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# Integrated Learning in Engineering Services: A Conceptual Framework

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***Abstract*—**This study explores how the mechanics of learning paves the way to engineering innovation. Theories related to learning in the new product/service innovation are reviewed from an organizational perspective, behavioral perspective, and engineering perspective. From this, an engineering team's external interactions for knowledge brokering and internal composition for skill balance are examined from a learning and innovation viewpoints. As a result, an integrated learning model is developed by reconciling the theoretical perspectives as well as developing propositions that emphasize the centrality of learning, and its drivers, in the engineering product/service development. The paper also provides a review and partial validation of the propositions using the results of a previously published field study in the aerospace industry.

***Keywords*—**Engineering Services, Integrated Learning, New Product Development, Service Innovation

## I. Introduction

As the majority of the developed nations have evolved into service-based economies, the service sector has become the largest economic activity of the world [1]. As such, the importance for progressively improving the services by stimulating innovation is strongly felt in both the domestic and the global markets [2]. In recent times, engineering as a service is steadily gaining popularity, especially in the offshore markets. As the Booze Allen survey report confirms, the offshoring of engineering is on a steady rise, and it is driven by a larger global strategy to access the broader talent pool [3].Engineering services span a wide range of activities in new product development, operations, and support functions. The role of engineering as a service is central in complex product development and in large scale systems integration. As the competition in global markets became intense, firms realized the importance of new product development innovation, organizational learning, and information acquisition and distribution [2]. Invariably, new product development involves accumulation and conversion of knowledge through innovation driven learning. Given this background, it appears that understanding the "mechanics of learning" in engineering services, and the systematic use of the knowledge gained in the new product/service designs, can serve a useful purpose of achieving higher levels of growth and development.

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## II. Purpose

This study examines the mechanics of learning in the domain of engineering services. In the process, this study reconciles the principles and practices of knowledge sharing as applied by systems engineers in product/service development, with insights of learning from the social psychologists in studying the organizational structure and behavior. A New Product Development (NPD) essentially consists of knowledge development and knowledge synthesizing activities performed by an array of individuals and groups [2]. It is generally understood that the enhanced knowledge at the individual, as well as the organizational levels, can contribute positively to the product and service innovations. This is echoed in various research studies that also have established the link between learning and innovation, underscoring the emergence of organizational learning as a key-competitive strategy [2], [4], [5]. The engineering efforts flowing into the product innovation and development process hinge upon unique properties of services that differentiate services from products. Aspects of services such as intangibility, simultaneity, heterogeneity, and perishability [6] place engineering as services in an exclusive realm. This study intends to: (1) explore the mechanics of organizational learning and its effect on engineering services and innovations, and (2) explore the interactions of the organizations and configuration of the teams in order to optimize product development and innovation capabilities.

## III. Literature Review

The literature review for this study consists of the following three areas: (A) Engineering as a service in the new product/service development, (B) Nature of services and innovation, and (C) Drivers for learning and innovation.

### *A. Engineering as a Service in the New Product/Service Development Life Cycle:*

Any complex product development and systems integration essentially consists of two primary stages of activity: (a) product definition and (b) product realization. The NASA view [7] for "systems engineering engine" depicts the system's development in three blocks that cover requirements flow-down, technical effort, and product realization (Appendix A). The Department of Defense's view [8] for "lifecycle framework" for systems consists of "engineering and manufacturing development" and "production and deployment" (Appendix B). In both these views, the highly skilled knowledge workers provide creative engineering in the product definition stage. The product realization stage, on the other hand, is dominated by the manufacturing operations that perform build-to-print.

The product definition activity is led by the systems engineering processes, where requirements integration, functional decomposition, concept selection, detailed design, qualification, and acceptance are performed in sequence [9]-[11]. The development of product definition is typically performed on a stage-gate template, where at each stage of development, various functional discipline experts, customers, and other stake holders perform incremental reviews to mature the product definition to the next stage [7]. The engineering effort is delivered in a multidisciplinary collaborative team environment, which is central to innovation within the complex development process. This study focuses on the learning aspect of the engineering effort during product/service development, by taking the service-centric view of engineering.

