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A Review of Error Framing and Its Influence on the Development of Innovation Skills within the Adaptive Expertise Framework

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Abstract
Innovation is the key to success. This empirical study critically re-examines existing managerial training paradigms to align with the dynamic skill demands of contemporary Multi-National Companies (MNCs), with a particular emphasis on developing innovation skills—a key dimension of adaptive expertise. Anchored in the theoretical foundations of error framing, self-efficacy, and learner-centred instructional design, the study proposes and tests a conceptual model to explore the interrelationships among these constructs. A cross-sectional, survey-based quantitative research design was adopted, with data collected from mid- to senior-level MNC managers using a rigorously validated questionnaire. Structural Equation Modelling (SEM) was conducted using SmartPLS 4.0 to assess both the measurement and structural components of the model, ensuring reliability, convergent validity, and discriminant validity through composite reliability, AVE, and HTMT ratios. The analysis yielded statistically significant results, indicating that error framing, as an instructional strategy, exerts a direct and positive influence on innovation skills. Moreover, self-efficacy was found to fully mediate this relationship, underscoring its pivotal role in fostering adaptive expertise through metacognitive and motivational pathways. These findings contribute to the advancement of theory in training design and provide actionable insights for engineering and corporate learning ecosystems seeking to build innovation capacity through evidence-based pedagogical interventions.

Keywords: innovation skills, error framing, error management training, active learning, self-efficacy, and adaptive expertise

1. Introduction

In fast-changing engineering management environments, developing innovation skills—a key part of adaptive expertise—is essential for professional success. Recent research has shown that framing errors as learning opportunities is an effective teaching method that boosts adaptive expertise in technical fields (Walsh & Schunn, 2025). At the same time, studies on work-based learning reveal that real-world engineering experiences encourage reflection, confidence, and innovation (Groenier et al., 2025). These findings highlight the need for research on how learner-focused error framing, supported by self-confidence, helps improve innovation skills in multinational company management training. This study addresses that need by using a detailed structural model and PLS-SEM analysis, offering evidence-based advice for creating corporate training programs that build adaptive expertise in engineering. The corporate world has witnessed revolutionary changes due to volatility and complexity in the international marketplaces. In today's fast-changing corporate and engineering world, being able to innovate despite uncertainty is a key skill (Choudhury et al., 2025). Traditional training methods, which focus on avoiding mistakes and following strict rules, often don't fit well with today's dynamic workplaces where flexibility, experimentation, and ongoing learning are crucial. Because of this, the idea of adaptive expertise has gained attention, especially the parts that stress being flexible, solving problems creatively, and using knowledge in new ways.

One effective teaching method is error framing—how mistakes are recognized and discussed during learning. When mistakes are seen in a positive light, they become chances to reflect, grow, and try new approaches. Combined with learner-centered training, error framing helps build self-confidence, which affects how confidently people tackle problems and come up with innovations. Although there is growing interest in this area, there are few studies that look at how self-confidence connects error framing with innovation skills, especially for training managers in multinational companies. This study fills that gap by proposing and testing a model to explore these connections, offering insights for both theory and the design of training programs aimed at developing adaptive expertise in high-performing workplaces.

The present-day MNC managers handle multifaceted jobs, including complex operations, both conventional and unconventional ones. Considering the dynamic geo-political scenarios and a need for the company to be a potent force in the global markets, there is a constant focus on acquiring cutting-edge technologies and best practices. In essence, the personnel must constantly handle a variety of technologies, human resource practices, logistics and complex operational situations (Gaikwad, 2024). Many dynamic challenges come with the ever-evolving nature of businesses and practices. The people are constantly relocated and have to deal with a new culture, language, local practices and leadership challenges (Gaikwad, 2014). Like in military operations, despite the best preparation for all such contingencies, they are expected to deal with unknown and unforeseen situations (Sookermany, 2016). It is also common for the managers to deal with such challenges with limited resources, and adding to this challenge is the impetus on 'lean staffing' and frequent lay-offs. With such a range of challenges, it is evident that there is an imminent need to re-examine the training strategies to sharpen the skill sets and prepare the MNC managers to handle such modern-day challenges.

