
Multi-Tiered Knowledge Management in a Turbulent Environment

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Abstract

James Gregory M. proposed corporate learning as a balance between the exploration of novel alternatives and the exploitation of inherent competencies in a corporation. This study extends James's model to consider exploration and exploitation in a hierarchical corporation. Primarily, the impact of additional tiers in a hierarchical corporation is analyzed and matched to James's original constructs of exploration, exploitation, attrition, and environmental turbulence. Secondly, the study evaluates additional effects of a knowledge management system that collects and shares knowledge from expert individuals in a corporation.

This study identifies that in the absence of staff turnover, a knowledge strategy of high exploitation and low exploration for a multi-tiered hierarchical corporation minimizes the veracity of mean individual knowledge levels when compared to alternative strategies. The magnitude of this reduction in veracity ameliorates as the number of tiers in a hierarchical corporation increase; flat corporations will witness less of a reduction compared to multi-tiered corporations. A weighted least-squares regression executed on a second set of data corroborates this central observation. Cumulative findings bear a strategic relevance for both corporate theory and the application of knowledge management systems.

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1. The Original Model

James's original model of corporate learning is succinct and abstract, comprising an external reality, individual knowledge about external reality, and a corporate code representing an approximation of external reality (James, 1991).

To conserve space, this paper assumes that the reader is exposed to this original model and devotes only a fixed set of paragraphs to its construction before presenting extensions. James's original model circumscribes external reality as a vector of $m = 30$ integers (either -1 or +1), each representing an independent dimension of reality. Individual knowledge comprises of a similar vector of 30 integers, with the allowance of a value of '0' for an independent dimension, representing no belief. Corporate code is a similar vector of 30 integers. James considers external reality as a constant and defines a corporation to consist of $n = 50$ individuals (i.e., 50 vectors of individual knowledge about external reality, each with 30 individual beliefs about reality); see figure 1 for details. James finds that the qualitative results of the model are insensitive to values of m and n . This premise similarly holds for the findings of this study.

James defines an "individual knowledge" level as the proportion of external reality accurately represented by an individual knowledge vector. Separately, corporate knowledge level is defined as the proportion of reality correctly represented by the corporate code. There is only one corporate code, hence only one corporate knowledge level. Both individual and corporate knowledge levels potentially change via corporate learning, represented as two distinct interactions among the 50 individuals (aforesaid) and an overarching corporate code. For each iteration of the model, every individual has the potential to change any belief to conform to the corresponding knowledge of the corporate code with a probability (p_1) representing the probability of a corporation to exploit existing knowledge; i.e., exploitation.

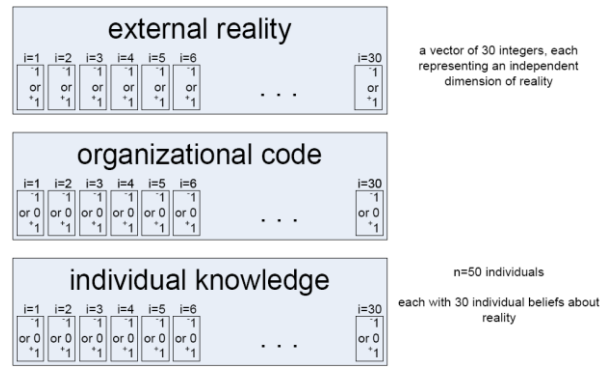


Figure 1 – Three Constructs of James’s original Model

This approximation of exploitative behavior serves to model individual learning from the corporate code. Equally, for each iteration, the corporate code has the potential to alter any belief to match the dominant knowledge of expert individuals with a probability (p_2) representing the probability of a corporation to explore new knowledge, i.e., exploration. This approximation of explorative behavior serves to model corporate learning from experts; see figure 2 for details. Individuals who approximate reality better than the corporate code are categorized as experts in any corporation.