The service-centric view [12] propounds that goods are essentially the distribution mechanisms for service provisions. According to this view, "service" becomes the core concept that replaces both goods and services, and the focus shifts to "value propositions" rather than products. Per this Service Dominated (S-D) logic, "value proposition" is understood as a potential value that is actualized by customer usage. Moreover, this value is co-created by the supplier and customer. Engineering as a service brings together both parties in creating the product definition and the functionality. Value is also reflected in the product development process, which is driven by a learning engine that transforms the collaborative knowledge into products and services.

### B. *Nature of Services* and *Innovation:*

Engineering activity is typically viewed as knowledge-based, problem-solving effort. To get a deeper understanding of how the engineering activity is consumed in product or service development lifecycle, it is worthwhile to review the specific characteristics and typologies of services in general.

The distinguishing features of services [6] from various scholarly sources are as follows:

1) Services are intangible, as opposed to manufactured products. Services should be seen as performances as opposed to objects. However, most services contain a mix of tangible and intangible attributes that constitute a service package [13].
2) Services constitute simultaneous production and consumption. This means substantial interaction occurs between the service providers and consumers. While the degree of overlap between service production and consumption can vary, the customer is very much involved in the process of service delivery and experience.
3) Services are significantly customized and they manifest heterogeneity. Research [14] indicates that various deliveries for the same service can be substantially different because of the personal perceptions of the clients.
4) Perishability of services is propounded by Vermeulen, who argues that services that are available but not consumed cannot be stored [15]. However, services such as computer software and engineering analysis are not perishable. De Jong et al conclude that products and services can be considered to be opposites on a continuum [6]. This endorses the view point of Easingwood that not all services are intangible, produced simultaneously, heterogeneous, and perishable [16]. Further, many manufactured goods may possess one or more of the above mentioned characteristics as well.

Another aspect of services pertains to the innovation process. It is well recognized that in manufacturing, innovation can be classified by two basic forms: changes to the products, and changes to the way these products are created. These changes are termed as product and process innovations [17]. However, in services, the dividing line between "product" and "process" innovation is blurred [18].

Innovation in services is considered to be far greater than the change in the service itself. According to Den Hertog, the following four dimensions can be used to describe a service: (a) service concept, (b) client interface, (c) service delivery system, and (d) technological options [19].

The discussion pertaining to the features of services, the process of innovation for services, and the dimensions of innovation for services has a strong bearing in examining the engineering activity as a service in the new product/service development. Innovation in engineering is primarily seen as a learning process consisting of reflective observation, practical experience, and transformation. These characteristics pertinent to learning are further observed in the subsequent sections.

### C. *Drivers for Learning and Innovation:*

#### *1) Design Mindset and Innovation*

Scholarly literature describes integrated design as a multidisciplinary problem-solving process. According to Owens [20], a design process essentially consists of both analytic and synthetic elements. The analytic phase of design focuses on finding and discovery, while the synthetic phase of design focuses on invention and making.

The four phases of the learning process—experiencing, reflecting, thinking, and acting—go hand in hand with both the grasping experience and transforming experience suggested by Kolb's [21] experiential learning theory. When these two learning experiences are viewed on the polar opposite abstract and concrete scales, four learning styles emerge: (1) assimilating (abstract grasping – abstract transforming), (2) diverging (concrete grasping – abstract transforming), (3) converging (abstract grasping – concrete transforming), and (4) accommodating (concrete grasping – concrete transforming).

Individual learning styles and their adaptability are critical to the implementation of an innovation process [22]. The integrated innovation process as a learning model suggests that design teams have representation from each of the learning styles on the team in order to have the best outcome from innovation efforts. The ability to move between the abstract and concrete, and between analysis and synthesis to execute the process, defines leading through innovation.

*2) Elements of Learning*

The scholarly literature on the innovation-driven learning in organizations essentially views the learning process as a staged activity of increasing maturity across the organization. This line of thinking seems to originate from the theory on hierarchy of learning as propounded by McKee [24] and consists of three levels of learning:

a. Single-loop learning, which occurs in a given organizational structure and a set of rules. The learning is a result of adjusting through repetition and routine, and involves simple association building.
b. Double-loop learning, which aims at adjusting the overall rules and norms. This type of learning requires skill development and insights. The associations that result from double-loop learning have long-term effects.
c. Meta-learning, which essentially aims at institutionalizing the ability to learn.