2. Background of Study

- **Adaptive Expertise**

The literature review establishes that developing adaptive expertise is essential for personnel to handle novel and unforeseen challenges. Adaptive expertise can be traced back to Hatano and Inagaki's paper on 'two courses of expertise' in 1984, highlighting that adaptive experts have a broader and more integrated knowledge base than routine experts (Hatano & Inagaki, 1984) . Adaptive experts think beyond typical situations and can formulate context-based analogies and apply them in novel situations (Barnett & Kozlowski, 2002). Adaptive expertise equips personnel to perform satisfactorily, even for unfamiliar job tasks and work methods (Bohle Carbonell et al., 2014) . Comparatively, routine experts can solve familiar domain tasks efficiently (Hatano & Inagaki, 1984) . However, they possess limited skills when faced with unfamiliar and novel situations. Therefore, in addition to handling routine situations efficiently in their domain, adaptive experts can handle complex, unforeseen, and unfamiliar situations efficiently and innovatively (Bohle Carbonell et al., 2014). Adaptive experts can handle such challenges because of the abstract structuring of their knowledge (van Dijk et al., 2023). Adaptive expertise has sub-dimensions of Domain Skills, Innovation Skills, and Metacognitive Skills (Bohle Carbonell et al., 2016). In the context of the present study, the focus is on the innovation skills dimension. Innovation skills refer to innovating and finding solutions to familiar and unfamiliar problems and must be fostered with focused training efforts. Individuals with innovation skills can analyse unfamiliar challenges out of context and draw analogies from previously encountered experiences (Bohle Carbonell et al., 2016). Hence, innovation skills are a key dimension of adaptive expertise, which sets routine experts apart from adaptive experts. Therefore, the innovation skills dimension of adaptive expertise is considered the dependent variable for the present study.

- **Error Framing**

Traditional training focuses primarily on general training without much consideration for the cognitive capabilities and limitations of the trainees (Vogel-Walcutt et al., 2013). In the traditional training model, the learner is passive while receiving the knowledge, which limits the trainee's participation in the learning process. However, active learning strategies ensure that the focus is on the trainee, who is an active participant and considers the trainee's cognitive capabilities (Vogel-Walcutt et al., 2013). This is a sort of inductive learning, where the knowledge is constructed by the trainee with the help of the environment and is referred to as the 'constructivist approach' (Bell & Kozlowski, 2008; Michael, 2006) . Many approaches to active learning include Problem-Based Learning, Project-Based Learning, Inquiry-Based Learning, Guided Discovery Learning, Error Framing (EF), etc. (Smith et al., 2004; An & Mindrila, 2020). Among these training strategies, the EF approach has been chosen as the independent variable for the present study. Error Framing, also referred to as Error Management Training (EMT), is a type of learner-centred training in which the trainees are encouraged to make errors, regarded as an instrumental part of the training process (Bell & Kozlowski, 2008; Keith & Frese, 2008). This concept has been extensively studied and has acquired adequate focus and significance as an active learning strategy (Keith & Frese, 2008). This training strategy involves framing errors as part of the active learning process, and errors are considered by-products and integral to the actual learning. They also help the trainees understand the gaps in knowledge, skills, and abilities (Keith & Frese, 2008). EF encourages the trainees to make errors during the training process and learn important lessons from the errors to avoid these mistakes when faced with similar situations. These instructions facilitate learning by encouraging trainees to seek out the causes of their errors through exploration (Dormann & Frese, 1994; Hardy et al., 2014).