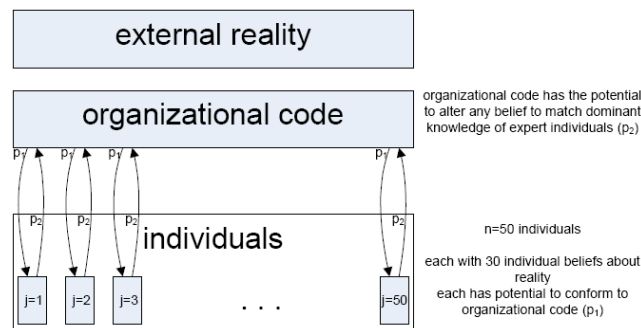


Figure 2 – Core Interactions of James’s Core Model

James expands his formative model to consider a more open system, comprising attrition and environmental turbulence. For each iteration, every individual has the potential to leave a corporation and be replaced by a new individual with a naïve set of beliefs, with a probability (p_3) reflecting this attrition. New individuals are replaced with randomly distributed beliefs. Equally, for all iterations, any dimension of external reality has the potential to fail, with a probability (p_4) reflecting external environmental turbulence. James’s model intentionally precludes both individuals and a corporation from directly observing external reality. Instead, enhancement in individual and corporate knowledge levels comes either from the corporate code adapting to the knowledge of expert individuals conforming to the knowledge of the corporate code. The corporate code can only distinguish expert individuals by their optimal individual knowledge levels, and cannot pinpoint which specific beliefs as true or false for a given dimension of reality.

2. Extending the Model

First, an extension made to James’s model considers the effect of additional tiers in hierarchical corporations. The original model considers all individuals as peers to each other, and hence represents a flat corporate structure. An extension positions a single supervisor at the top tier in the hierarchical corporation with a set of direct reports (b). This reporting authority (supervisor) corresponds to the corporate code in James’s reality. Multiple corporate codes are permitted to exist as different tiers in the proposed hierarchical corporation with each direct report, in turn, a supervisor for another set of direct reports recursively until the bottom tier is reached. Individuals at the bottom tier have no straight reportees’. The hierarchical corporation consists of a maximum of five tiers (d, where d is a mid-integer of 2 and 5); see figure 3 for details. In this first extension, each individual backs-up the potential to conform to the beliefs of their supervisor (p_1) and each supervisor retains the potential to alter a belief to match the dominant

knowledge of expert direct reports (p_2) attrition (p_3) and environmental turbulence (p_4) are retained for this extension. The knowledge equilibrium of a multi-tier hierarchical corporation is now best defined as the convergence of individual knowledge levels to a stable equilibrium.

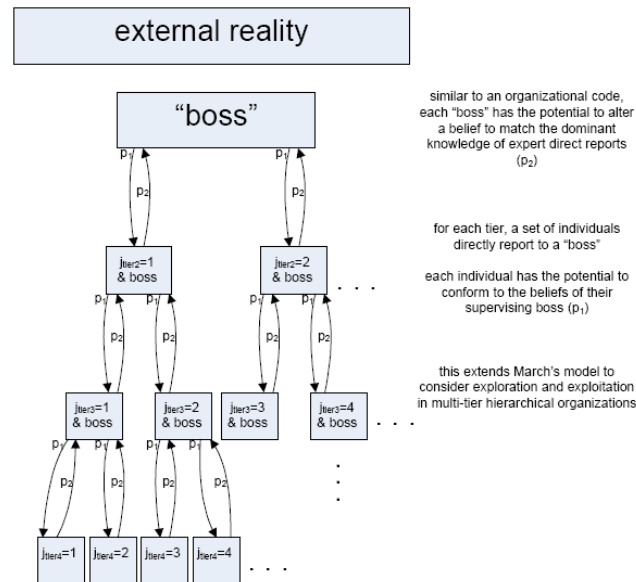


Figure 3 – An extension to James's model to consider a multi-tier hierarchical corporation

Such an extension to the model is simple, intuitive, and with precedent. Learning in multi-tier hierarchical corporations has been considered in other models (Carley, 1992; Carley & Lin, 1997; Rivkin & Siggelkow, 2003), but no research to date has expressly advanced James's seminal model for such purposes, and only a few have considered the effect of environmental turbulence. Kane and Prietula did make an extension to James's model, but for a two-tiered hierarchy only and this research did not consider a multi-tier hierarchical corporation, nor did their model include the effects of attrition and environmental turbulence (Kane & Prietula, 2003; Weingart & Prietula, 2005). The proposed extension has the advantage of allowing for initial validation and subsequent extension of all constructs contained in James's model (Burton & Obel, 1995).

In terms of sustained research value, hierarchies remain the basic structure of most large, ongoing human corporations (Jaques, 1990; Leavitt, 2003). Similarly, collecting and sharing expert knowledge has been shown to produce a long-term competitive advantage for a corporation (Alavi & Leidner, 2001; Tsai, 2001; Lee & Choi, 2003). Recent research has conceptualized varying corporate structures as different networks of social individuals whose position in the network can influence knowledge transfer and corporate learning (Lee, Lee, & Lee, 2003; Hansen, Mors, Løvås, 2005; Inkpen & Tsang, 2005).