In line with this thinking, Zhang, Lim and Cao [2] have advocated a model for innovation-driven learning, which consists of individual learning, project-level learning, and organizational-level learning.

Knowledge creation and conversion in the organizations are also addressed by a model proposed by Nonaka et al [24]. It links individual and organizational learning through mental models and explains how individual learning is transferred to the organization through the four modes of conversion:

a. Socialization, which is a process of sharing mental models and technical skills between team members.
b. Externalization, which is a process of codifying the knowledge at the group and organizational levels.
c. Combination, which is the cross-leveling knowledge phase, where an enterprise shares knowledge both intra- and inter-organizationally.
d. Internalization, which is embodying the explicit knowledge to tacit knowledge between the team members.

*3) Strategic Context and Innovation*

Organizational context is the single most important factor in shaping the approach to learning during any new product or service innovation. Learning intent within an organization is considered a strategic activity. In this regard, Hamel [26] observed that some firms maintained a purely transactional relationship with suppliers without any learning intent, while others took a different approach. According to Huang and Chu [26], the organizational learning intent, as well as the team setup, had significant bearing in how inter- and intra-organizational learning occurred between the suppliers and product developers. From empirical research, they concluded that interactive learning between the suppliers and customers was positively associated with internalized learning. Furthermore, the interactive learning was also positively correlated with product development capability of the suppliers.

Technological parity between the firm and the industry is another important factor that can influence a firm’s position on learning. In the industries where core technologies cannot be protected, high technological parity is likely to exist, and the technological knowledge appropriability regimes become predictably weak. The concept of a firm’s innovation-related learning capability is an encompassing competency that produces actionable knowledge [27]. From empirical research, it is established that the learning capability is positively related to a firm’s reliance on the internal mode of innovation when technological parity is high. Also, the learning capability is found to be positively related to a firm’s reliance on the cooperative mode of innovation when technological parity is low [28]. Another factor that influences a firm’s domain of interaction for knowledge is the “learning distance.” According to Hoskisson and Busenitz [29], firms choose an internal development mode when the learning distance between “what a firm currently knows” and “what it needs to know” is low. On the other hand, when the learning distance is high, firms resort to acquisitions or cooperative development ventures.

The literature review for this study poses the following questions:

What are the interfaces and drivers for learning at individual, project and organizational levels with regards product/service development and innovation?

How can the elements that drive learning be best configured to optimize the product/service innovation?

## IV. Conceptual Framework for Learning in the Engineering Services

This section attempts to develop a framework to capture the structure of learning in an engineering development environment. It also maps the pathway that outlines how learning feeds and shapes new products/services. In doing so, the study presents a notional view of how engineering services fits into the overall product/service development process as established and practiced by the aerospace and defense industry. Further, an integrated model for learning is developed for engineering services by combining the organizational context, and the engineering innovation context. The integrated learning model aims at understanding the learning process in engineering the complex product development and large-scale systems integration environments.

### *A. Mechanics of Learning*

The fundamental building blocks for learning pertain to perception, imagination, and action. As discussed in the literature review regarding design mindset and innovation, the two types of cognitive skills, reflective learning and active experimentation, dictate the outcomes of an engineering innovation effort. In this regard, Kolb’s [21] experiential learning theory emphasizes the importance of balance within the team composition with respect to these skills. The learning involved in the design effort consists of an analysis phase and a synthesis phase. On the analysis side of the model, the thought process is carried from concrete to abstract whereas on the synthesis side of the model, the thought process is carried from abstract to concrete. These two complementing halves in essence constitute the knowledge cycle, which can be thought of as a combination of grasping knowledge and transforming knowledge. Kolb's model as discussed in the literature review is presented in Figure-1.