EF aims to reduce errors by offering correctly guided instructions in the training process. The trainees are given minimal guidance and encouraged to explore and discover the concepts actively. Such a training strategy fosters an environment of accepting errors and provides positive feedback (Keith & Frese, 2008) . Adaptive experts accept making errors as part of the learning process to acquire an integrated knowledge base beyond simple declarative or procedural knowledge (Hatano & Inagaki, 1984). In the EF, the trainees are also given error management instructions to handle the stress and frustration of making errors. In the context of the study, it is somewhat similar to handling newer challenges when relocated across the globe. EF explains the cause-and-effect relations, helps correlate the same in actual situations, and improves the 'transfer of training' for optimal retention of learning. Therefore, EF is a better option than error-avoidant traditional training strategies for promoting the transfer of training to novel tasks (Keith & Frese, 2008).

- **Self-efficacy**

Active learning approaches result in self-regulatory processes, like the development of self-efficacy, which help develop adaptive expertise (Bell & Kozlowski, 2009). Self-efficacy means believing in one's ability to apply knowledge and skills in any situation. Self-efficacy plays a crucial role in adaptability, as an individual will likely exhibit adaptable behaviour with the necessary confidence (Griffin & Hesketh, 2003). The active learning approach is an influential antecedent for academic self-efficacy (Phan, 2011). Such a learning approach develops a positive orientation to learning and results in the development of necessary skills. Error framing significantly influences the trainees' metacognition and instils self-efficacy to handle even unfamiliar situations (Steele-Johnson & Kalinoski, 2014) . It is also scientifically validated that promoting self-efficacy and incorporating errors is vital for maximum training effectiveness (Salas et al., 2012) . Error framing results in a mastery orientation for the trainees and positively influences the motivational process of self-efficacy (Bell & Kozlowski, 2008; Steele-Johnson & Kalinoski, 2014). Therefore, self-efficacy is chosen as the mediating variable in the present study.

3. Objectives of Study:

- To examine the direct influence of error framing as a learner-centred training strategy on the development of innovation skills among engineering professionals in multinational corporations
- To assess the role of self-efficacy as a mediating variable between error framing and innovation skills development within the framework of adaptive expertise
- To validate a conceptual model using structural equation modelling (PLS-SEM) that integrates error framing, self-efficacy, and innovation skills in the context of professional training for engineering managers

4. Review of Literature

Error framing, as a teaching strategy, is gaining recognition for its ability to encourage intentional learning by helping students reflect on mistakes and see them as opportunities to grow. Recent studies in higher education show that structured error management training helps learners handle uncertainty better and supports innovative problem-solving, which is key to developing adaptive expertise (van Dijk et al., 2024). Furthermore, research comparing high-reliability and error-management approaches finds that positive error framing—encouraging exploration and understanding—leads to greater improvements in metacognitive skills and innovation (Schulz & Mayer, 2024).

Self-efficacy, or the belief in one's ability to complete tasks, plays an important role in turning learning strategies into actual behavior. A 2024 meta-analysis in engineering education confirmed that self-efficacy strongly predicts student engagement, persistence, and innovative performance (Hartelt & Martens, 2024). Workplace studies also show that well-designed error framing can boost employees' confidence in using complex technical skills, highlighting the important connection between training methods and self-efficacy (Groenier et al., 2025).

Building innovation skills, especially in engineering, is crucial for adaptive expertise, which involves creative problem-solving and applying learning to new situations. Work-based learning (WBL) environments offer real-world challenges that encourage engineers to come up with new solutions and practice reflection (Groenier et al., 2025). Studies on design thinking programs also report clear gains in creative thinking, problem-solving, and self-efficacy, showing how teaching methods and innovation capacity work hand in hand (Li et al., 2024).

The adaptive expertise framework focuses on combining efficiency with innovation through reflection and metacognition (Hatano & Inagaki, 1986; Schwartz & Bransford, 2005). Recent reviews emphasize that learner-centered error framing, supported by increased self-efficacy, is an effective teaching approach in both engineering education and corporate training (Groenier et al., 2025; Hartelt & Martens, 2024). However, most studies are still fragmented, leaving a need for a more complete model. This study aims to fill that gap by exploring how self-efficacy mediates the relationship between structured error framing and the development of innovation skills in professional engineering training.