3. Experiment I: Verification

First, for the purposes of replication and validation of James's model, a two-tier hierarchical corporation is generated. The simulation runs for 200 iterations for three different values of individual learning ($p_1 = 0.1; 0.5; 0.9$) and for three different values of corporate learning ($p_2 = 0.1; 0.5; 0.9$), similar to the original model. The absence and presence of attrition ($p_3 = 0.00; 0.02$) is considered alongside the absence and presence of environmental turbulence ($p_4 = 0.00; 0.02$). Each simulation is repeated 40 times, accounting for the stochastic properties of the original model. The qualitative results of this initial scenario confirm James's original observations: there is a central dichotomy between exploitative and explorative corporate learning strategies.

An exploitative strategy (p_1) represents refinement of existing competencies in a corporation, with predictable short-term returns. Conversely, an explorative strategy (p_2) represents experimentation with new alternatives in a corporation, with uncertain long-term returns. Though both strategies occur independently, finding an appropriate balance between the two is a primary factor in determining the veracity of average individual knowledge levels with

external reality. A corporation with a misaligned exploitation and exploration knowledge strategy will quickly lose its relevancy. Further, under conditions of environmental turbulence ($p_4 = 0.02$) with no attrition ($p_3 = 0.00$), the mutual learning between corporate and individual knowledge levels produces a long-term degenerative effect. Corporate and average individual knowledge levels converge to match each other, reducing the possibility for either to change to approximate external reality with greater veracity. Once knowledge equilibrium is achieved, the probability for either corporate or average individual knowledge levels to change becomes zero since all individuals now share the same exact beliefs. Such knowledge degeneracy can be avoided if there is a modest level of attrition. Introducing a new individual exposes the corporation to a set of naïve, non-conforming ideas. This provides potential opportunities for individuals in the corporation to improve their knowledge levels.

4. Experiment II: Extension

Second, for the purposes of extending the original model, a multi-tiered hierarchy of multiple corporate codes (i.e., supervisors) is considered. The number of tiers (d) is an independent variable and is evaluated in tandem with the number of individuals reporting to a single supervisor (b). Four different hierarchical corporations are considered ($d = 2$ and $b = 132$; $d = 3$ and $b = 11$; $d = 4$ and $b = 5$; $d = 5$ and $b = 3$), each representing a corporation with approximately 136 individuals. For example, a three-tiered hierarchical corporation with each supervisor having 11 direct reports represents $133 =$ individuals in a corporation. The size of hierarchical corporation does not vary over time. Similar to James's model, initial belief values for individuals without any direct reports are randomly distributed (i.e., either -1 ; 0 ; $+1$), whereas the belief values for supervisors (i.e., distinct corporate codes with direct reports) are all initially neutral (i.e., set to 0). Supervisors have the possibility of exploratory learning (p_2) from an expert direct report with the highest number of beliefs matching that of external reality. In the event of tied experts, the supervisor selects one of the top individuals randomly.

On average, a knowledge strategy of high exploitation ($p_1 = 0.5$) and low exploration ($p_2 = 0.1$) in the absence of no attrition ($p_3 = 0.00$) reduces the veracity of average individual knowledge levels with external reality for a multi-tiered hierarchical corporation, as compared to alternative strategies. Such a finding is significant only when a knowledge strategy of high exploitation and low exploration is considered for hierarchical corporations with multiple tiers. James's original model did not observe such a finding since it considered only a flat corporation. Specifically, for a flat corporation with only one corporate code ($d = 2$), this study finds no significant difference between such a knowledge strategy of high exploitation and low exploration, compared to a strategy of either high exploitation ($p_1 = 0.5$) and high exploration ($p_2 = 0.5$) or a strategy of low exploitation ($p_1 = 0.1$) and high exploration ($p_2 = 0.5$). Such results concur with James's findings. However, for a multi-tier hierarchical corporation ($d = 3, 4, \text{ or } 5$), in the absence of attrition, this study does find a significant difference between such a knowledge strategy of high exploitation and low exploration, when compared to the aforementioned alternatives. High exploitation and low exploration for a multi-tier hierarchical corporation reduces the veracity of average individual knowledge levels. Different studies are evaluated by employing post-hoc t-tests at the 0.05 significance level to compare their average individual knowledge levels after 200 iterations.

