DISCLAIMER

ORNL/TM-2025/4285

Bridging Practice and Andragogy: Evidence-Based Approaches for Manufacturing Workforce Trainers

Qi Sun
Wei Guo
Paulomi Nandy
Kalie Miera
Ethan Guo
Melrose Pan
Thomas Wenning
Sachin Nimbalkar

March 2026

OAK RIDGE National Laboratory

ORNL IS MANAGED BY UT-BATTELLE LLC FOR THE US DEPARTMENT OF ENERGY

ORNL/TM-2025/4285

Manufacturing Science Division

BRIDGING PRACTICE AND ANDRAGOGY: EVIDENCE-BASED APPROACHES FOR MANUFACTURING WORKFORCE TRAINERS

Qi Sun*
Wei Guo†
Paulomi Nandy†
Kalie Miera†
Ethan Guo†
Melrose Pan†
Thomas Wenning†
Sachin Nimbalkar†

* University of Tennessee, Knoxville
† Oak Ridge National Laboratory

March 2026

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, TN 37831
managed by
UT-BATTELLE LLC
for the
US DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

CONTENT

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Oak Ridge National Laboratory and the University of Tennessee Knoxville, developed a series of 16 Train-the-Trainer Tip Sheets to strengthen the educational foundation of the manufacturing and energy workforce. This work was funded by the U.S. Department of Energy's Office of Critical Minerals and Energy Innovation Contract No. DE-AC05-00OR22725.

Whereas many training programs emphasize technical skills, trainers often lack resources that translate educational theory into practical instructional methods. The ISEED Tip Sheets bridge this gap by distilling proven adult learning theories, instructional strategies, and behavioral principles into concise, actionable guidance for technical trainers.

Following is a summary of the 16 tip sheets, which reflect a holistic view of adult learning in technical and workforce environments:

- Tip Sheet 1: Andragogy—The Science of Adult Education.
- Tip Sheet 2: Self-Directed Learning.
- Tip Sheet 3: McClusky's Theory of Margin.
- Tip Sheet 4: Problem-Based Learning in the Workplace.
- Tip Sheet 5: Cognitive Apprenticeship Model.
- Tip Sheet 6: Adult Learning Preferences.
- Tip Sheet 7: Communities of Practice and Situated Learning in Workforce Development.
- Tip Sheet 8: Simulation and Role-Play in Adult Learning.
- Tip Sheet 9: Constructivist Learning in the Workplace.
- Tip Sheet 10: Motivation Theory in the Workplace.
- Tip Sheet 11: Emotional Intelligence.
- Tip Sheet 12: Technology Integration in Adult Learning.
- Tip Sheet 13: Blended Learning in the Workplace.
- Tip Sheet 14: Experiential Learning.
- Tip Sheet 15: Active Listening in Workforce Development Programs.
- Tip Sheet 16: Ethical Considerations in Workplace Training.

INTRODUCTION

The US manufacturing workforce benefits from numerous programs and resources that develop technical expertise; however, fewer tools exist to help trainers strengthen how they design and deliver training programs. Most technical trainers have deep engineering and operational knowledge but limited exposure to the science of Adult Learning, known as Andragogy. Addressing this gap can significantly enhance the effectiveness and reach of workforce development efforts. The Train-the-Trainer Tip Sheets were created to fulfill this requirement by converting research-based educational theories into practical, actionable strategies specifically designed for trainers working with adult learners within manufacturing and energy efficiency settings.

These Tip Sheets are designed to empower instructors, technical experts, and training organizations to integrate evidence-based adult learning principles, models, and theories into their programs. Each document introduces a key educational theory or instructional approach of Andragogy, such as, Self-Directed Learning, Motivation Theory, Problem-Based Learning, Simulation and Role-Play, and Community of Practice, and translates that theory or approach into workforce-relevant applications. By applying these concepts, trainers can create more engaging, inclusive, and effective learning environments that improve retention, motivation, and on-the-job performance.

Each Tip Sheet includes the following:

- A brief overview of the theory or concept and its relevance to adult and workforce learning.
- Practical strategies and real-world examples of how to apply the concept in technical training environments.
- Key takeaways summarizing how trainers can implement the ideas immediately in their classrooms, workshops, and on-the-job training programs.

Together, the 16 Tip Sheets form a comprehensive toolkit that connects the science of adult learning with manufacturing workforce development. They are modular, so that trainers can use each sheet independently or as part of a broader professional development series.

Trainers can use these Tip Sheets to do the following:

- Enhance instructional design by aligning training with adult learning principles.
- Adapt delivery methods to diverse learner needs, including multimodal and experiential learning.
- Incorporate reflection, feedback, and motivation strategies to strengthen learner engagement.
- Foster collaboration and mentorship through communities of practice and situated learning.
- Build learning cultures that promote continuous improvement and adaptability.

Following is the complete set of all 16 ISEED Train-the-Trainer Tip Sheets, providing detailed theoretical background, strategies, and implementation examples for each topic.

1. ANDRAGOGY—THE SCIENCE OF ADULT EDUCATION

1.1 WHAT IS ANDRAGOGY?

Andragogy is the study of how adults learn. In 1967, Malcolm Knowles introduced andragogy to the US as a set of adult learning principles based on six assumptions that have evolved over the year [1]. It emphasizes the distinct needs and characteristics of adult learners, adopts a learner-centered approach, and presents a model for the learning process.

1.2 ANDRAGOGICAL ASSUMPTIONS OF ADULT LEARNERS

Figure 1 presents the assumptions common to adult learning.

1. **Need to Know**: Why they need to learn something.
2. **Self-Concept of the Learner**: Self-directing, autonomous, responsible for their learning
3. **The Role of Experience**: Accumulated experiences as learning resources.
4. **Readiness to Learn**: Life and role-related developmental tasks.
5. **Orientation to Learning**: Problem-centered, situational, and contextual.
6. **Motivation to Learn**: Intrinsic values [1, 2, 3].

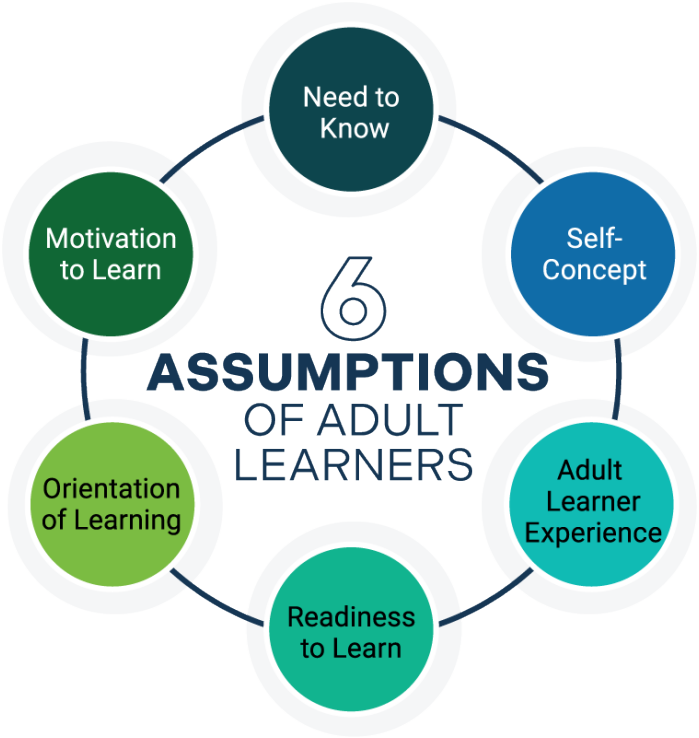

Figure 1. Six Assumptions of Adult Learners. *Image Credit* [1].

1.3 ANDRAGOGY VS. PEDAGOGY

While **Andragogy** is the study of how adults learn, most people are more familiar with **Pedagogy**, which is the study of how children learn. Understanding the differences between andragogy and pedagogy is crucial in designing and delivering effective workforce training programs. Effective workforce training often requires a blend of both andragogical and pedagogical models to tailor to the learners' specific needs and training context. This distinction informs how training programs effectively meet the needs of both learning goals and adult learners, particularly those in the manufacturing sectors. Table 1 shows the difference in assumptions between Andragogy and Pedagogy for various categories.

Table 1. The Difference of Assumptions between Andragogy and Pedagogy. [1].

Assumptions about Learners		
Category	**Andragogy (Adult Learning)**	**Pedagogy (Child Learning)**
Self- Concept	Self-directiveness	Dependency
Experience	Learners are a rich resource for learning	Of little worth
Readiness	Developmental tasks of social roles	Biological development social pressure
Time Perspective	Immediacy of application	Postponed application
Learning Orientation	Problem centered	Subject centered
Motivation	Intrinsic	Extrinsic

1.4 ANDRAGOGY VS. PEDAGOGY IN PRACTICE

Andragogy recognizes that adult learners are self-directed and bring a wealth of experience to the learning process. In contrast, pedagogy assumes that learners depend on the

instructor for knowledge and guidance. **Andragogical programs** focus on a learning process with goals and strategies relevant to the learners' sense of self, needs, experiences, and resources. **Pedagogical programs**, on the other hand, emphasize content and the dissemination of information, as they assume that learners rely heavily on the instructor. Both approaches benefit the learning and training of adults.

Example: An example of andragogy is applied when real-life scenarios and case studies are used in training sessions to draw upon learners' prior knowledge. Workers in the manufacturing sector often have practical experience. Training should leverage this experience, allowing employees to contribute insights and apply new knowledge directly to their roles; however, some concepts, (e.g., health worker and safety) can be more universal and may be rigidly structured through regulatory requirements. In these instances, a pedagogical approach may be more beneficial. In the workplace settings, a balance of both pedagogy and andragogy may be required for effective training.

