

ADAPTING GUIDELINE-BASED ENGINEERING TRAINING FOR CULTURALLY DIVERSE TEAMS: INSIGHTS FROM INDUSTRIAL CAD/PLM TRANSITIONS

Liliane G NGAHANE NANA, Amaniye ARSLAN, Sascha ADAMCZYK, Nedim CIFTCIOGLU and Senem ÖZMEN
ARTECH Consulting GmbH, Germany

ABSTRACT

Engineering organisations undergoing CAD/PLM transitions can benefit from guideline-based training, which supports learning and harmonises engineering practices across distributed teams. However, in global engineering environments, cultural backgrounds, professional experience and reasoning strategies can affect how these guidelines are understood and implemented. This paper examines guideline-based learning from the perspective of cultural cognition within an industry-led CAD/PLM transition involving geographically and culturally diverse engineering teams. Adopting a qualitative, practice-oriented approach, the study analyses how participants interacted with shared instructional artefacts during training and operational activities. The findings emphasise the need to balance organisational standardisation with interpretative flexibility when designing learning frameworks for global engineering and product design environments.

Keywords: CAD/PLM transition, global teams, cultural cognition, guideline-based learning

1 INTRODUCTION

The practice of engineering and product design is increasingly influenced by globalisation, digital integration and organisational complexity. Design activities are now often carried out by geographically distributed teams with diverse cultural, educational and disciplinary backgrounds. Meanwhile, both the industry and education sectors are facing the rapid evolution of digital design environments driven by the widespread adoption of integrated Computer-Aided Design (CAD) and Product Lifecycle Management (PLM) systems. These technological advancements mean that designers must not only master new tools, but also adapt to standardised workflows, collaborative processes and data-driven practices throughout the entire product lifecycle [1], [2].

Guideline-based learning is often adopted in industrial training to facilitate transitions, providing a structured learning approach that fosters consistency and facilitates knowledge transfer between teams. Design guidelines, procedural rules, and modelling conventions help to align training with organisational standards, enabling designers to apply their skills in real-world contexts. These guidelines serve as learning resources and reference materials, facilitating knowledge transfer across diverse user groups and teams.

However, although guideline-based learning approaches are usually presented as neutral and universally applicable, they are actually shaped by learners' cultural and contextual backgrounds. Research in cultural cognition has demonstrated systematic differences in how individuals from different cultures perceive structure, interpret rules and solve problems. These variations can have a significant impact on the interpretation and application of design guidelines, particularly in teams that are distributed across the globe [3].

In global engineering environments, in particular, there is a critical need for a guideline-based learning framework that can accommodate cultural diversity. Misinterpretation of guidelines can lead to modelling inconsistencies, misunderstandings and reduced confidence in new workflows. This emphasises the importance of understanding how practitioners from different backgrounds interact with shared instructional artefacts during training and further development processes.

This paper examines guideline-based learning from the perspective of cultural cognition in the context of an industry-led CAD/PLM transition. Building on prior research, the study explores the influence of cultural thinking patterns on designers' engagement with structured learning artefacts. The paper highlights the challenges of adapting guideline-based learning frameworks for use with culturally diverse teams and offers insights that contribute to the broader discussion on diversity and inclusivity in engineering and product design education.

2 CONCEPTUAL BACKGROUND AND POSITIONING

This section outlines the study's conceptual framework by situating guideline-based learning within discussions on CAD/PLM transitions, workplace learning, and engineering design education. It also introduces cultural cognition as an analytical approach to understanding how globally distributed engineering teams interpret shared instructional artefacts.

2.1 Guideline-based learning in CAD/PLM transitions

The growing complexity of digital engineering environments has emphasised the importance of structured learning approaches during CAD/PLM transitions. In industrial contexts, guideline-based learning is commonly employed to support the adoption of modelling conventions, workflow procedures, and collaborative practices associated with integrated digital engineering systems [4]. Rather than focusing on software functionality, this approach integrates learning into real engineering activities and organisational processes.

Guidelines usually formalise modelling principles, procedural rules, and coordination mechanisms designed to promote consistency among engineering teams. During CAD/PLM transitions, these artefacts often serve operational and educational purposes, supporting standardisation while facilitating learning and knowledge transfer among users with varying levels of expertise and professional experience. From a workplace learning perspective, guidelines can be understood as artefacts that facilitate participation in professional practice by mediating interaction between organisational expectations and individual engagement [5]. Similarly, research on learning objects highlights the role of structured instructional resources in facilitating the transfer and reuse of knowledge in different learning situations [6]. Within communities of practice, such artefacts also facilitate the negotiation of shared meanings and professional identities among practitioners [7]. Previous industrial experiences with structured learning approaches have similarly highlighted the potential of guideline-centred training to support procedural understanding, knowledge transfer and scalable learning during complex software transition processes.