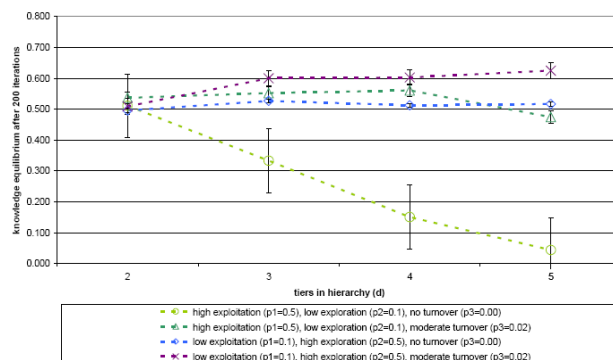


Figure 4 – Effect of Tiers in Hierarchy on Corporate Knowledge: Equilibrium in response to Constant Level of Environmental Turbulence

Curiously, keeping all other variables constant, increasing the number of tiers in a hierarchical corporation increases the reduction in veracity; see figure 4 for details. In the absence of attrition, a five-tiered hierarchical corporation (d

= 5) will see a greater reduction in veracity from a knowledge strategy of high exploitation and low exploration, compared to a three-tiered hierarchical corporation (d = 3) with approximately the same number of individuals employing the same strategy.

5. Experiment III: Knowledge Management

Third, for the purposes of evaluating knowledge management strategies, two variables are manipulated: the effect of increasing or decreasing the probability of learning from a knowledge management system (pKM), and the effect of collecting knowledge from wider or narrower ratios of expert individuals (rEX). Three probabilities are considered for the likelihood of individuals learning from a knowledge management system (pKM = 0.01; 0.05; 0.09). These values represent low, moderate, and high values of reliance on a knowledge management system and are similar to values chosen by James to test differences between exploitation and exploration in his original model. Three different ratios of expert knowledge collected also are evaluated (rEX = 1 per cent; 10 per cent; 100 per cent).

Variable 'turbulence' (p4=0.02) kept constant, percent "expert" stored consensus (1per cent) kept constant tiers in hierarchy (d=4) kept constant, thus total number of individuals kept constant bars indicate standard error margin

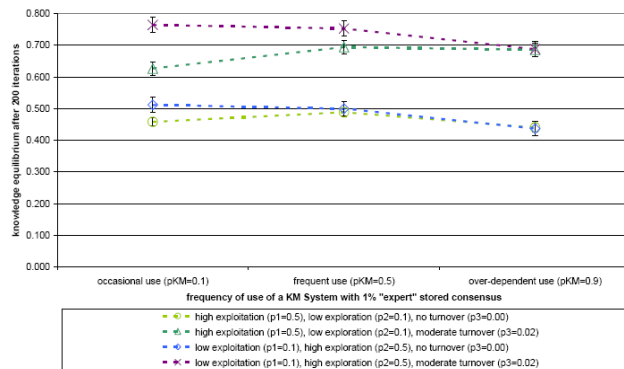


Figure 5 - Effect of Frequency of use of a KM System on Corporate Knowledge Equilibrium in Response to Constant Level of Environmental Turbulence

Coefficients^{a,b}

Model		Unstandardized Coefficients		Standardized Coefficients		t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta				Tolerance	VIF
1	(Constant)	.658	.006			117.572	.000		
	probP1	.170	.014	.300		12.330	.000	.176	5.688
	probP2	.124	.006	.215		21.039	.000	1.000	1.000
	probP3	2.118	.118	.182		17.875	.000	1.000	1.000
	probP4	-5.646	.118	-.488		-47.876	.000	.999	1.001
	interactP1Depth	-.055	.003	-.446		-17.104	.000	.153	6.549
	countBreadth	-.001	.000	-.297		-21.028	.000	.520	1.922

- A. Dependant Variable: Corr-OrgCMatch
- B. Weighted Least Squares Regression – Weighted by count Depth

Figure 6 - Weighted Least-Squares Regression, Depth (d) as Weighting Variable Veracity of Individual Knowledge as Dependent Variable (Y)