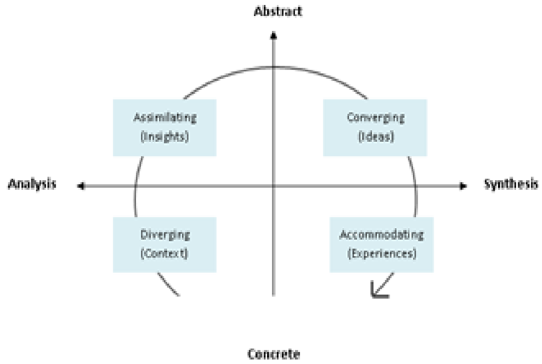



Fig. 1 Innovation process and learning styles-Beckman and Berry (2007)

The mechanics of successful knowledge creation, dissemination, and application within organizations, is well articulated in the seminal SECI (Socialization, Externalization, Combination, and Internalization) theory propounded by Nonaka and Takeuchi [30]. The theory postulates that the people, and the cultures that influence their behaviors, are the most critical factors for knowledge management. To address the cognitive, social, and organizational learning processes essential to the success of a knowledge management strategy, Nonaka and Takeuchi have created a model that elucidates the process of learning at the individual, team, and organizational levels. Figure 2 illustrates their model, which lucidly explains the cycle of learning in which the knowledge flow takes place from the individual's tacit knowledge, is converted and codified into explicit knowledge, is used and validated by teams as combined knowledge, and finally is set as an organization's internalized knowledge. The model suggests a spiral process for the learning to occur continuously, built on social and organizational processes. The SECI is model is crucial for understanding the learning process that takes place in a large scale engineering product/service development.

The SECI model complements the Organizational Learning Cycle developed by Huang and Chu [26], which is also discussed in the literature review. Presented in Figure-3, the model charts factors that translate the team learning from external interactions into product development capabilities.

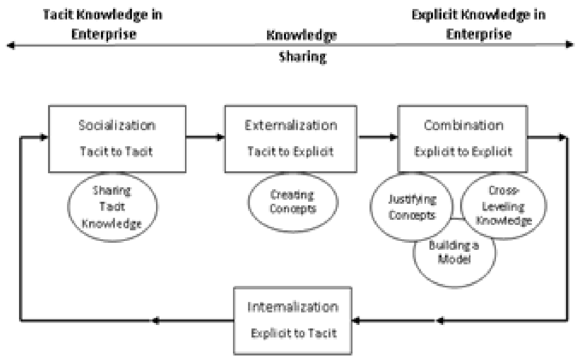



Fig. 2 Knowledge sharing and enterprise knowledge-creation model. - Nonaka, Takeuchi, Umemoto (1997)

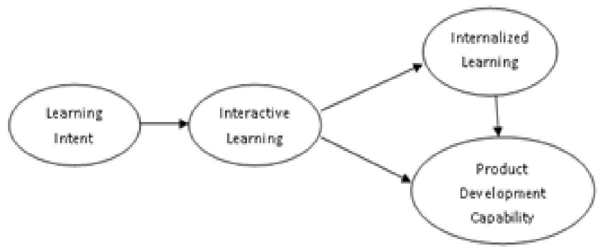



Fig. 3 Learning interactions and product development capabilities - Huand and Chu (2010)

### *B. Product/Service Development Process in the Aerospace and Defense Industry*

The integrated product development life cycle as practiced in the aerospace and defense industry is presented in the waterfall models found in the NASA Systems Engineering Handbook [7] and DOD Acquisition Guidelines [8]. A simplified model, specifically emphasizing the product definition tasks where engineering services drive the process, is illustrated in Figure-4. The various arrow-blocks represent the discrete activities within the product development, where cross-functional product teams are involved to render multidisciplinary engineering services. The product definition activity takes place between market shaping and CDR, whereas the product realization activity takes place between CDR and FCA/PCA. Within the product definition activity, there are two qualitatively differentiable efforts, "concept selection" that is tied to grasping experience and "design integration" that is tied to the "transforming experience." Each of these engineering activity blocks house iterative processes with infusion of new ideas, inserting new technologies, conducting several parametric studies, and designing tradeoffs. The product teams actively interact with the stake holders at the stage-gate reviews. These reviews, which occur at the junctions of the activity blocks, help to mature the product definition for that stage and give a go-ahead to progress to the next stage. The progressive and iterative learning pertaining to the engineering effort, as discussed in the previous section, takes place within each of the arrow-blocks shown below.