1.5 TIPS FOR IMPLEMENTATION OF ANDRAGOGY

- Design a physically and psychologically friendly learning environment (e.g., seating, lighting)
- Provide self-planning, self-diagnostic, and self-evaluating experiences

- Provide proper timing for tasks, being sensitive to grouping learners
- Use proper language, terms, and style for different audiences
- Provide rationales for training objective and purposes of learning activities
- Engage Learners: Use interactive techniques such as discussions, problem-solving activities, and case studies
- Leverage Experience: Incorporate the learners' existing knowledge and practical experiences into the training
- Facilitate Self-direction: Encourage learners to set learning goals and seek resources
- Apply Learning: Design training activities that allow immediate application of skills in real-world scenarios

1.6 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

1.7 REFERENCES

[1] Malcom Shepherd Knowles. *The adult learner: a neglected species*. Gulf Publication Company, Houston, TX, 4th edition, 1990.

[2] M. S. Knowles. *The modern practice of adult education: From pedagogy to andragogy*. Cambridge Books, New York, NY, 2nd edition, 1980.

[3] M. S. Knowles, E. F. Holton III, R. A. Swanson, and Petra A. Robinson. *The adult learner*. Routledge, London, 9th edition, 2020.

2. SELF-DIRECTED LEARNING

2.1 WHAT IS SELF-DIRECTED LEARNING?

Self-directed learning (SDL) is an educational process in which individuals take primary responsibility for planning, executing, and evaluating their learning experiences [1], often driven by intrinsic motivation and critical reflection. This concept is rooted in adult education theories and has gained prominence due to its alignment with lifelong learning and adaptability in a rapidly changing world. The importance of SDL lies in fostering autonomy and self-motivation among adult learners. Expanding on Knowles' framework, Garrison proposed a comprehensive model (Figure 2) highlighting the interplay between self-management, self-monitoring, and motivation in SDL [2].

Figure 2. Dimensions of Self-Directed Learning. *Image Credit* [2].

SDL involves individuals taking the initiative to understand adult learning needs, set goals, identify resources, select strategies, and assess learning outcomes [1]. SDL fosters the development of critical competencies such as problem-solving, decision-making, and critical thinking, which are essential for addressing complex workplace challenges [3]. It also promotes lifelong learning habits, vital skills for career development, and adaptability in a rapidly changing job market.

2.2 BENEFITS OF SELF-DIRECTED LEARNING FOR TRAINING

- Increases learner motivation and engagement as employees take ownership of their learning,
- Promotes flexibility, enabling learners to pursue knowledge and skills directly relevant to their roles and career aspirations,

- Encourages the development of critical thinking and problem-solving skills,
- Promotes the active exchange of shared ideas among learners to solve issues,
- Organizations that invest in creating an environment conducive to SDL can benefit from a more skilled, innovative, and reliable workforce, ultimately enhancing their competitive edge in the market.

2.3 STRATEGIES TO SUPPORT SELF-DIRECTED LEARNING

- **Create a Supportive Environment:** Foster a culture that values learning and encourages trainees and employees to take initiative.
- **Offer Guidance:** While SDL emphasizes learner autonomy, providing mentorship and support can help guide learners in their journey.
- **Provide Resources:** Offer access to various learning materials, including online courses, workshops, and reading materials to support learners.
- **Integrate Technology:** Utilize learning management systems and various digital tools to enhance access to learning resources and monitor progress.
- **Application:** Provide field employees with mobile learning tools and resources that they can access remotely, allowing them to learn at their own pace and immediately apply new knowledge. Varius strategies can enhance the integration of SDL in workplace training, such as offering access to a wide range of learning resources, ensuring mentorship and support, and cultivating a learning culture that values and rewards self-directed efforts [4].

2.4 TIPS FOR IMPLEMENTING SELF-DIRECTED LEARNING

- **Assess Needs:** Help employees identify their learning needs and set realistic goals.
- **Encourage Reflection:** Create opportunities for learners to reflect on their learning experiences and outcomes.
- **Provide Feedback:** Offer constructive feedback to help learners stay on track and achieve their goals.
- **Promote Collaboration:** Encourage peer learning and knowledge sharing through group activities and discussions.

2.5 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

2.6 REFERENCES

[1] Malcolm Shepherd Knowles. *Self-directed learning: A guide for learners and teachers*. Association Press, New York, NY, 1975.

[2] D. R. Garrison. Self-directed learning: Toward a comprehensive model. *Adult Education Quarterly*, 48(1):18–33, 1997.

[3] Stephen D. Brookfield. *Powerful techniques for teaching adults*. Jossey-Bass, San Francisco, CA, 2013.

[4] Andrea D Ellinger. The concept of self-directed learning and its implications for human resource development. *Advances in developing human resources*, 6(2):158–177, 2004.

3. MCCLUSKY'S THEORY OF MARGIN

3.1 WHAT IS MCCLUSKY'S THEORY OF MARGIN?

McClusky's Theory of Margin [1, 2, 3, 4], shown in Figure 3, focuses on the relationship between an individual's "**Load**"—comprising responsibilities, stressors, and demands—and their "**Power**" which includes resources, skills, and support. This theory determines an individual's capacity for learning and provides a critical framework for understanding adult learning by examining the interplay between "Load" and "Power." "Load" encompasses the cumulative demands placed on adults, such as occupational familial, and social responsibilities, while "power" refers to the resources and capacities—like time, skills, and support systems—that individuals can leverage to manage these demands. The "**Margin**" (**Margin = Power/Load**) signifies the energy available for learning and growth [4]. In adult education, particularly in workforce development, maintaining a favorable Margin—where Power sufficiently exceeds Load—is essential for optimizing learning outcomes. This balance allows learners to allocate the necessary cognitive and emotional resources to acquire new competencies, facilitating professional advancement and adaptability.

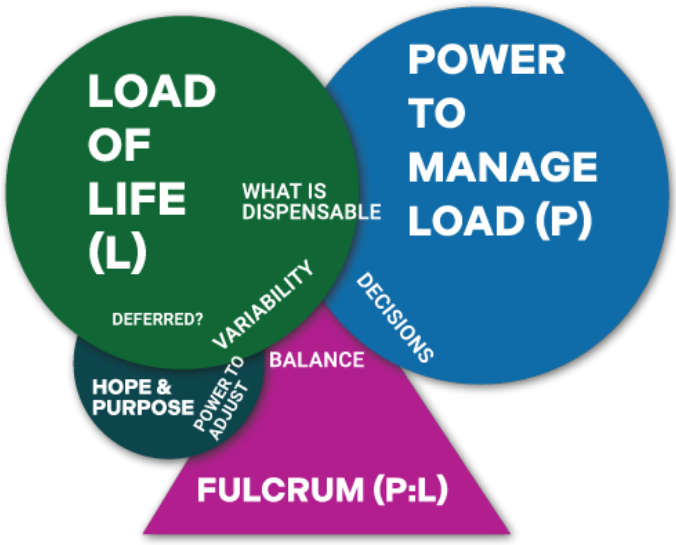

Figure 3. McClusky's Theory of Margin. *Image Credit* [1].

In workforce training and development, trainers play a crucial role in helping employees maintain this margin. By applying McClusky's theoretical insights, trainers become more mindful when designing educational programs that accommodate the existing responsibilities of adult learners. They incorporate support mechanisms such as flexible scheduling, individualized learning pathways, and improved resource access [5]. By acknowledging the diverse pressures faced by adult learners, trainers can foster a learning environment that empowers these learners, thereby enhancing their ability to manage their responsibilities and succeed in their professional development efforts [6].

3.2 APPLICATION OF MCCLUSKY'S THEORY OF MARGIN

Manufacturers can leverage McClusky's theory to design training environments that significantly enhance workers' learning capabilities. This leads to a more seamless adoption of Industry 4.0 and 5.0 technologies, as well as improved productivity. Organizations can empower employees by offering flexible scheduling, providing access to skills development resources, and cultivating supportive learning

environments [5]. These strategies enable employees to effectively manage their "Loads" with increased "Power" while concentrating on their professional training and growth.

Personalized learning pathways and mentorship opportunities further enhance employees' "power," increasing their ability to manage responsibilities while engaging in continuous learning [6]. This approach not only benefits individual employees but also boosts overall organizational performance.

3.3 STRATEGIES AND EXAMPLES FOR IMPLEMENTING MCCLUSKY'S THEORY OF MARGIN

Implementing mentorship programs connects employees with experienced colleagues who can offer guidance and support. This relational resource increases employees' "Power" by providing advice, feedback, and encouragement, which helps them navigate workplace challenges and learning processes more effectively. Such support networks can mitigate the impact of their existing "Load" and enhance their capacity for professional growth.

1. **Assess and Reduce "Load" in Training Programs:** Assessing the demands (Load) and resources (Power) of employees through surveys and interviews helps identify specific times and areas of need and supports required.

   According to Merriam and Bierema, understanding learners' contexts is crucial for effective adult education [7].

   a. Workload Balance: Avoid overwhelming trainees with training sessions during high-stress production periods. Schedule training during downtime or lighter shifts,

   b. Simplify Complexity: Break technical training into smaller, manageable modules to reduce cognitive load,

   c. Address Psychological Stress: Provide mental health resources to mitigate stress by adapting mindfulness and relaxation activities to new technologies.