From an educational perspective, guideline-based learning can be viewed as a type of scaffolded workplace learning that links abstract system knowledge with practical engineering experience. This approach aligns with experiential and practice-oriented learning theories, which emphasise integrating conceptual, procedural, and reflective knowledge through authentic task engagement [8], [9]. Recent discussions in engineering education also highlight the importance of contextualised, practice-based learning environments in supporting collaborative engineering work and developing digital competencies.

At the same time, guideline-based learning differs from instructional or tool-oriented training approaches because it relies heavily on interpretation. Rather than providing exhaustive coverage of every possible modelling situation, guidelines are designed to be interpreted and adapted by users within evolving engineering contexts. Therefore, the effectiveness of guideline-based learning depends on both the quality of the guidelines and how learners engage with them. This is particularly important in globally distributed engineering environments, where teams may have different approaches to structure, ambiguity, and professional judgement.

2.2 Cultural cognition and diversity in engineering design practice

Research in cultural cognition suggests that reasoning processes and decision-making strategies are influenced by culturally embedded norms, educational traditions and professional practices [3]. Rather than assuming that all learners interpret information in the same way, this perspective recognises that individuals may prioritise different forms of coherence, justification and problem solving when engaging with complex engineering tasks. These differences can affect how design engineers organise activities, interpret procedures and evaluate acceptable solutions in collaborative engineering

environments. Additionally, research on design teamwork has shown that diversity in learning styles and cognitive approaches can impact team interaction and engineering problem-solving processes [10]. These aspects become particularly relevant when formalised learning artefacts, such as modelling guidelines or workflow conventions, are introduced to regulate engineering practices. Although these guidelines aim to reduce ambiguity and promote consistency, their implementation is neither neutral nor uniform. Design engineers interpret and apply guidelines through the lens of their prior experience, local practices and culturally influenced expectations regarding autonomy, rules and professional judgement. Consequently, identical guidelines may lead to different interpretations and modelling behaviours across teams, even when the formal instructions themselves remain unchanged.

From an engineering and product design education perspective, these dynamics challenge learning models that focus solely on standardisation. Educational research increasingly highlights that effective learning environments should accommodate diverse reasoning strategies, modes of participation and professional perspectives, rather than assuming a single ideal approach to learning and problem solving. In communities of practice, learning emerges through compliance with formal rules, negotiation, interaction and shared meaning-making among practitioners. Similarly, recent discussions on inclusive, cross-cultural design learning emphasise the importance of creating collaborative learning environments that support multiple forms of participation and interpretation within globally distributed teams [11], [12].

These considerations align closely with current discussions surrounding diversity and inclusivity in engineering education. Inclusive learning environments require more than the dissemination of standardised procedures; they must also recognise and support the various ways in which people understand and engage with engineering knowledge. In globally distributed engineering teams, cultural diversity should not be viewed as an obstacle to standardisation, but as a factor that must be explicitly considered when designing learning frameworks that rely on shared artefacts and collaborative interpretation.

Figure 1 illustrates the conceptual relationship between organisational standardisation objectives, guideline-based learning and culturally influenced interpretation in engineering environments across the globe. It presents guideline-based learning as a framework that connects shared organisational practices with diverse reasoning strategies, workplace learning processes and collaborative meaning-making among engineering teams.