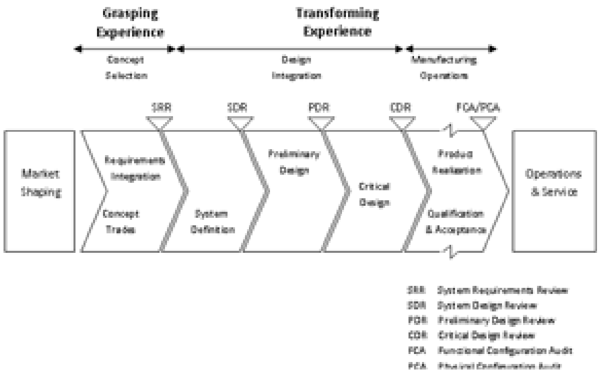



Fig. 4 Product Definition Blocks within the Product Development Process Flow-Pilla (2011)
(Credits: Nasa SP-6105, 2007, DODI 50 02, 02, 2008)

### *C. Integrated Model for Learning in Engineering Organizations*

From this study, an operations view is chalked out to depict the centrality of learning in the overall product/service development activity, as shown in the Figure 5. The operations view illustrates a pathway for organizational and individual knowledge, through learning, towards the creation of final innovative products and services. The execution layer of the blocks shown on the left, consisting of management systems, engineering systems, and operations systems, indicate the overall activities involved in the new product development effort [9], [11]. The knowledge layer of the blocks shown on the right, consisting of the knowledge perspectives, knowledge principles, and knowledge practices [31] indicate the baseline for the collective knowledge of the firm. The lower layer of the blocks, shown below the learning block, indicates the external interactions that trigger the infusion of new information into the team. Finally, the knowledge layer, the execution layer, and the external interaction layer are connected in a two-way fashion to learning block.

The learning block shows the elements of the SECI model [30]. The upper layer of the blocks, shown above the learning block, indicates the dimensions of a service [19], which is shown as the gateway towards validating and delivering the final engineering product/service output.

The knowledge-sharing and knowledge-creation model by Nonaka and Takeuchi [30] can be mapped to the experiential learning model by Kolb [21] and the innovation driven learning model by Zhang, Lim, and Cao [2] as shown in the Table I. Keeping the learning process consisting of socialization, externalization, combination, and the internalization as the basis, one can see how the cognitive behavioral aspects, as well as the individual to the organizational learning can line up with the process.

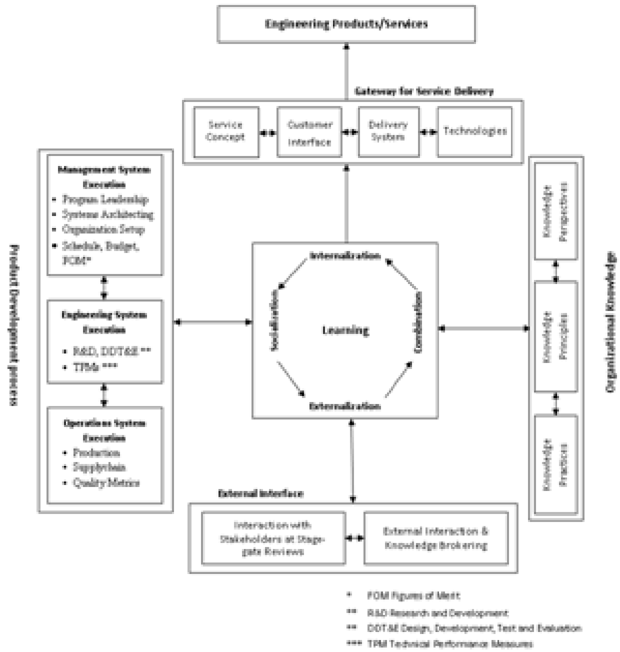



Fig. 5 Operations view of learning in the creation of engineering Products/Services - Pilla (2011)
Credits: Nonaka & Takeuchi (1995), Den Hertog (2000), Huang and Chu (2010), Small and Sage (2006)

TABLE I
LEARNING MODES IN ENGINEERING SERVICES

<table>
<tr><td colspan="4">Reflective Observation</td><td colspan="4">Active Experimentation</td><td colspan="4">Institutionalization of Learning</td></tr>
<tr><td colspan="3">Socialization</td><td colspan="3">Externalization</td><td colspan="3">Combination</td><td colspan="3">Internalization</td></tr>
<tr><td colspan="4">Individual Learning</td><td colspan="4">Team Level Learning</td><td colspan="4">Organizational Learning</td></tr>
</table>