2. **Enhance "Power" Through Support Systems:** Establish a system and ensure employees access necessary learning materials and technologies, empowering learners to manage their load effectively. Develop peer mentorship programs and support groups/networks and allocating training time can increase employees' power, which helps balance personal and professional demands. As suggested by Kram, mentoring programs are instrumental in empowering trainees by providing guidance and emotional support for enhancement [8].

   a. Peer Mentorship: Pair new hires with experienced workers to create a support system (increasing "Power" through shared knowledge)

   b. Skill-Building Tools: Equip workers with accessible resources (e.g., guided tutorials, microlearning applications) to build confidence in using learning

   c. Managerial Backing: Ensure supervisors actively endorse training time and provide feedback to reinforce learning

3. **Optimize the "Margin" for Effective Learning:** Research by Bork & Rucks-Ahidiana demonstrates that flexibility in learning environments enhances engagement and retention which enhance learners'

"Margin" Flexibility, adequate training, audience characteristics, and recognition as a motivational force can all enhance the margin for effective learning outcomes [9].

a. Flexible Training Formats: Offer blended learning (e.g., virtual + hands-on) to accommodate varying workloads and learning paces,

b. Just-in-Time Training: Offer on-demand modules (e.g., troubleshooting guides through mobile apps) to enable workers to resolve issues without interrupting workflow,

c. Recognition Programs: To encourage participation and balance the "Load" of training and reward skill mastery (e.g., certifications and bonuses),

d. Personalized Pathways: Tailor training intensity based on roles (e.g., assembly-line workers vs. engineers) and experience levels,

e. Work-Life Integration: Avoid scheduling training outside of shifts for hourly workers to reduce non-work "Load" such as family obligations,

f. Develop Flexible Learning Options: Provide a variety of training formats, including online courses and hybrid models, to accommodate diverse schedules and lighten employee workloads.

3.4 KEY TAKEAWAYS

- **Balance is Key:** Understand the importance of balancing "Load" (responsibilities and stressors) and "Power" (resources and support), as a favorable margin enhances learning capacity,

- **Assess Learners' Needs:** Regularly evaluate the demands on your learners and their available resources. This helps tailor training programs to better support their learning journey,

- **Flexible Learning Options:** Provide flexible training schedules and formats to accommodate varying personal and professional commitments, reducing the learners' load,

- **Enhance Support Systems:** Implement mentorship and peer support networks to increase learners' "Power" by offering guidance and encouragement,

- **Resource Accessibility:** Ensure learners have easy access to necessary materials and tools, empowering them to manage their responsibilities and learning effectively.

3.5 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

3.6 REFERENCES

[1] T.M. Stafford. Learning Theory—The Margins of Learning Management: How to Keep Learning Indispensable, 2012.

[2] H. J. McClusky. The course of the adult life span. *Psychology of Adults*, pages 10–19, 1963.

[3] H. Y. McClusky. The demand for continual learning in modern society. *University of Michigan School of Education Bulletin*, 34(8):113–118, 1963.

[4] H. Y. McClusky. A dynamic approach to participation in community development. *Journal of Community Development Society*, 1:25–32, 1970.

[5] R. M. Smith. *Learning How to Learn: Applied theory for adults*. Perason Prentice Hall, 2010.

[6] S. D. Brookfield. *Understanding and facilitating adult learning: A comprehensive analysis of principles and effective practices*. Jossey-Bass, 1986.

[7] S. B. Merriam and L. L. Bierema. *Adult learning. Linking theory and practice.* Jossey-Bass, San Francisco, CA, 2014.

[8] Kathy E Kram. *Mentoring at work: Developmental relationships in organizational life.* University Press of America, 1988.

[9] R. H. Bork and Z. Rucks-Ahidiana. The role of flexibility in online learning. *Journal of Online Learning and Teaching*, 9(2):174–189, 2013.

4. PROBLEM-BASED LEARNING IN THE WORKPLACE

4.1 EXPLORING PROBLEM-BASED LEARNING IN WORKFORCE DEVELOPMENT ENVIRONMENTS

Problem-Based Learning (PBL) is an instructional approach that prioritizes learning and applying knowledge through the investigation of real-world problems (Figure 4). This pedagogical method encourages learners to learn actively by engaging them in collaborative inquiry, which fosters essential skills such as critical thinking, communication, and problem-solving [1].

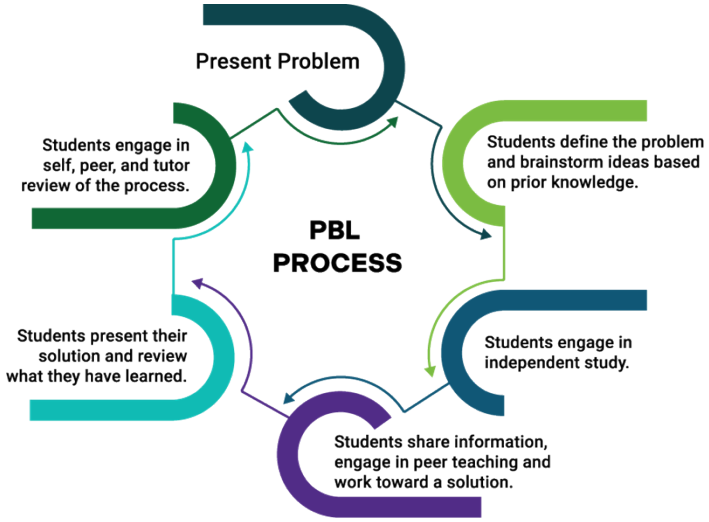

Figure 4. Typical Steps in Problem-Based Learning. *Image Credit* [2].

The key components of PBL include: 1) Learner-Centered Education: encouraging learners to take an active role and be responsible for actively engaging in learning. 2) Real-World Problems: focusing on relevant problems and issues to engage learners. 3) Collaborative Learning: fostering teamwork and knowledge co-construction. 4) Self-Directed Learning: enabling learners to identify needs, set goals, and find resources, promoting independence and critical thinking. PBL represents experiential learning, inquiry-driven exploration, and reflective practice. PBL is a practical strategy for motivating adult learners to actively participate in their training programs by tackling problems directly relevant to their work.

In industrial environments, workforce development programs that incorporate Problem-Based Learning can significantly enhance employees' adaptability to constantly evolving work conditions. By presenting participants with real-world challenges tailored to their industries, PBL improves their understanding of workplace dynamics and fosters a collaborative spirit essential for effective teamwork [1]. PBL encourages collaboration among participants, allowing them to leverage their experiences, knowledge, and skills to address real issues in impactful ways. The combination of inquiry and reflection in PBL not only enriches the learning experience but also equips employees with crucial skills for thriving in a dynamic industrial environment. By perceiving real-world challenges as educational experiences, PBL prepares the workforce to navigate complexities and adapt to new requirements, supporting their professional growth and the success of their organizations.

4.2 PRACTICAL APPLICATIONS

4.2.1 Problem-Based Learning in Workforce Development

Problem-based learning can be effectively applied in workforce development training programs by engaging adult learners in real-world challenges pertinent to their workplace. This approach facilitates participants to collaboratively identify, analyze, and devise solutions for issues and problems they encounter in their roles. By centering the learning experience around actual scenarios, PBL fosters critical thinking and problem-solving skills and ensures that the knowledge acquired is directly applicable and relevant to the participants' daily tasks. As Thomassen and Jørgensen noted, integrating practice with theory allows learners to reflect on their experiences, enhancing their capacity to navigate and manage the multifaceted challenges present in contemporary industrial settings.

4.2.2 Strategies for Applying PBL

To effectively implement PBL in workforce development programs, trainers can employ several strategies to encourage participant engagement.

- Designing learning activities grounded in authentic workplace challenges enables learners to work on problems they are likely to face in their roles.

- Facilitating group discussions and encouraging peer-to-peer interactions, thereby creating a supportive atmosphere for shared learning.

- Providing structured guidance on how to approach problem-solving—such as defining the problem, generating potential solutions, and evaluating outcomes—can help learners navigate the complexities of their tasks.

- Incorporating regular reflection sessions will allow participants to assess their learning and adapt their strategies based on their experiences, thus reinforcing the iterative nature of PBL.

4.2.3 Examples of Implementing PBL

4.2.3.1 Example 1: Real-World Case Studies

Description: Utilize actual challenges/problems the company faces as case studies for problem-based learning. This method engages employees in analyzing and solving issues that they may encounter in their daily operations.

Implementation: Choose a recent workplace issue, such as a production delay caused by equipment failure. Divide employees into small groups and provide them with pertinent data, including production schedules and maintenance records. Instruct each group to analyze the situation and propose solutions based on their findings and insights.

Expected Benefit: This approach aids employees in developing critical thinking and problem-solving skills while empowering them to contribute to solutions that directly enhance their work environment. Employees gain a deeper understanding of operational challenges and learn to apply theoretical knowledge to practical situations.

4.2.3.2 Example 2: Learning to Practice

Description: Organize workshops focused on application towards resolving issues, where employees collaboratively tackle assigned challenges using learned knowledge and skills. These workshops encourage learners to connect theory, knowledge, and skills with practical, innovative solutions.

Implementation: Organize regular workshops where trainees bring specific problems they face. Trainers share updated knowledge and skills that may help resolve problems. Host structured brainstorming sessions that allow participants to connect to theoretical knowledge and skills insights for discussing issues, examine root causes from various perspectives, encourage learners to pinpoint relevant learning materials or techniques, and collaboratively craft actionable solutions. Introduce methodologies such as the "5 Whys" or Fishbone Diagram and tools like cause-and-effect diagrams or flowcharts to illustrate the problem-solving process.

Expected Benefit: This hands-on approach promotes learning through doing, which is experiential in nature, and empowers learners to take ownership and apply what they learn. By actively engaging in practice, employees enhance their intentional learning and integrate theory with analytical skills to work collaboratively, leading to more efficient processes and knowledge application.

4.2.3.3 Example 3: Cross-Functional Team Projects

Description: Form cross-functional teams to tackle specific challenges or projects that require collaborative learning and reflective inquiries that blend skills and perspectives from various sectors within the industrial setting.

Implementation: Identify a current issue in the workplace, such as inefficiencies in a production line. Form teams that include individuals from various departments to ensure a mix of skills and perspectives. Provide clear objectives and a timeline for the project. Teams should research the problem, brainstorm solutions, and create a presentation detailing their findings and recommendations. Support team members in their learning process, such as identifying issues, sourcing resources, and evaluating for improvement.

