprising of only fashion design agents, teams and concepts also shows a trend towards leaders and followers. However, unlike the architectural design society, in fashion design society agents at lower levels of knowledge tend to have greater divergence and attraction towards the knower mode. As a result, the knowledge divide between fashion design leaders and followers tends to increase over time because some of the followers at lower knowledge levels develop greater attraction for the social dimension. While fashion design agents were assumed in the model to have greater attraction towards knower mode, we had not expected the emergence of differential knower level pulls corresponding to agents' relative knowledge levels. Furthermore, simulation results indicate that in the fashion design society the rate of growth of design agents (brown) may outpace teams (black).

A society of engineering design agents primarily follows the knowledge dimension, and the design agents (grey) and teams (black) grow at comparable rate. The society of engineering design agents shows patterns that were expected and are consistent with the assumptions.

Given that the three different design societies show distinct emergent patterns that broadly conform to the underlying legitimation code theory of design practice for the known disciplines, the findings from case 4 should provide insights into emergent social patterns of design practice in a multidisciplinary design society, which has not been empirically studied so far. It was expected that the multidisciplinary design society will show a greater balance between knowledge and knower driven design practice, with design agents distributed along both dimensions. Though the emergent patterns in multidisciplinary design society does create a balance (compare right hand side of case 4 with the right hand side patterns of cases 1, 2 and 3), the design agents from different disciplinary backgrounds tend to cluster along different knowledge levels. Engineering design agents grow faster towards the knowledge dimension (being knowledge driven), during the same period the fashion design agents remain at lower knowledge levels as compared to the architecture design agents. Similarly, the growth of architecture and fashion design agents along the social dimension is greater than engineering design agents during the same duration. Thus, the simulation results in case 4 suggest that unless there is greater overlap in design concepts and practices across the different design disciplines, segregation of design agents across disciplinary groups is likely to emerge creating knowledge and social gaps that will widen over time.

In order to test whether the social pattern observed across the different cases depends on the number of design agents, teams and concepts, all the simulations listed in Table 4 were repeated with double the number of entities, i.e., 64 design agents, 12 teams and 24 concepts. The emergent social patterns in simulations with 64 design agents are similar to the observed patterns in simulations with 32 design agents. Findings suggest that the differential social pattern of design practice across different disciplines is potentially scalable, which can be tested further by varying the population sizes by higher order. Similarly, by changing the initial values of the parameters we can investigate how this pattern varies with the position of the influential design agents?

6 Conclusion

A computational model of legitimation of design practice is developed as a simulation test-bed, based on the specialization principles of legitimation code theory. The computational model is developed as a research infrastructure that supports generating and testing what-if scenarios with various design societies, starting with the comparison of the legitimation practices in uni-disciplinary design societies against multi-disciplinary design society. The emergent social patterns across the different cases involving design agents associated with architecture, fashion design and engineering are broadly consistent with the expected patterns, as known from the literature. The consistency of the simulation results with empirical data provides internal validity of the simulation platform, suggesting that the assumptions within the model can be relied upon for further studies. Findings from the simulation results suggest that irrespective of the social composition and disciplinary backgrounds, clusters of design agents are created at different knowledge levels. This clustering of agents in a multidisciplinary society is marked by disciplinary segregation. Though the assumptions and the simulations were based on relative epistemic and social code values for the studied disciplines, i.e, architecture, fashion and engineering design, the studies can be extended to study and compare the legitimation practices across other design disciplines and sub-disciplines.

Nonetheless, the primary challenge at this stage is to externally validate the model and simulation results because there are no empirical studies to benchmark the comparative patterns of legitimation practice across uni-disciplinary and multi-disciplinary design societies. Thus, the current scope of the computational model is limited to simulate what-if scenarios and generate potentially interesting hypotheses to be investigated empirically. The primary contribution of this paper is to describe the development, and demonstrate the usefulness, of an agent based simulation model in studying the legitimation of design practice as a socially emergent phenomenon.

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