5. Theoretical Framework

The concepts of error framing, innovation skills and self-efficacy have been discussed in the preceding sections. The objective of this section is to briefly summarise the theoretical underpinnings of these concepts. Error framing, like other learner-centred or active training approaches, is based on the 'constructivism theory' approach to training (Alvidrez, M., Louie, N., & Tchoshanov, M., 2024 & Bell, B. S., & Kozlowski, S. W. J., 2009). In this approach, the trainees construct their knowledge through interactions with peers and instructors, and the instructor only guides the trainee in this process. This approach requires the active participation of the trainees in comprehension of the subject, and contextually applying it in real-life field situations (Vogel-Walcutt et al., 2013; Vygotsky, 1978). The theoretical framework for adaptive expertise was put forth by Schwartz et al. (2005). This theory highlights that the progress of adaptive expertise is based on balancing efficiency and innovation dimensions (McKenna, 2007; Schwartz et al., 2005). While routine expertise is developed by efficiency dimension, innovation skills are essential for the development of adaptive expertise (Bohle Carbonell et al., 2016). Saleh et al. (2023) empirically proved in their theoretical framework, positive influence of self-efficacy on adaptive expertise. The complete framework linking error framing, self-efficacy and innovation skills in the present study is based on the 'integrated conceptual model of active learning' proposed by Bell, B. S., & Kozlowski, S.W.J. (2009).

6. Research Methodology

Conceptual Framework

The scope of the present study involves testing a conceptual model consisting of EF (representing active learning) as the independent variable, innovation skills (dimension of adaptive expertise) as the dependent variable, and self-efficacy as the mediating variable, and is represented in Figure 1. The aim is to quantitatively establish the influence of EF on the development of innovation skills through self-efficacy.

Hypotheses. The proposed hypotheses are as follows: -

(a) **$H_0$1**. There is no significant relationship between error framing and innovation skills.
(b) **$H_0$2**. There is no significant relationship between error framing and self-efficacy.
(c) **$H_0$3**. There is no significant relationship between self-efficacy and innovation skills.

Data Collection

A survey questionnaire with five indicators for each variable was administered to 65 managers. The survey questionnaire is based on a 5-point Likert scale. The details are summarised in Table 1. The respondents were chosen based on a minimum of 10 years of experience and willingness to participate in the research process. Though the sample size is relatively small, it meets the minimum threshold for SEM analysis, calculated using G*power software with a larger effect size and 5% significance. The content validity was checked based on valuable inputs provided by the subject matter experts. Survey instruments for all three variables are adapted from the existing literature, and the details are presented in Table 1.

Table 1. Sources of survey instruments.

Variable	No of indicators	Source
Error Framing	05	(Rybowiak et al., 1999)
Innovation Skills	05	(Bohle Carbonell et al., 2016)
Self-efficacy	05	(Griffin & Hesketh, 2003)

7. Results and Findings

Data analysis was undertaken using 'Smart PLS 4', a second-generation multivariate statistical analysis software. This software enables the simultaneous modelling and estimation of complex relationships among multiple dependent and independent variables, including multiple regression analysis**.** One significant advantage of PLS-SEM (Partial Least Squares – Structural Equation Modelling) is that it makes no distributional assumptions and performs nonparametric analysis (Hair et al., 2019). It is developed as a causal-predictive model to enable simultaneous analysis of multiple variables complexly related (Hair et al., 2019; Sharma et al., 2023). Also, PLS-SEM is an appropriate statistical analysis tool for small sample sizes (Hair et al., 2019). The data analysis involves validating the 'Measurement Model' and assessing the 'Structural Model'. The PLS-SEM model is shown in Figure 1. In the model, EF refers to error framing (independent variable), SE refers to self-efficacy (mediating variable), and IS refers to innovation skills (dependent variable).