Expected Benefit: This collaborative methodology fosters innovation by integrating diverse perspectives and enhancing communication across various departments. Participants gain a deeper understanding of the interconnections between their respective roles, leading to more cohesive operations and promoting a stronger learning organization culture.

4.3 KEY TAKEAWAYS

Emphasize Real-World Relevance: Choose problems and projects that directly reflect the challenges faced in the workplace. This relevance boosts engagement and motivates learners to apply their skills in practical, meaningful ways.

Shift the Center to Learners: Offer clear learning guidelines by examining real scenarios that align better with trainees' needs

Facilitating Self-Directed Learning: Provide essential resources and guidance to address existing challenges or identify potential issues. This will teach learners how to learn and enable them to develop the skills necessary for effective problem-solving.

Reflect and Iterate: After each project or problem-solving session, it is crucial to involve learners in reflecting on their learning processes and the relevant content obtained and utilized as resources to tackle

practical issues. This reflective inquiry process strengthens deep learning and encourages continuous engagement with real-world problems across various disciplines.

4.4 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

4.5 REFERENCES

[1] Rosa Huiju Chen. Fostering students' workplace communicative competence and collaborative mindset through an inquiry-based learning design. *Educational Sciences (Basel)*, 11(1):17, January 2021.

[2] Kate Gukeisen. Problem based learning basics, 2013. https://www.slideshare.net/kategukeisen/problem-based- learning-basics.

5. COGNITIVE APPRENTICESHIP MODEL

5.1 WHAT IS THE COGNITIVE APPRENTICESHIP MODEL?

The Cognitive Apprenticeship Model, developed by Collins, Brown, and Newman, is a framework that extends traditional apprenticeship into cognitive domains, emphasizing the importance of learning through guided experiences and social interaction (Figure 5). This model is effective for adult learners as it aligns with the principles of situated learning, where knowledge is constructed within authentic contexts [1, 2].

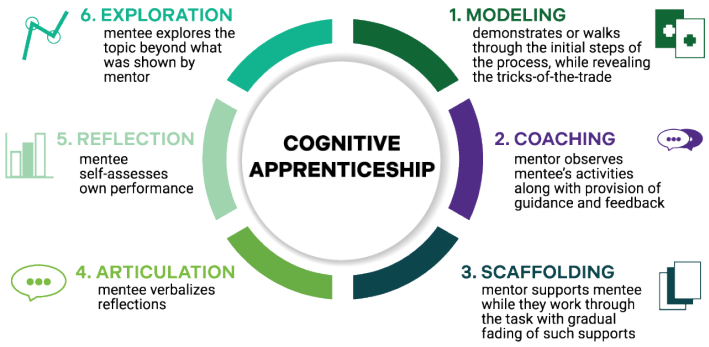

Figure 5. Cognitive Apprenticeship Model. *Image Credit* [1].

The model consists of several key components: modeling, coaching, scaffolding, articulation, reflection, and exploration [3]. Trainers demonstrate tasks (modeling) while explaining their thought processes, then provide guidance and feedback (coaching) as employees practice skills. Scaffolding involves offering support that is gradually removed as learners gain proficiency, fostering independence. Articulation and reflection encourage learners to verbalize their understanding and critically evaluate their performance while exploration allows them to apply skills in novel situations, promoting deeper learning and adaptability [1].

5.2 APPLICATION OF THE COGNITIVE APPRENTICESHIP MODEL

Applying the Cognitive Apprenticeship Model helps bridge the gap between theoretical knowledge and practical application. For example, trainers might demonstrate a complex procedure in a technical training program, explaining each step and the underlying principles. Employees then attempt the procedure with guidance, gradually taking on more responsibility as their confidence and competence grow.

Reflection sessions can be incorporated, where learners discuss what they have learned and how it applies to their roles, enhancing their critical thinking and problem-solving skills [4]. This approach not only improves skill acquisition but also fosters a culture of continuous learning and professional growth, which is essential for adapting to the rapidly changing demands of the modern workplace.

5.3 EXAMPLES OF APPLYING THE COGNITIVE APPRENTICESHIP MODEL

5.3.1 Example 1: Technical Skills Training

In a manufacturing company, trainers can apply the Cognitive Apprenticeship Model to teach new employees how to operate complex machinery. The trainer begins by performing the task while explaining each step and the reasoning behind their actions (modeling). Next, the trainer supervises the employees as they attempt the task, providing real-time feedback and guidance (coaching). As employees

become more proficient, the trainer gradually reduces direct assistance, allowing them to take on more responsibility (scaffolding). Employees are encouraged to articulate their understanding of the processes and reflect on their performance during debrief sessions, which helps solidify their learning and identify areas for improvement.

5.3.2 Example 2: Maintenance and Repair Training

In an industrial setting, trainers can use the Cognitive Apprenticeship Model to improve employees' maintenance and repair skills. Initially, the trainer demonstrates the diagnostic and repair process on a piece of equipment, explaining the tools and techniques used (modeling). Employees then practice these techniques under the close supervision of the trainer, who provides feedback and corrects any mistakes (coaching). As employees become more confident, the trainer gradually reduces their direct involvement, encouraging the employees to perform the repairs independently while still being available for support if needed (scaffolding). Regular reflection sessions are held where employees discuss what they learned, share experiences, and suggest improvements to the maintenance procedures.

5.3.3 Example 3: Project Management Training

In a corporate setting, the Cognitive Apprenticeship Model can be applied to train employees in project management skills.

The trainer begins by leading a project planning session, explaining the rationale behind each decision and the use of various project management tools (modeling). Employees then participate in planning their own projects, and the trainer provides guidance and feedback (coaching). As the employees gain confidence and skill, the trainer gradually steps back, allowing them to take full control of their projects (scaffolding). Throughout the process, employees are encouraged to articulate their thought processes, reflect on their project outcomes, and explore new project management techniques and tools, fostering continuous learning and adaptation.

5.4 KEY TAKEAWAYS

- **Model Overview:** The Cognitive Apprenticeship Model emphasizes learning through guided experiences. It combines traditional apprenticeship methods with cognitive processes, focusing on developing thinking skills alongside practical skills

- **Authentic Context:** Training should occur in real-world contexts where learners can see and practice skills as they would be applied in actual situations. This helps bridge the gap between theory and practice.

- **Scaffolding:** Trainers provide support structures (scaffolding) to help learners gradually take on more complex tasks. As learners become more proficient, this support can be gradually removed, promoting independence.

- **Modeling:** Effective trainers demonstrate the skills and thought processes involved in tasks. This modeling helps learners understand not just what to do, but how to think through problems and make decisions.

- **Coaching:** Trainers should engage in active coaching, providing feedback and guidance during practice. This interaction helps learners refine their skills and develop critical thinking.

- **Articulation:** Encourage learners to verbalize their thought processes and strategies. This articulation helps them clarify their understanding and allows trainers to identify areas where additional support may be needed.

- **Reflection:** Incorporate opportunities for reflection after tasks or training sessions. Reflective practices help learners analyze their performance, understand their learning journey, and identify areas for improvement.

- **Collaboration:** Foster a collaborative learning environment where learners can work together, share insights, and support each other. Peer interactions can enhance understanding and encourage diverse perspectives.

- **Gradual Complexity:** Introduce tasks that increase in complexity over time. This helps learners build confidence and competence without becoming overwhelmed.

- **Assessment of Learning:** Use formative assessments to gauge learners' progress and adapt training approaches accordingly. Continuous assessment helps ensure that learners are developing the necessary skills and understanding.

5.5 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

5.6 REFERENCES

[1] Collins, J. S. Brown, and S. E. Newman. *Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics*. Lawrence Erlbaum Associates, 1989.

[2] J Lave and E Wenger. *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press, 1991.

[3] A Collins, J S Brown, and A Holum. Cognitive apprenticeship: Making thinking visible. *American Educator*, 15(3):6–11, 38–46, 1991.

[4] J. Herrington and R. Oliver. An instructional design framework for authentic learning environments. *Educational Technology Research and Development*, 48:23–48, 2000.

6. ADULT LEARNING PREFERENCES

6.1 EXPLORING ADULT LEARNING PREFERENCES AND DIFFERENT APPROACHES TO EFFECTIVE TRAINING

Adult learners engage with and process information through diverse preferences shaped by their experiences, cognitive styles, and professional contexts. These preferences are categorized not only into distinct learning styles—such as visual, auditory, and kinesthetic—but also reflect broader approaches like independent and collaborative learning (Figure 6).

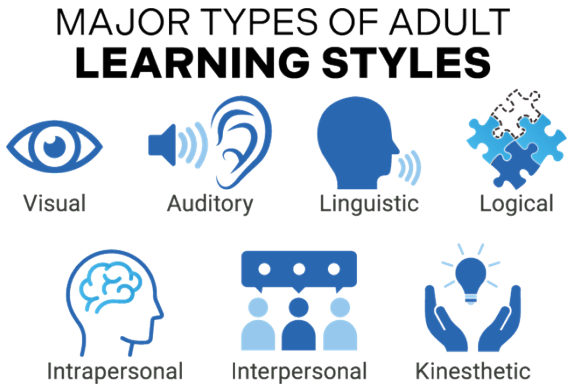

Figure 6. Major Types of Adult Learning Styles. *Image Credit* [1].

Traditional categorizations such as visual, auditory, and kinesthetic (**VAK**) learning styles are often referenced, particularly in industrial workforce development settings, where aligning instructional methods with adult learners' preferred styles significantly enhances motivation and achievement [2, 3, 4]. Contemporary critiques emphasize the need to move beyond rigid style-based frameworks. For instance, **multimodal approaches**—which integrate visual, auditory, and hands-on methods—are shown to better accommodate adult learners in technical training environments. **Microlearning**—short, task-focused modules—has also emerged as a key strategy for upskilling workers. By recognizing the diverse background and varying learning preferences of adults learners and utilizing various instructional strategies, program trainers and educators can foster meaningful learning experiences that improve knowledge retention and enhance performance outcomes in training programs that promote continuous professional development and growth [4].