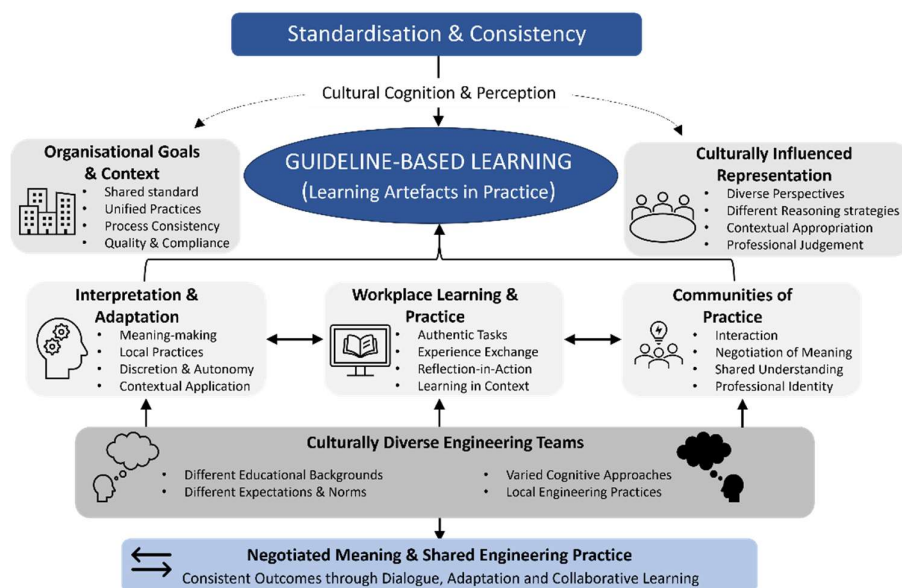


Figure 1. Guideline-based learning as a mediating framework

Adopting this perspective, the present study conceptualises guidelines as interpretative resources, the effectiveness of which depends on how they are negotiated within culturally diverse learning environments, rather than viewing them as static sets of instructions. This conceptual positioning provides the basis for analysing how guideline-based learning can support standardisation and inclusivity in global engineering and product design.

3 INDUSTRIAL CONTEXT AND METHODOLOGICAL APPROACH

This study is based on a CAD/PLM transition project led by industry and carried out within an international engineering organisation operating across geographically distributed sites. The project involved deploying shared modelling conventions, workflow procedures and training guidelines to support the harmonisation of engineering practices within a global digital engineering environment.

3.1 Industrial project context

The transition programme was based on a guideline-driven learning strategy. Rather than focusing exclusively on software functionalities, the training programme integrated modelling rules, workflow conventions, and procedural recommendations directly into practical engineering activities. The guidelines therefore functioned as both operational reference documents and learning artefacts, supporting knowledge transfer and collaborative interpretation among users.

The guidelines were developed and deployed through an iterative and participatory process involving project managers, key users, engineering specialists and the external consulting team. Initially, experienced users contributed to defining and validating modelling conventions based on operational requirements and existing engineering practices. These guidelines were then disseminated progressively to broader engineering teams through structured training sessions, collaborative workshops, and workplace support activities.

The guideline documents combined procedural descriptions, workflow recommendations, and structured organisational information, all of which were intended to support practical engineering activities. Figure 2 illustrates an example of the structure and organisational content of the guideline documents used during the CAD/PLM transition project.

Guideline for Document Template	Content
Version: XX Last Review Day Month Year Date: Day Month Year Accountable Manager: Name of the Manager Owner: XXXXXXXXXXXX Scope: All Engineers of XXXXXXXXXXXX Purpose This guide ensures that the appropriate site is selected for the project and that the templates and system parameters specific to that site are used for the design. Scope This design guideline applies to all areas of XXXXXXXXXXXX.	1. Introduction 5 1.1. Definition and purpose of part families 5 1.2. Advantages of using part families 5 1.3. Areas of application of part families 5 2. Create and handle part families in Siemens NX 6 2.1. Prerequisites 6 2.2. Creating a master component 6 2.3. Defining variants 8 2.4. Working with part families using external spreadsheets 12 2.5. Creating child components 14 2.6. Managing part families 15 3. Working with part families in Siemens NX 16 3.1. Changing variants 16 3.2. Creating drawings and parts lists 17 3.3. Using part families in assemblies 17 3.4. Managing part families in a team 19 4. Best practices for part families in Siemens NX 19 4.1. Standardization of designations and structures 19 4.2. Effective use of attributes and formulas 21 4.3. Integration with PLM Teamcenter 21

Figure 2. Example structure of a guideline document used during the CAD/PLM transition

3.2 Methodological approach

The study takes a qualitative, practice-oriented approach, focusing on how guideline-based learning was interpreted and implemented in the context of industrial software transition processes. Rather than quantitatively measuring learning outcomes, the objective was to identify recurring patterns in the way engineering teams engaged with shared instructional artefacts during training and operational activities. The findings presented in this paper are derived primarily from feedback, observations, and experience reports produced by the external experts and trainers who were involved in implementing and supporting the transition project. These observations were made during training sessions, collaborative workshops, user support activities, and discussions with project stakeholders, which were conducted throughout the deployment process. Therefore, the study does not rely on controlled experimental observation of participants, but rather on interpretative analysis of practices, interactions, and recurring issues identified during implementation of the learning framework.

The analytical process focused on identifying recurring themes related to:

- engagement with structured guidelines;
- expectations regarding levels of prescription and autonomy;
- interpretation of modelling conventions;
- collaborative clarification processes;
- adaptation of shared practices within culturally diverse engineering teams.