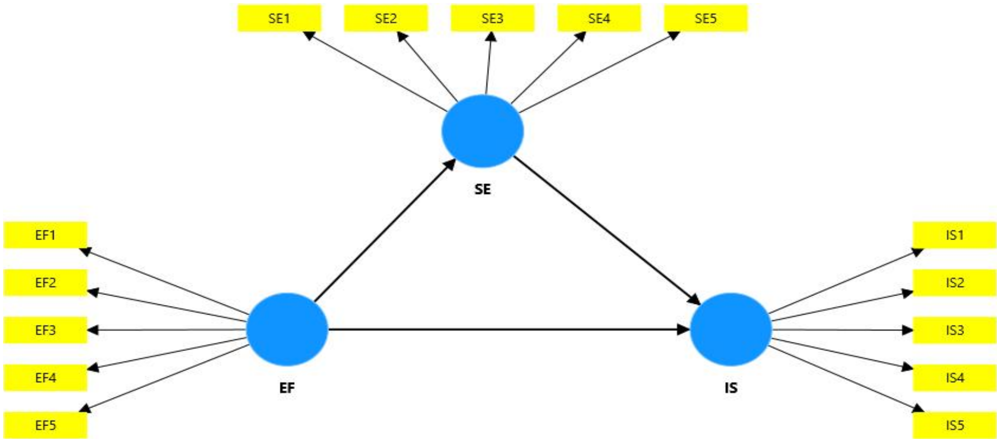

Figure 1. Conceptual Model in Smart PLS-SEM 4

Measurement Model Analysis.

Metrics of the measurement model include factor/ indicator loading, reliability, composite reliability, and convergent validity (Hair et al., 2019) . These are summarised in Table 2. The correlation between the indicators or factors and the variable is checked using factor loading. The measurement model analysis indicates strong factor loading (Λ) values above the desired threshold of 0.7, except for two indicators of innovation skills and one indicator of error framing. However, none of these values are below the lowest threshold value of 0.4, and reliability and average variance values are well above the threshold limits of 0.708 and 0.5, respectively (Hair et al., 2019) . Hence, all the indicators are retained for the analysis. The alpha coefficient (Cronbach α) and Composite Reliability (CR) reflect the reliability measure. The construct's actual reliability is considered within these two extreme values (Hair et al., 2021). The reliability values of all variables reflected in Table 2 are well above the reference threshold value of 0.708 (Hair et al., 2019), which confirms that the model is reliable. Average Variance (AVE), which measures the convergent validity of the variables, is well above the threshold value of 0.5 (Hair et al., 2019).

Table 2. Item loadings, reliability, and convergent validity.

	Λ	α	CR	AVE
Error Framing		0.768	0.841	0.518
EF1	0.747			
EF2	0.828			
EF3	0.537			
EF4	0.741			
EF5	0.714			
Innovation Skills		0.792	0.855	0.543
IS1	0.690			
IS2	0.642			
IS3	0.756			
IS4	0.849			
IS5	0.731			
Self-efficacy		0.798	0.860	0.552

SE1	0.745
SE2	0.782
SE3	0.700
SE4	0.756
SE5	0.730

Discriminant validity values, which indicate the distinctiveness of each variable from the other, summarised in Table 3, confirm the threshold value of less than 0.85 as per the Heterotrait-Monotrait ratio (HTMT) criterion values ((Hair et al., 2019) . Also, the conservative approach of the Fornell-Larcker criterion validates the discriminant validity of the measurement model. The results are highlighted in Table 4. Thus, the measurement model is validated before progressing with the structural equation model analysis to test the above-stated hypotheses.