6.2 PRACTICAL APPLICATION OF DIFFERENCES IN ADULT LEARNING STYLES

Traditional VAK learning styles have significantly helped educators select appropriate approaches for learners who prefer certain types of styles. Visual learners benefit from graphical representations of information, such as charts, diagrams, and videos, which help them visualize concepts and retain knowledge more effectively. Auditory learners thrive in environments where they can engage in discussions, listen to lectures, and participate in verbal exchanges, as these methods allow them to process information through sound. Kinesthetic learners, who prefer hands-on experiences, excel when manipulating materials or engaging in simulations that allow them to apply theoretical knowledge in practical contexts [5].

Contemporary critiques emphasize moving beyond rigid style-based frameworks. Therefore, **multimodal approaches**—which integrate visual, auditory, and hands-on methods—are shown to better accommodate adult learners in technical training environments. For example, Newton and Miah argue that focusing on evidence-based strategies leads to more effective instruction in manufacturing. This aligns with

Kirschner's call to prioritize methods that universally enhance retention, such as combining diagrams, verbal instructions, and practice tasks to reinforce technical skills [6, 7].

Experiential learning remains foundational in manufacturing education, where learners integrate prior knowledge with hands-on problem-solving. In industrial training settings, adult learners thrive in **collaborative learning environments** that balance autonomy with peer interaction. Johnson et al. demonstrated that team-based problem-solving activities in manufacturing workforce development programs significantly improved skill retention and motivation compared to isolated training modules [8]. Similarly, technology-driven methods like **virtual reality (VR) simulations** are increasingly used to bridge theory and practice. Smith et al. found that immersive VR training for automotive assembly line workers reduced error rates by 25%, highlighting how experiential, context-driven tools align with adult learners' preference for applied, real-world relevance [9].

Microlearning—short, task-focused modules—has emerged as a key strategy for upskilling workers. Gonzalez reported that microlearning interventions in manufacturing settings improved just-in-time knowledge application, addressing adults' shorter attention spans and their need for immediate relevance through reflective practice; context-driven tools align with adult learners' preference for application [10]. Brown and Lee illustrated this through case studies in smart factories, showing that reflective practice during machinery troubleshooting enhanced both technical mastery and critical thinking [11].

Additionally, social learners often value **collaborative activities** and group projects as they gain insights through interactions and shared experiences with peers. In contrast, solitary learners may prefer independent study and self-paced learning, which facilitate reflection and personal exploration of concepts. These approaches promote autonomy and relevance in training [4].

6.3 STRATEGIES FOR INTEGRATING VARIOUS ADULT LEARNING PREFERENCES

Instructors can use various strategies to foster an engaging and adaptable learning environment and effectively integrate adult learning preferences into workforce development programs:

Assessing learners' preferred learning styles through simple surveys or informal discussions enables trainers to customize training activities and materials effectively. To address the diverse ways adults learn, trainers can use various teaching methods, including collaborative group projects, open discussions, multimedia presentations, and hands-on exercises.

Incorporating self-directed learning methods empowers adult learners to take charge of their education by establishing personal goals and exploring topics at their own pace.

Technology-driven strategies such as interactive online platforms and multimedia resources foster personalized and engaging learning experiences.

Moreover, trainers can support individual learning preferences and foster autonomy in training by providing **resources** for independent discovery, reflection, and feedback through **learning contracts**

6.4 EXAMPLES OF INTEGRATING VARIOUS ADULT LEARNING PREFERENCES

6.4.1 Visual Learning with Interactive Diagrams

1. **Description**: Utilizing visual aids, such as charts, diagrams, and videos, can help visual learners understand complex information related to machinery and processes in an industrial setting.

2. **Implementation**: Instructors can create detailed visual presentations that outline key processes or equipment operations. For example, before a hands-on training session, show a video illustrating how to operate a specific machine, followed by a diagram highlighting its key components. Or create large, detailed posters or digital displays of the machinery highlighting key components, functions, and workflows. During training sessions, use these diagrams to guide discussions, allowing trainees to visualize the machinery in action, which can incorporate tools like augmented reality (AR) applications to enable employees to see 3D models of the equipment. Set up posters in the training area featuring step-by-step flowcharts for processes, allowing learners to reference them during practical exercises.

3. **Support the Learner**: Instructors can support visual learners by encouraging them to take notes using diagrams and by asking them to summarize information using visual representations. Additionally, providing access to digital resources that include interactive simulations can enhance their understanding and retention.

4. **Benefit**: This method will enhance visual learners' understanding, leading to improved retention of information about machinery operation and maintenance. This will reduce errors and increase efficiency on the job.

6.4.2 Hands-On Workshop with Kinesthetic Learning

1. **Description**: Hands-on training allows kinesthetic learners to gain knowledge by practicing and experiencing through physical engagement with materials and procedures in a controlled environment for safe practice.

2. **Implementation**: Set up various stations that focus on different aspects of industrial tasks, such as assembly techniques, safety protocols, and equipment operation. Each station should include clear instructions and the necessary tools or equipment. Instructors can rotate small groups of learners through each station, guiding them through tasks and encouraging them to observe and ask questions about their techniques throughout the process. This can be performed individually or with a group for SDL or collaborative learning.

3. **Support the Learner**: Instructors can assist kinesthetic learners by providing immediate demonstrations while they practice tasks. They should also encourage learners to exchange ideas and share their experiences at each station, promoting observation and reflection on what they have learned and how they can apply it to real-life situations. This approach can also be integrated with group or collaborative demonstrations for social learners to create new and improved operational strategies.

4. **Benefit**: This approach empowers kinesthetic learners by allowing them to apply their knowledge in real time. It can boost their confidence in operating equipment, ultimately enhancing productivity and safety on the floor.

6.4.3 Group Discussion for Auditory Learners

1. **Description**: Auditory learners benefit from listening to explanations and participating in conversations. Group discussions can help reinforce learning by allowing employees to share their thoughts and experiences.

2. **Implementation**: Schedule regular team meetings or training sessions where employees can discuss topics related to safety procedures, quality control, or process improvements. Use a facilitator to

guide the conversation and encourage all participants to share their insights and ask questions. Consider video recording these discussions for future reference and reflection.

3. **Benefit**: This method fosters a collaborative environment where auditory learners can thrive through dialogue. It promotes knowledge sharing, strengthens team dynamics, and helps reinforce best practices, leading to a more cohesive and knowledgeable workforce.

6.4.4 Collaborative Learning and Group Discussions

1. **Description**: Promoting collaborative learning through group discussions and projects enhances understanding and retention for auditory learners who thrive on verbal interactions.

2. **Implementation**: Organize regular team meetings where learners can discuss specific topics relevant to their work, such as safety practices or process improvements. Assign small group projects that require collaboration to solve real workplace challenges, encouraging each participant to contribute their insights. Use techniques like round-robin discussions to ensure everyone has the opportunity to speak. This approach enhances peer-driven verbal interactions (e.g., team projects, structured discussions), promoting engagement and inclusive participation. Instructors reinforce learning with summaries and recorded reviews.

3. **Support the Learner**: Instructors can support learners by summarizing key points discussed during group activities or by providing opportunities for them to summarize and ask follow-up questions, which facilitates reflection on real workplace challenges. Additionally, they can arrange for recordings of discussions for later review, allowing learners to reflect on their contributions and the ideas shared by their peers.

4. **Benefit**: Supports diverse learners by utilizing collaborative dialogue and aligning with evidence-based practices while promoting social and cognitive connections among one another.

6.5 KEY TAKEAWAYS

- **Diversify Instructional Methods**: Employ a mix of instructional strategies to cater to various learning preferences. Integrate visual aids, hands-on activities, group discussions, and multimedia presentations to engage all types of learners. This diversity will help keep interest and enhance retention.

- **Create Hands-On Learning Opportunities**: Set up practical, hands-on learning stations where learners can interact directly with equipment and processes. This method is especially advantageous for kinesthetic learners, enabling them to practice skills in a safe environment while obtaining immediate feedback.

- **Facilitate Collaboration and Discussion**: Promote collaborative learning through group projects and discussions. This approach supports auditory learners and encourages teamwork, enabling participants to share insights and learn from each other's experiences.

- **Promote Self-Directed Learning**: Provide resources for self-directed study to empower learners to take charge of their education. Encourage them to set personal goals and explore topics at their own pace, which fosters engagement and ownership of their learning journey.

- **Utilize Technology and Multimedia Resources**: Leverage technology-driven tools, such as interactive online platforms and multimedia resources, to create personalized learning experiences. These resources can cater to various learning styles and make training more engaging.

- **Encourage Reflection and Feedback**: Provide opportunities for learners to reflect on their experiences and offer feedback on the training process. This reflection will help them internalize their learning and give instructors valuable insights into the effectiveness of the program.

- **Foster an Inclusive Learning Environment**: Cultivate an atmosphere that respects and values the diverse backgrounds and experiences of adult learners. An inclusive environment encourages active participation and enriches the overall learning experience.

- **Assess Effectiveness**: Regularly evaluate the effectiveness of your training programs by measuring knowledge retention, skill application, and learner satisfaction. Use this information to continuously refine the approach and provide better support for adult learners.

6.6 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

6.7 REFERENCES

[1] Corey Bleich. 7 Adult Learning Styles And Best Practices To Follow. https://www.edgepointlearning.com/blog/adult-learning- styles/.

[2] Lauren M. Barela. Cultural diversity in the workplace: A guide for effective instruction for all adult learning styles. *Regis University Student Publications (Comprehensive Collection)*, 24, 2010.