These themes were interpreted through the conceptual perspectives introduced in Section 2, particularly cultural cognition, workplace learning, and communities of practice. The objective was not to categorise participants according to national culture or demographic characteristics, but rather to explore how reasoning patterns influenced by culture and professional contexts shaped interactions with shared learning artefacts.

3.3 Scope and limitations

As the study is based on a single industrial CAD/PLM transition project, it reflects a context-specific learning environment. While the project involved geographically distributed teams and culturally diverse engineering contexts, the findings should not be interpreted as being applicable to all industrial sectors or engineering organisations.

Additionally, the study primarily relies on qualitative interpretations derived from industrial practice, rather than quantitative learning assessments or controlled comparative analyses. Consequently, the paper does not attempt to establish causal relationships between cultural background and specific learning outcomes. Instead, it seeks to identify recurring interpretative dynamics and practical considerations relevant to guideline-based learning within global engineering environments.

Nevertheless, the project's industrial scale, the diversity of the engineering teams involved, and the systematic implementation of structured learning artefacts provide a meaningful basis for discussing how guideline-based learning frameworks may support standardisation and inclusivity in engineering and product design education. Future work could build on this research by comparing multiple industrial contexts and combining qualitative observations with quantitative indicators related to learning performance, modelling consistency, and collaborative efficiency.

4 FINDINGS AND IMPLICATIONS

The analysis revealed recurring patterns relating to engagement with guidelines, the interpretation of modelling conventions and collaborative learning processes within culturally diverse engineering teams. Despite working with the same instructional materials and organisational objectives, the analysis revealed that engineering teams did not engage with guideline-based learning in a uniform manner. Differences in interpretation of modelling conventions, approach to procedural instructions, and balancing of formal rules with professional judgement emerged repeatedly. Some users preferred highly structured and explicit guidance, treating the guidelines as authoritative references primarily intended to minimise ambiguity during the transition process. Others took a more flexible approach to the guidelines, focusing on understanding the rationale behind modelling conventions and adapting recommendations to specific engineering situations and local practices.

These differences were not necessarily linked to levels of expertise or technical competence; rather, they reflected different expectations concerning the structure of engineering work, autonomy, and approaches to problem solving. Both engagement patterns contributed to effective learning when supported through collaborative interpretation and contextual explanation. In practice, the guidelines rarely functioned as static repositories of instructions. Instead, they became focal points for clarification, negotiation and collaborative interpretation during training sessions and operational activities. Questions relating to exceptions, contextual adaptations, and the interpretation of modelling rules often sparked discussion among users and trainers, fostering shared understanding and flexible standardisation across teams.

Therefore, the findings support the perspective introduced in Section 2 that guidelines operate not only as procedural documents, but also as learning artefacts, the meaning of which emerges through interaction and situated practice. In globally distributed engineering environments, the effectiveness of guideline-based learning depends on the quality and clarity of the guidelines, and on learning environments accommodating diverse reasoning strategies and collaborative interpretation processes.

From an engineering and product design education perspective, these observations emphasise the importance of designing structured learning frameworks that balance standardisation with interpretative flexibility. While shared modelling conventions and workflow procedures are necessary for

organisational consistency, inclusive learning environments should also facilitate discussion, contextual explanation, and various forms of engagement with engineering knowledge. The findings suggest that culturally responsive, guideline-based learning frameworks could strengthen organisational harmonisation and collaborative learning within global engineering contexts.

5 CONCLUSIONS

This paper examined guideline-based learning in the context of an industry-led CAD/PLM transition involving geographically dispersed engineering teams. The findings show that shared guidelines are not uniformly interpreted, but are instead shaped by various reasoning strategies, professional practices, and expectations concerning structure and autonomy. Rather than functioning solely as procedural documents or static sets of rules, the guidelines operated as mediating learning artefacts, the meaning of which emerged through interaction, discussion and situated engineering practice.

The study highlights the importance of balancing organisational standardisation with interpretative flexibility in global engineering environments. Although structured guidelines are important for harmonising engineering practices, effective learning frameworks must also support collaborative interpretation and accommodate various approaches to professional problem solving. The findings suggest that productive learning can be supported by different modes of engagement with guidelines when accompanied by opportunities for discussion, contextual explanation and reflection.

Although this study is based on a single industrial case and relies primarily on qualitative interpretations derived from practice-oriented observations, it provides insights into how culturally responsive, guideline-based learning could support inclusivity and knowledge transfer in engineering and product design education. Future work could build on this research by comparing multiple industrial contexts and combining qualitative observations with quantitative indicators related to learning performance and collaborative engineering practices.

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