The behavioral aspects of learning are also mapped to the elements of engineering services in new product development. Reflective observations through interpersonal interactions include the collaborative systems view and shared Technical Performance Metrics (TPM), leading to convergence in a complex multidisciplinary environment. The active experimentation in engineering services pertaining to product definition includes developing integrated solutions, multidisciplinary optimization, and active risk management. The institutionalization of learning consists of both tacit and codified knowledge disseminating in terms of knowledge perspectives, knowledge principles, and knowledge practices within an organization. See Table II.

From this study, a systems view is chalked out to depict the Integrated Learning Model as shown in Figure 6. This model synthesizes the existing seminal theories on learning and further develops the concept of service-oriented learning. The relationships between the characteristics of the engineering services and the components of the learning mechanisms have been incorporated by drawing upon the literature research. The “Integrated Learning Model for Engineering Services” proposed in this study consists of two major domains: (1) domain of organizational context, and (2) domain of engineering innovation.

TABLE II
INTERNAL AND EXTERNAL ORGANIZATIONAL INTERACTIONS

| Reflective Observation | Active Experimentation | Institutionalization of Learning |
|---|---|---|
| Systems View | Int. Solutions | Knowledge Perspectives |
| Shared TPMs | MD-Optimizations | Knowledge Principles |
| Converging Paths | Managed Risks | Knowledge Practices |

The domain of organizational context includes the structural elements and strategic focus of the team, as well as the cognitive and behavioral composition of the team. Thus the domain of organization context addresses the external interactions for knowledge brokering and the internal skill base for a balanced cognitive approach to innovation.

The conversion of knowledge leading to the new product/service development, based on the organizational elements, which is previously illustrated in the operations view, is structurally depicted in the domain of engineering innovation in Figure 6.

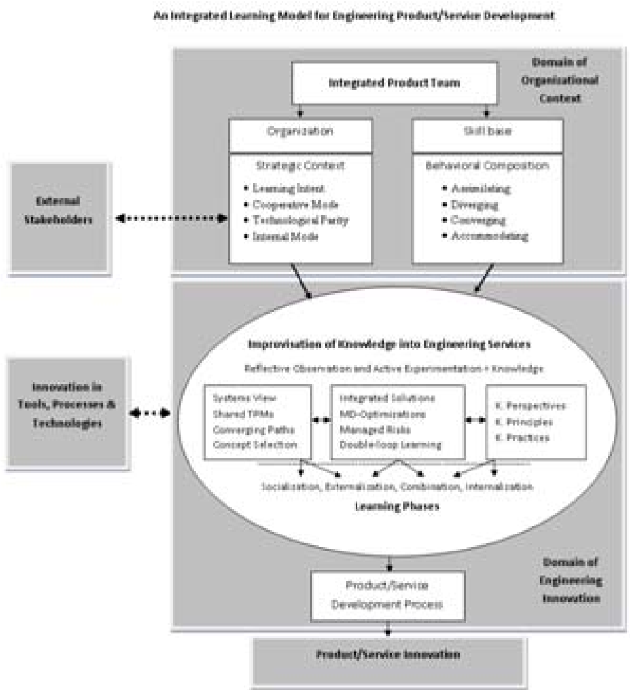



Fig. 6 Systems view of learning creation of engineering products/services-pilla (2011)
Credits: Nonaka & Takeuchi (1995), Beckman & Barry (2007), Huang and Chu (2010)

The domain of engineering innovation draws upon the organizational context. It essentially houses the knowledge sharing, learning through reflective observation, learning through active experimentation, and internalization of knowledge. Each of the new product/service definition activity blocks, as shown in Figure 4 for the product definition process, goes through the cycles of learning until the knowledge gained is internalized. The innovations in tools, processes, technologies, and culture play into this process of engineering innovation as shown in the overall systems view for learning in Figure 6. The integrated learning and knowledge sharing activity creates the innovative engineering products/services.