[3] A K Hamada, M Z Rashad, and M G Darwesh. Behavior analysis in a learning environment to identify the suitable learning style. *International Journal of Computer Science and Information Technology*, 3(2):48–59, 2011.

[4] Altunay, E., & Özdemir, N. (2024). Identifying adults' learning strategy profiles in the workplace: relations to organisational identity, work flexibility, and personal characteristics. Studies in Continuing Education, 47(1), 111–134.

[5] S. Graf and T. C. Liu. Supporting teachers in identifying students' learning styles in learning management systems: An automatic student modelling approach. *Educational Technology Society*, 12(4):3–14, January 2009.

[6] Philip M. Newton and Mahallad Miah. Evidence-based higher education—is the learning styles 'myth' important? *Frontiers in Psychology*, 8 - 2017:444, 2017.

[7] Paul A. Kirschner. Stop propagating the learning styles myth. *Computers Education*, 106:166–171, 2017.

[8] L. Johnson. Leveraging Team-Based learning in manufacturing workforce development. *Journal of Workplace Learning*, 34(3):256–270, 2022.

[9] K. Smith. Immersive virtual reality for assembly training in automotive manufacturing. *International Journal of Advanced Manufacturing Technology*, 125(7-8):3215–3230, 2023.

[10] C. Gonzalez. Microlearning for Just-in-Time training in manufacturing. *TechTrends*, 66(2):210–219, 2022.

[11] T. Brown and M. Lee. Experiential learning in smart factories: A case study. *Journal of Workplace Learning*, 33(5):345–360, 2021.

7. COMMUNITY OF PRACTICE AND SITUATED LEARNING IN WORKFORCE DEVELOPMENT

7.1 EXPLORING COMMUNITY OF PRACTICE AND SITUATED LEARNING IN WORKFORCE TRAINING

A Community of Practice (CoP) is a group of individuals who share a common interest, profession, or challenge and engage in collaborative learning through regular interaction (Figure 7). CoPs are rooted in situated learning theory, which emphasizes that knowledge is best acquired through shared experiences, social interaction, and real-world problem-solving—not merely through formal education. Situated learning theory, developed by Jean Lave and Etienne Wenger, describes situated learning as the process of placing thought and action within a specific context [1]. Specifically, situated learning involves engaging with fellow learners, environments, and activities to create meaning, as well as the thinking and doing processes employed by experts to accomplish knowledge and skill tasks in a particular setting [1]. Four essential aspects to consider in understanding situated learning [2]:

Figure 7. Community of Practice. *Image Credit* [3].

- **Content**: situated learners' everyday experiences.
- **Context**: a process of engaging with and intervening in the social, psychological, and material environment where learners are situated [4].
- **Communities of Practice**: a setting for learners to discuss, reflect, and develop personal, meaningful perspectives on complex issues [1, 5].
- **Participation**: the active exchange of shared ideas among learners to solve issues.

Four central principles explain how learning occurs: 1) Learning is rooted in the actions of everyday situations. 2) Knowledge is acquired contextually and transfers to similar environments. 3) Learning

arises from a social process that includes ways of thinking, perceiving, and problem-solving. 4) Learning is not disconnected from the world of action but exists within dynamic, complex, and social environments made up of actors, activities, and situations [6]. Situated learning occurs through participation in real-world community activities.

Furthermore, situated learning indicates that learning happens through the relationships among individuals, connections to prior knowledge, and authentic, informal, often unintended contextual learning. The community provides a setting for social interaction that enables learners to gain different perspectives on an issue [1, 5]. Stein noted that "community is the joining of practice with analysis and reflection to share tacit understandings and create shared knowledge from the experiences of participants in a learning opportunity" [2]. These concepts reflect what Lave and Wenger call the process of "legitimate peripheral participation." [1].

In workforce development training programs, communities of practice and situated learning facilitate social interactions that enable experts and peers to exchange knowledge in an informal setting, thereby presenting information in an authentic context. This approach allows participants to apply theoretical knowledge and practical skills to real workplace challenges through collaboration and joint participation, thus promoting long-term skill development beyond isolated training sessions. Trainers can use CoPs and situated learning to bridge the disparity between formal training and on-the-job application by establishing a community of experts and encouraging collaborative efforts, particularly in high-risk industries such as energy and manufacturing, where tacit knowledge holds significant importance. CoPs emphasize that learning is:

- Socially constructed through participation, including exchanging ideas, the desire to address challenges and learners' interaction with others.

- Context-dependent and tied to real-world practice, learning is grounded in the actions of everyday situations.

- Iterative and evolving through shared experiences— bonding together by fostering a sense of joint enterprise and creating a shared repertoire [7].

7.2 PRACTICAL APPLICATIONS OF WORKFORCE DEVELOPMENT TRAINING

Community of Practice and Situated Learning are powerful frameworks for designing effective training programs. Some example strategies include:

- Onboarding New Members—Matching them with seasoned professionals.

- Enhancing Employee Skills—Regular problem-solving sessions focused on new knowledge, skills, and technologies.

- Cross-Department Collaboration—Breaking down barriers between engineers, safety officers, and operators.

7.2.1 Example 1: Power Plant Operations Training

Situated Learning: Trainees learn by working in an actual or simulated plant environment.

Community of Practice: Experienced operators and engineers share tacit knowledge.

Learning Goals: To facilitate learning that happens in a realistic operational setting (situated); to gain knowledge through shared experiences and interactions (CoP).

Learning Activities: Control room simulations: trainees operate a digital twin of a power plant under supervision. Shadowing senior operators: new hires observe and assist in real-time decision-making (e.g., handling grid fluctuations). Incident debriefs: teams analyze past failures (e.g., turbine malfunctions) and discuss solutions.

7.2.2 Example 2: Safety and Compliance Training

Situated Learning: Trainees practice safety drills in high-risk scenarios.

Community of Practice: Safety officers and field workers co-develop protocols.

Learning Goals: Reinforce safety skills and new knowledge in near-real conditions (situated); construct norms by collective experience.

Learning Activities: VR emergency drills: simulate gas leaks or electrical fires with VR headsets. Hazard hunt workshops: teams inspect real worksites for risks and discuss mitigation. Regulatory roundtables: compliance experts and workers interpret new OSHA/EPA rules together.

7.2.3 Example 3: Smart Grid and Digitalization Training

Situated Learning: Engineers interact with IoT-enabled grid systems.

Community of Practice: Cross-functional teams (IT, electrical engineers) solve integration challenges.

Learning Goals: Learning occurs through real tech applications (situated); innovation spreads through collaborative problem-solving (CoP).

Learning Activities: Cybersecurity war games: Teams defend a mock grid from simulated cyberattacks. Data analytics sprints: Analyze real grid data (e.g., demand spikes) to optimize performance. Trainers and trainees quarterly (or monthly/annual site/virtual visits) meetings where engineers demo new tools (e.g., AI for load forecasting) for learning and discussion.

7.3 KEY TAKEAWAYS

1. Use simulations, fieldwork, and real data to anchor learning in practice.
2. Leverage CoPs through mentorship, forums, and cross-team collaboration.
3. Focus on problem-solving (e.g., outages, energy-saving technology, safety breaches) to make learning actionable

7.4 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

7.5 REFERENCES

[1] J Lave and E Wenger. *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press, 1991.

[2] D. Stein. *Situated learning in adult education.* ERIC Clearinghouse on Adult, Career, and Vocational Education, 1998.

[3] Etienne Wenger-Trayner and Beverly Wenger-Trayner. Introduction to communities of practice. https://www.wenger-trayner.com/introduction-to- communities-of-practice/.

[4] D Boud. Conceptualizing learning from experience: Developing a model for facilitation. In *Proceedings of the 35th Adult Education Research Conference*, pages 49–54. University of Tennessee, 1994.

[5] Ann L. Brown. The advancement of learning. *Educational Researcher*, 23(8):4–12, 1994.

[6] John R Anderson, Lynne M Reder, and Herbert A Simon. Situated learning and education. *Educational Researcher*, 25(4):5–11, May 1996.

[7] E. Wenger. Communities of practice: Learning as a social system. *Systems Thinker*, 9(5):2–3, 1998.

8. SIMULATION AND ROLE-PLAY IN ADULT LEARNING

8.1 WHAT IS SIMULATION AND ROLE-PLAYING IN ADULT LEARNING?

As shown in Figure 8, simulations provide adult learners with a powerful tool for experiential learning by replicating real-world scenarios in a controlled environment. This immersive approach allows individuals to practice complex tasks, make decisions with simulated consequences, and refine their skills without the risk associated with real-world applications.

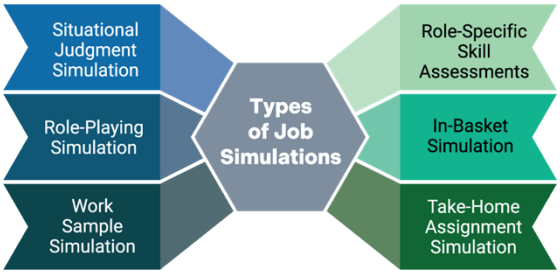

Figure 8. Types of Job Simulations. *Image Credit* [1].

Role-playing is a highly effective pedagogical technique that fosters interpersonal skill development in adult learning settings. By assuming assigned roles and acting out specific scenarios, participants can actively engage in communication practice, conflict resolution, and perspective-taking. This interactive approach encourages participants to analyze social dynamics, develop emotional intelligence, and receive immediate feedback on their performance. Whether used in customer service training, enhancing performance skills, or leadership development programs, role-playing provides a safe and engaging space for individuals to refine their communication styles and enhance their ability to navigate interpersonal challenges effectively.

8.2 APPLICATION OF SIMULATION AND ROLE-PLAYING

There are various ways to engage learners through simulation and role-play. Role-playing enables learners to observe others through modeling, offering opportunities to learn from one another through action and observation [2]. Simulation can take place in diverse settings and can be conducted individually, allowing instructors to provide action-learning opportunities to individual learners with greater flexibility in terms of availability and venue capacity. Simulation and role-playing encourage adult learners to actively participate in their learning, engaging their minds and bodies.