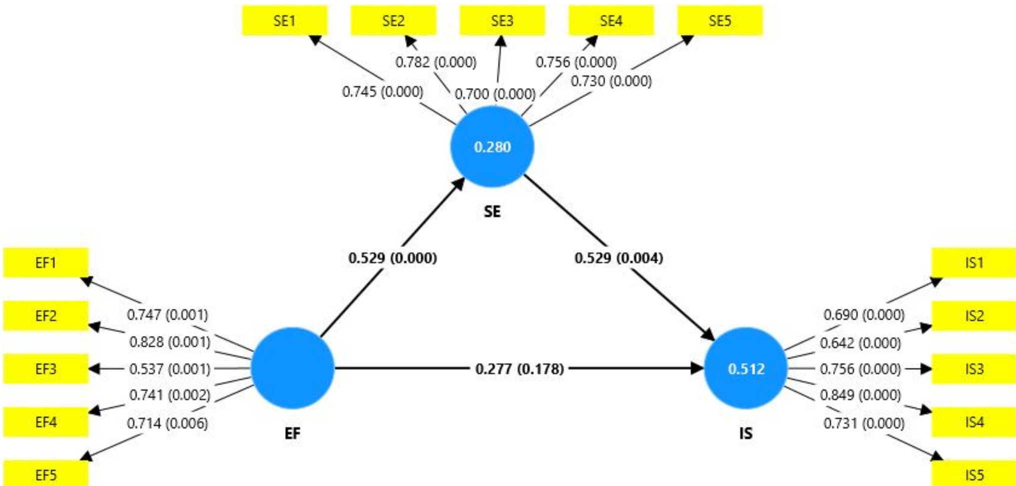

Figure 2. Structural Model Analysis in Smart PLS-SEM 4

Table 3. Discriminant Validity (HTMT)

	EF	IS	SE
EF			
IS	**0.643**		
SE	0.600	**0.776**	

Table 4. Discriminant Validity (Fornell-Larcker Criterion)

	EF	IS	SE
EF	0.720		
IS	0.557	0.737	
SE	0.529	0.676	0.743

- **Structural Model Analysis**

Structural Model Analysis using Smart PLS 4 is depicted in Figure 2. Variance Inflation Factor (VIF) values of the independent variables are less than the threshold limit of 3 (Hair et al., 2019), the highest value being 1.389 for EF and SE. Hence, no collinearity issues exist. The structural model analysis in Table 5 indicates R^2 values of 0.280 and 0.512 for SE and IS, respectively. A more accurate measurement is the adjusted R^2 value (Hemmert et al., 2018; Montgomery & Morrison,

1973) , and the calculated values are 0.259 and 0.483 for SE and IS, respectively. The model's predictive power and goodness of fit are validated since the calculated values exceed the reference threshold limiting value of 0.25 for social sciences research (Hair et al., 2011) . Also, p-values support alternate hypotheses H2 and H3, signifying the positive effect of error framing on self-efficacy and self-efficacy on innovation skills, respectively. However, the data does not support the alternate hypothesis H1, which implies a direct significant relation between error framing and innovation skills. Path analysis in Figure 2 highlights these aspects. As seen in the mediation results in Table 6, this is a case of the indirect-only type of mediation (Zhao et al., 2010), which indicates that error framing significantly affects the development of innovation skills mediated through self-efficacy.

Table 5. Results of structural model path coefficients (direct relationships)

Hypotheses	Relationship	β	SD	t-value	Confidence Interval (bias corrected)	Decision
					2.5% 97.5%	
H1	EF->IS	0.277	0.206	1.348	-0.189 0.645	Not supported
H2	EF->SE	0.529	0.117	4.527	0.011 0.682	Supported
H3	SE->IS	0.529	0.184	2.882	0.065 0.836	Supported
	R^2	R^2 adjusted				
SE	R^2 =0.280	R^2 adjusted=0.259				
IS	R^2 =0.512	R^2 adjusted =0.483				

Table 6. Summary of structural model mediation results.

Total effect (EF on IS)		Direct effect (EF on IS)		Indirect effect (EF on IS)			
β	p-value	β	p-value	β	SD	t-value	p-value
0.554	0.000	0.277	0.178	0.280	0.135	2.082	0.037

8. Conclusion

The present study analysed the influence of error framing as an active learner training strategy on innovation skills, a sub-dimension of adaptive expertise. The study also included the mediation role of self-efficacy between error framing and innovation skills. It has validated the hypothesis that error framing positively and significantly influences innovation skills through the self-efficacy of the learner. This study thus lays the foundation for the implementation of active learning strategies, like error framing, for the development of innovation skills among managers and leaders for handling novel situations while handling complex job operations across the globe.

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