The Integrated Learning Model for Engineering Services has provided insights into the end-to-end process of learning as practiced in new product/service development. Taking a systemic view of the structure and process of the learning activity, this study brings forward two propositions.

### D. *Propositions*

This study argues that both the external interactions, as well as the team composition, influence the learning in a new product/service development. Learning further feeds into the innovation of products/services. This argument is supported by the studies by Huang and Chu [26], which establishes the connection between the external interactions of the product development teams, and the firm's capability to innovate. In a separate study Kolb [21] suggests that the team's balance between the grasping experience and transforming experience do weigh into the successful innovation outcomes. According to this experiential learning theory, the ability to move between the abstract and concrete and between analysis and synthesis to execute the process defines leading through innovation.

The Integrated Learning Model from this study reconciles these two theories as illustrated in the Figure 7, to propose the following:

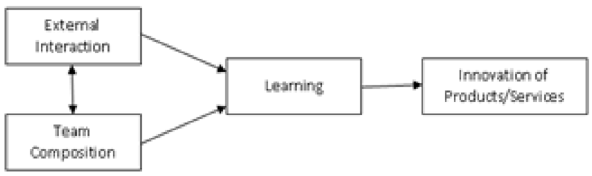



Fig. 7 Organizational Context influencing the innovation through learning
Source: Primary

*Proposition 1: (a)* External interactions and knowledge brokering enhance engineering team's learning. (b) Balance in team's composition with respect to grasping and transforming abilities enhance engineering team's learning. (c) The enhanced learning from these two factors will lead to team's improved innovation outcomes.

In the case of engineering services during the product definition, the team must conceive a common systems view and shared TPMs that feed into creating a winning concept. The subsequent multidisciplinary team effort would give rise to the integrated solutions and multidisciplinary optimization that define the product. When the collaborative activities in the engineering services, are viewed with respect to the optimal team composition for innovation, the Integrated

Learning Model from this study proposes the following:

Proposition 2: (a) Engineering team's composition weighted in "imaginative membership" enhances innovation in "concept selection." (b) Engineering team's composition weighted in "experimental membership" enhances innovation in "design integration."

This conceptual model is validated from a comparison with a field case study analysis on Learning in Engineering from the Aerospace Industry as given below:

*E. Collaborative knowledge sharing in composite new product development (NPD) at Bombardier [32]*

The case study aimed at exploring the acquisition, embedding, and use of new knowledge from multiple sources in the composites of new product development. The findings showed that in addition to the traditional internal and external knowledge sources, out-of-sector knowledge (in this case from Healthcare Diagnostics) could also be used to better inform specialist technologies. Furthermore, it is found essential that knowledge from multiple sources be effectively integrated within the engineering process for successful NPD. The salient observations from the case study strongly support the centrality of engineering learning in the new product development and innovation. These observations, viewed from the perspectives of the Mechanics of Learning (Figure 5) and the Integrated Learning Model (Figure 6), are presented below, along with the author's commentary:

1) The need for effective knowledge sharing both internally and externally is found to be a key driver for NPD and especially for high technology areas such as Composites in Aerospace. Within the Composites NPD, process experts readily share their expertise to assist others through informal social relationships. However, there is a lack of systematic plans and measures for such knowledge sharing and a failure to effectively use available knowledge sharing IT tools [32].

Commentary: Findings from this case study are in line with the results of the empirical research [26]. The Operations View for Learning in Figure 5 and the Integrated Learning Model in Figure 6 have illustrated the inflows from both internal and external knowledge sharing, leading to the product/service innovation.

2) Internal knowledge development in the program is facilitated through effective management support, communication of the vision and customer needs, and cross-functional sharing of knowledge, leading to a "charged team," using the CAE group.
   a) Engineering functions and departments support program needs and are responsible for the development and governance of processes, systems, and procedures including data accuracy and compliance audits. The problem for effective knowledge embedding and use lies in the conflict of aims between the need for accurate information and the difficulties of obtaining it.
   b) There are a number of projects underway to improve internal knowledge sharing. These projects, however, recognize that it is difficult to promote a change in a large design and manufacturing organization with embedded traditional structures. This scenario is mitigated by establishing linkages between the quality department and other engineering departments (design, stress, materials and weights), which have been improved by co-location and use of common knowledge sharing tools and platforms [32].