8.3 EXAMPLES OF APPLYING SIMULATION AND ROLE-PLAYING

8.3.1 Example 1: Manufacturing and Logistics

- **Guide a Warehouse Simulation Debrief**: After trainees complete a warehouse simulation, lead a discussion analyzing their decisions, the impact on efficiency, and key takeaways about inventory management and supply chain dynamics.

- **Design a Production Line Challenge**: Create a production line simulation with specific challenges related to quality control, material shortages, or equipment malfunctions. Have teams compete to meet production goals while navigating these obstacles.

8.3.2 Example 2: Workplace Communication and Conflict Resolution

- **Structure Difficult Conversation Role-Plays**: Provide trainees with role-playing prompts that involve addressing performance issues, giving constructive feedback, or resolving interpersonal conflicts. Observe their communication styles and facilitate discussions about effective strategies.

- **Assign Roles for Team Projects**: When starting a new team project or concept, assign specific roles to participants. This enables them to experience various perspectives within team dynamics and enhance their collaboration skills.

8.3.3 Example 3: Leadership and Management

- **Guide a Change Management Simulation**: Design a scenario where trainees must lead a team through a significant organizational change. Encourage them to apply change management models, communication strategies, and leadership styles to navigate the process.

- **Provide Feedback During Performance Review Role-Plays**: Have trainees practice conducting performance reviews with each other. Then, have them role-play as the employee receiving feedback to provide valuable insights and coaching on their delivery and communication style.

8.4 KEY TAKEAWAYS

- **Authentic & Relevant Practice:** Simulation and role-play go beyond traditional learning by using lifelike workplace scenarios. This immersive approach allows learners to apply knowledge, make decisions, and experience consequences in a safe environment before facing similar situations on the job

- **Learner-Driven Engagement:** These methods empower adult learners by shifting the focus from passive listening to active participation. Instructors, as facilitators, encourage learners to direct their learning, collaborate with peers, and discover solutions together.

- **Diverse Learning Experiences:** From simple role-playing exercises to complex computer-based simulations, these adaptable methods cater to a range of learning styles, especially benefiting kinesthetic learners who thrive in hands-on environments.

- **Targeted Skill Development:** Simulations and role-playing are highly effective for developing critical workplace skills, including:
  - Communication
  - Teamwork and Collaboration
  - Problem-solving and Critical Thinking
  - Decision-making Under Pressure
  - Conflict Resolution

- **Transfer of Learning:** By mirroring authentic workplace contexts and challenges, these activities bridge the gap between theory and practice, giving learners the confidence to apply their newly acquired skills directly to their jobs.

- **The Power of Debriefing:** It is crucial to hold a structured debriefing session after the activity. This guided reflection allows learners to analyze their actions, receive feedback, share insights, and solidify their understanding of key concepts, maximizing the impact of the experience.

8.5 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

8.6 REFERENCES

[1] WeCP. What is a Job Simulation? Types, Benefits & How-To Use? https://www.wecreateproblems.com/blog/job-simulation.

[2] D H Schunk. *Learning theories, an educational perspective*. Pearson Education, Boston, MA, 2012.

9. CONSTRUCTIVIST LEARNING APPROACH IN THE WORKPLACE

9.1 EXPLORING CONSTRUCTIVIST LEARNING IN WORKFORCE DEVELOPMENT ENVIRONMENTS

As an educational philosophy and a learning theory, constructivism asserts that learners actively construct their own knowledge and understanding through diverse experiences, reflective practices, and social interactions. Consequently, learning is characterized not merely as a passive absorption of information but as a dynamic process in which learners build upon existing knowledge to generate new insights. Influenced by Jean Piaget, who formulated Cognitive Constructivism, this theory emphasizes individual cognitive development through stages of adaptation, namely assimilation and accommodation. Conversely, the social constructivist paradigm championed by Lev Vygotsky underscores the significance of social interaction, cultural context, and scaffolding- guidance provided by more knowledgeable individuals- as fundamental to the learning process. Furthermore, John Dewey advocates for an experiential, inquiry-based approach to education that is closely tied to real-world contexts. Constructivism reshapes education by prioritizing deep, meaningful learning through active participation and social interaction, preparing learners for real-world problem-solving. It emphasizes learners' active role in constructing knowledge rather than passively receiving information. The main components include:

- Active Engagement: Learners participate in problem-solving, exploration, and critical thinking.
- Prior Knowledge: New learning builds upon existing mental frameworks (schemas).
- Social Collaboration: Knowledge develops through dialogue, collaboration, and shared experiences.
- Contextual Learning: Authentic, situated tasks enhance relevance and retention.

In short, constructivist learning theory emphasizes that knowledge is constructed through active engagement and experiential learning, in which individuals build new insights upon their existing understanding through meaningful interactions within their environment [1, 2].

In workforce development, constructivist principles can enhance training by fostering environments where employees engage in hands-on activities, collaborate with peers, and reflect on their learning experiences (Figure 9). This approach increases the relevance and applicability of training, empowering employees to take ownership of their learning, thus boosting their motivation and retention of information. Moreover, by promoting a culture of inquiry and reflection, trainers can strengthen learners' abilities to critically analyze their learning processes and adapt to new challenges, constructing new knowledge and understanding.

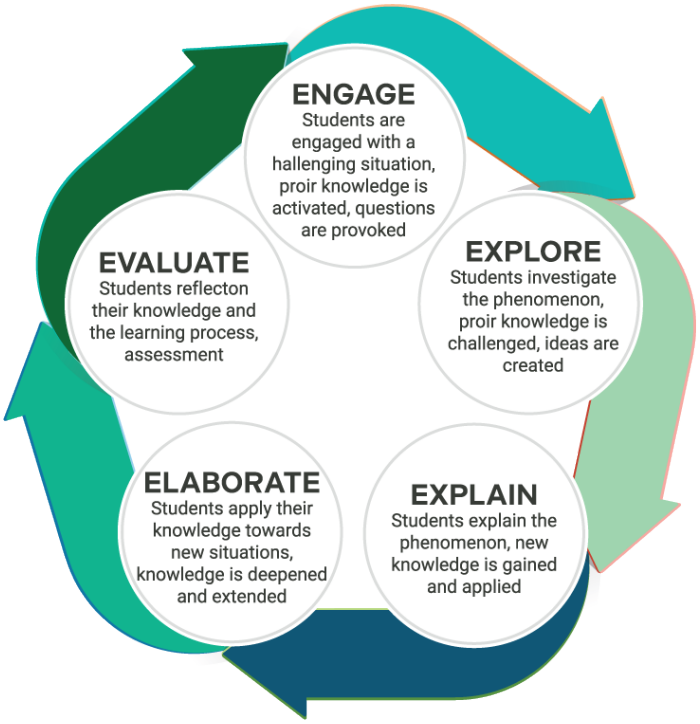

Figure 9. Phases of the 5E Instructional Model. *Image Credit* [3].

9.2 STRATEGIES FOR APPLYING CONSTRUCTIVIST LEARNING TO WORKFORCE DEVELOPMENT

1. Experiential and Hands-On Learning
   - Simulations and Role-Playing: Use realistic workplace scenarios to build skills through practice.
   - On-the-Job Training (OJT): Pair trainees with mentors to learn tasks in real work environments.

2. Problem-Based Learning
   - Present real workplace problems (e.g., process inefficiencies, conflict resolution) for teams to analyze and solve.
- Encourage research, experimentation, and reflection to develop critical thinking.

3. Collaborative Learning
   - Group Projects: Assign cross-functional teams to tackle complex tasks (e.g., designing a workflow improvement).
- Peer Teaching: Have experienced learners teach colleagues skills, reinforcing their knowledge.

4. Scaffolded Skill Development
   - Break complex tasks into smaller steps, providing support (e.g., checklists, templates) that gradually fades as competence grows.
- Use microlearning (short, focused modules) to build knowledge incrementally.

5. Reflection and Metacognition
   - Debrief Sessions: After training exercises, discuss what worked, what didn't, and how to improve.
- Learning Journals: Encourage employees to document challenges, solutions, and lessons learned.

9.3 EXAMPLES OF IMPLEMENTING CONSTRUCTIVIST LEARNING

Constructivist activities can vary based on training needs. Here are some examples of how constructivist learning can be implemented in the training program.

9.3.1 Example 1: Upstream Drilling Safety Training

- Constructivist Activity: Teams analyze a real-life blowout incident (e.g., Deepwater Horizon).
  - Step 1: Trainees review raw data (pressure logs, crew communications).
  - Step 2: Groups identify critical failures and redesign safety protocols.
  - Step 3: Role-play emergency responses with simulated rig-floor VR

- Theory Link: Social constructivism (collaborative problem-solving) + Piaget's adaptation (adjusting mental models of risk).

9.3.2 Example 2: Wind Turbine Maintenance Program

- Activity: "Fault Roulette" simulation.
  - Trainees spin a wheel to land on a random turbine fault (e.g., gearbox failure, sensor error).
  - They must diagnose and repair it using only schematics and peer input.

- Theory Link: Vygotsky's Zone of Proximal Development (peers scaffold knowledge)
  - + Dewey's "learning by doing".

9.4 KEY TAKEAWAYS

1. Emphasize Real-World Relevance: Ensure that learning activities are directly connected to adult learners' real-world tasks and experiences in their industrial settings. This enhances motivation and helps learners see the immediate applicability of their skills.

2. Foster Collaborative Learning Environments: Encourage teamwork and peer interactions to allow learners to share their experiences, knowledge, and problem-solving strategies. This collaborative approach helps construct knowledge collectively and leverages diverse perspectives.