On average, increasing the likelihood of individuals learning from a knowledge management system (pKM) increases the veracity of average individual knowledge in the presence of attrition (p3 = 0.02) when combined with a strategy of high exploitation (p1 = 0.5) and low exploration (p2 = 0.1). This is the only instance where an increase in the probability of learning from a knowledge management system improves the veracity of average individual knowledge. On average, increasing pKM reduces the veracity of average individual knowledge, in either the presence or absence of turnover when combined with a strategy of low exploitation (p1 = 0.1) and high exploration (p2 = 0.5). Equally, increasing pKM reduces the veracity of average individual knowledge, in the absence of turnover combined with a strategy of high exploitation and low exploration. Again, the different studies are evaluated by employing post-hoc t-tests at the 0.05 significance level to compare their average individual knowledge

levels after 200 iterations; see figure 5 for details. Both the number of tiers in the hierarchy (d) and different types of knowledge collection from expert individuals (rEX) are held constant. Perhaps predictably, keeping all other variables constant, increasing the ratio of expert knowledge collected (rEX) reduces the veracity of average individual knowledge in a corporation. Attempting to discern true knowledge through a majority consensus results in all knowledge strategies converging to 0.500 (i.e., only half of the knowledge beliefs held are correct).

6. Experiment IV: Regression

To alleviate concerns that the findings of this study could be a result limited to its definition of low, moderate, and high levels of different constructs, a fourth experiment is performed in which 6,000 random samples are drawn from the total population of all possible corporate strategies. Exploitation (p1) and exploration (p2) are random numbers ranging from 0.1 to 0.9. Attrition (p3) and environmental turbulence (p4) also are random numbers ranging 0.000 to 0.040 (to three decimal places). The number of tiers (d) for different hierarchical corporations varies, with the veracity of average individual knowledge (Y) as the dependent variable. The assumption of normality is confirmed by observing a plot of the residuals (expected Y - predicted Y) and a Q-Q plot of standardized residuals. All plots indicate normality. The effects of the different variables are approximately linear. A plot with the number of tiers on the X-axis and the standardized residuals on the Y-axis reveals increasing variance in the error term.

This heteroscedasticity is adjusted by performing a weighted least-squares regression with the number of tiers (d) as the weight, thus adjusting the variance of the residuals to be approximately equal. From the results of Experiment 2, an interaction term is included between exploitation (p1) and the number of tiers in the hierarchical corporation (d). The resulting regression produces an adjusted-R² of 0.376 with all coefficients significant at p-values < 0.005, including the interaction term. The main effects of exploitation (p1) and exploration (p2) on the dependent variable are both positive, with exploitation somewhat greater in magnitude. This is consistent with James's original observations. More importantly, the interaction term (between p1 and d) is negative, with a magnitude roughly one-third the value of the main effect of exploitation. This is consistent with Experiment II, where increasing exploitation has negative consequences for multi-tiered corporations, but not for flat corporations; see figure 6 for details.

7. Conclusions

This study extends James's stylized model to account for hierarchical corporations. In the absence of attrition, a knowledge strategy of high exploitation and low exploration reduces the veracity of average individual knowledge levels for a multitier hierarchical corporation. Keeping all other variables constant, increasing the number of tiers in a hierarchical corporation increases this reduction in veracity. A theoretical implication is that hierarchical corporations that rely on a heavy "top-down" exploitative strategy, combined with little or no attrition, may not be ideal for adjusting to turbulent environments. Traditionally, such corporations have been justified as being best suited for maintaining their own internal reality or corporate code (e.g., or most military or government institutions). This study supports such a premise, but also demonstrates that when confronted with a rapidly changing external reality, heavy "top-down" exploitative hierarchical corporations may not be sufficiently agile to maintain their veracity with a changing, external reality.

Moreover, increasing the likelihood of individuals learning from a knowledge management system has value only in the presence of attrition combined with a strategy of high exploitation and low exploration. In all other instances, increasing the likelihood of individuals learning from a knowledge management system reduces veracity of average individual knowledge. Similarly, increasing the ratio of expert knowledge collected reduces the veracity of average individual knowledge in a corporation. Thus, another implication is that knowledge management efforts should seek to collect and share expert knowledge only from the top 1per cent of individuals, and corporations should employ a knowledge management system for selective cases vs. moderate or frequent use. If overused, a knowledge system can preclude exploratory corporate learning. The only exception to this implication is if the corporation relies on a heavy "top-down" exploitative strategy with little exploratory learning. In this case, one method to counteract the negative consequences of heavy exploitation (sans high levels of exploration) in such a multi-tiered, hierarchical corporation is to encourage attrition coupled with more frequent use of a knowledge management system providing the expert insights of the top 1per cent of individuals.

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