Commentary: Findings from this case study are in line with the theoretical models propounded by Nonaka and Takeuchi [33]. The case study succinctly captured the Socialization, Externalization, Combination, and Internalization elements in action. To facilitate this learning process, the engineering teams were provided with the much needed autonomy and functional collocation. The Operations View for learning in Figure 5 and the Integrated Learning Model in Figure 6 have illustrated the mechanics of the learning process as an interwoven activity, needing tight collaboration with the stake holders.

3) The organization used a Competitive Intelligence program covering a wide range of knowledge from external sources to drive their NPD efforts. However, this external knowledge was not systematically incorporated because the CAE group had insufficient skills, time, and resources (budget constraints).
   a) At present, research and development in medical diagnostics is leading industrial diagnostics, largely due to greater healthcare spending. Hence the company has developed an out-of-sector benchmarking partnership for knowledge sharing with the diagnostics department of a leading UK Hospital Trust.
   b) The company formed a number of formal partnerships with universities to share knowledge in composites technology for NPD. The objective of the partnership networks was to improve NPD performance by increasing the knowledge transfer of technology into the case organization and by accelerating the rate at which this process occurs.
   c) The external knowledge from universities researching in composites technologies for NPD in the organization is seen as central to the organization's goal of maintaining their inter-group standing as a center of excellence for Composites NPD [32].

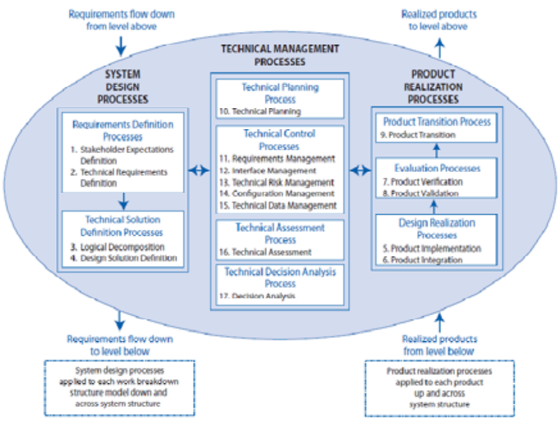
Commentary: Findings from this case study are in line with the empirical research done by Huang and Chu [26]. The Operations View for Learning in Figure 5 and the Integrated Learning Model in Figure 6 have illustrated the relationship between the external interactions and knowledge brokering, and engineering learning.

## V. Conclusions and Discussion

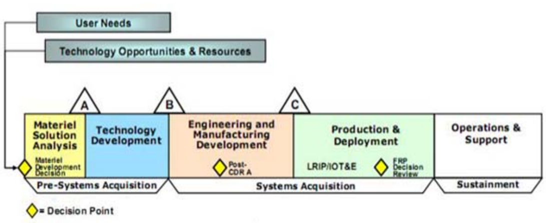
The current theories of learning are fragmented, and this study makes an effort to integrate those theories into a meta-theory. More importantly, this study has reconciled the understanding of innovation that is attributable to learning by the organizational theorists, behavioral theorists, and systems engineers. The two propositions developed here are partially validated by the case study presented in this paper. The case study revealed considerable observation with respect to the interactions within and across the teams. However, very little information is gathered on the cognitive skills of the team members. Additional field studies and quantitative research can further the validation of the propositions presented here. Also, the Integrated Learning Model presented in this paper can be a guiding source for developing many new propositions.

The results from this study apply to the organizations that seek to gain on innovation capabilities from learning. The primary focuses for the study is the aerospace and defense industry, which implements traditional systems engineering to address complex product development. However, the concept framework developed in this study has wider applicability to other industries as well. It enhances the understanding of the centrality of learning and the drivers for learning in the arena of new product/service development.

## Appendix




Appendix A: Technical Management Processes.
Source: NASA Systems Engineering Handbook (NASA/SP-2007-6105)
http://education.ksc.nasa.gov/esmdspacegrant/Documents/NASA%20SP-2007-6105%20Rev%201%20Final%2031Dec2007.pdf




Appendix B
DOD – Lifecycle Framework View (DODI 5002.02, 2008)

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