3. Engage in Hands-On Learning: Include practical, hands-on activities that enable learners to apply theoretical concepts in a controlled setting. This experiential approach enhances understanding and retention of skills.

4. Facilitate Interaction and Reflection: Create opportunities for learners to reflect on their experiences and the learning process. Reflection can be guided through discussions, journals, or group debriefings, helping learners connect new knowledge to existing frameworks.

9.5 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy,

Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

9.6 REFERENCES

[1] Anne O'Connor and Arlene McCurtin. A feedback journey: employing a constructivist approach to the development of feedback literacy among health professional learners. *BMC Medical Education*, 21(1), December 2021.

[2] Satish Prakash Chand. Constructivism in Education: Exploring the Contributions of Piaget, Vygotsky, and Bruner. *International Journal of Science and Research (IJSR)*, 12(7):274–278, July 2023.

[3] Bala Krishnian Muniandy, Fei Ping, and Rames Prasath. Revisiting the framework of 5e flipped learning environment. *Jurnal Sains Sosial dan Pendidikan Teknikal— Journal of Social Sciences and Technical Education (JoSSTEd)*, 5(1):1–14, 2024.

10. MOTIVATION THEORY IN THE WORKPLACE

10.1 EXPLORING MOTIVATION THEORY APPLICATIONS FOR WORKFORCE DEVELOPMENT

Motivation Theory, especially in relation to adult learners in workforce development settings, highlights the intrinsic and extrinsic factors that motivate individuals to engage in learning for development. Adult learners are often motivated by how relevant the training and materials are to their personal and professional goals. According to Deci and Ryan's Self-Determination Theory (Figure 10), intrinsic motivation—which involves engaging in activities for their inherent satisfaction—can be enhanced by autonomy (a sense of choice), competence (mastery of skills), and relatedness (connection with others) [1, 2]. By intentionally addressing these needs in the workplace, organizations can cultivate environments where intrinsic motivation flourishes.

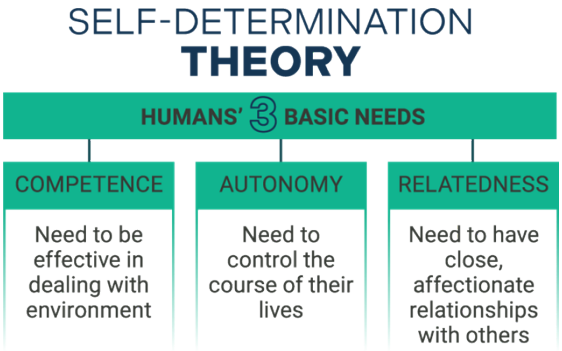

Figure 10. Self-Determination Theory. *Image Credit* [1].

Additionally, Herzberg's Two-Factor Theory (the Motivation-Hygiene Theory) [3, 4] proposes motivators and hygiene factors, which provide valuable insights for training professionals in workforce development.

1. **Hygiene Factors**: External elements like *salary, working conditions*, and *company policies* can lead to **job dissatisfaction when lacking** but do not inherently motivate employees when improved.

2. **Motivators**: Intrinsic factors such as *achievement, recognition*, and *opportunity for growth* directly lead to enhanced **job satisfaction** and engagement.

For instance, training programs that prioritize skill mastery (a motivator) will struggle to engage employees if essential hygiene factors, like fair compensation and safe work environments, are ignored [5]. Motivators foster genuine satisfaction and performance, while hygiene factors mitigate dissatisfaction [3], and they are influenced by separate, mutually exclusive factors [5].

Understanding these motivational factors is crucial for trainers who develop training programs that align with trainees' career goals and provide clear pathways for skill advancement.

According to Wlodkowski, adult learners are more engaged when their learning is directly relevant to their job roles and future opportunities [6]. Therefore, creating a supportive learning environment that acknowledges individual achievements and minimizes distractions can effectively boost motivation.

10.2 WHY APPLY MOTIVATION THEORY?

The practical application of Motivation Theory in the workplace can create an environment that fosters both intrinsic and extrinsic motivation, leading to enhanced employee engagement in training and improved job productivity.

Aligning training initiatives with employees' career goals boosts their motivation to learn and contributes to overall organizational success.

Herzberg's Two-Factor Theory emphasizes the need to address basic hygiene factors like fair compensation and safe working conditions to avoid dissatisfaction. It also highlights motivators such as recognition and opportunities for professional growth, which contribute to higher levels of motivation [7]. Recent studies indicate that organizations implementing recognition programs and providing opportunities for skill development experience a significant increase in job satisfaction and retention [8].

Applying these motivational principles in workplace training and development improves learning outcomes, ultimately encouraging a more committed and productive workforce in organizations.

10.3 STRATEGIES TO APPLY MOTIVATION THEORY

- **Personalized Learning Plans**: Develop personalized learning and development plans for trainees that align with their career aspirations and interests. Tailor training to individual goals to enhance intrinsic motivation. This will help employees to see a direct connection between their personal growth and workplace success.

- **Regular Feedback**: Cultivate a culture that provides regular, timely, and actionable feedback as well as insights into trainees' learning and performance. Emphasizing task-specific feedback is crucial for growth and connects feedback to adaptive workplace learning [9].

- **Encourage Autonomy** Develop training programs or sessions that give learners some control over their learning paths. Offer choices in training topics and methods—for instance, allow employees to choose based on their competency levels, areas for improvement, delivery methods, and timelines for completion—to enhance their intrinsic motivation by making the learning experience more relevant and enjoyable.

- **Utilize Real-World Applications** Incorporate practical, real-world scenarios into training sessions; when learners understand how their training relates to their job roles, their motivation to learn increases; engagement and knowledge retention improve significantly. For instance, after adopting this approach, IBM reported a 40% decrease in incident resolution time as employees linked training to actual system vulnerabilities [10].

10.4 EXAMPLES OF APPLICATION

10.4.1 Goal-Setting Workshops

- **Description**: Workshops focused on goal-setting that help employees define their personal and professional development objectives. By encouraging participants to share their aspirations, trainers can cultivate intrinsic motivation. This method aligns with Deci and Ryan's Self-Determination Theory, emphasizing the importance of autonomy and competence [2].

- **Holding** a workshop could help employees in establishing Specific, Measurable, Achievable, Relevant, and Time-bound (SMART) goals [11]. This would align with Locke and Latham's focus on structured goal-setting, which should be accompanied by regular check-ins to monitor progress and celebrate achievements, a practice that enhances motivation [12, 13].

10.4.2 Recognition and Rewards Program

- **Description**: A structured recognition program alongside training initiatives that acknowledge employees' achievements with awards. Herzberg's Two-Factor Theory illustrates that recognition serves as a strong motivator, boosting job satisfaction and encouraging further personal and professional development.

- **Establishing** an awards system entails both formal and informal public recognition, opportunities for promotion and additional learning, and incentives or even a simple meeting announcement to celebrate training milestones.

These elements can greatly help foster a culture of appreciation that meets trainees' psychological, emotional, and economic needs, making them feel valued and encouraging them to engage actively in training initiatives.

10.4.3 Peer Learning and Collaboration

- **Description**: Promote peer learning through collaborative projects and team training activities. Adult learners benefit from social interaction, a sense of community, and shared purpose and experiences, which enhance mutual support by increasing motivation and improving learning outcomes.

- **Organizing** cross-sector teams to address real workplace challenges promotes peer learning through collaboration, a practice aligning with situated learning theory [14]). By participating in shared tasks, trainees co-construct knowledge and refine their skills in authentic contexts, thereby enhancing competence. This collaborative approach also fosters **relatedness** by creating psychologically safe communities, which are key motivators in Self-Determination Theory [2].

10.5 KEY TAKEAWAYS

1. **Understand Intrinsic vs. Extrinsic Motivation**: Recognize the difference between intrinsic motivation, which is driven by internal satisfaction and personal goals, and extrinsic motivation, which is influenced by external rewards.

2. **Tailor Training Methods**: Enhance both types of motivation, ensure that learners find personal relevance in their training.

3. **Measure and Engage Motivation**: Regularly assess learner motivation and engagement throughout the program. Use surveys, feedback sessions, and performance metrics to gauge what drives your learners and adjust your approach accordingly.

4. **Foster a Supportive Learning Environment**: Create an atmosphere that encourages independence, collaboration, and personal growth. Facilitate opportunities for peer interaction and provide ongoing feedback to enhance motivation and engagement.

10.6 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

10.7 REFERENCES

[1] Courtney E. Ackerman. Self Determination Theory and How It Explains Motivation.

[2] Richard M Ryan and Edward L Deci. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am. Psychol.*, 55(1):68–78, 2000.

[3] F. Herzberg. *Work and the nature of man*. World Publishing, 1966.

[4] F. Herzberg, B. Mausner, and B. B. Snyderman. *The Motivation to Work*. Routledge, 1993.

[5] F. Herzberg. *The motivation to work*. John Wiley Sons, New York, 1959.

[6] R. Wlodkowski and M. Ginsberg. *Enhancing adult motivation to learn: A comprehensive guide for teaching all adults*. Jossey-Bass, San Francisco, CA, 4th edition, 2017.

[7] Frederick Herzberg et al. *One more time: How do you motivate employees*, volume 65. Harvard Business Review Boston, MA, 1968.

[8] Abdul Samad Dahri, Abdul Sami Dahri, Ummi Naiemah Saraih, Mansoor Ahmed Khuhro, Junaid Ahmed Shaikh, and Muhammad Shahzeb Shahzeb Khan. Employee satisfaction and engagement are crucial for organizational success. In *Strategies and Approaches of Corporate Social Responsibility Toward Multinational Enterprises*, pages 184–201. IGI Global Scientific Publishing, 2024.

[9] John Hattie and Helen Timperley. The power of feedback. *Review of educational research*, 77(1):81–112, 2007.

[10] Angelo S DeNisi and Kevin R Murphy. Performance appraisal and performance management: 100 years of progress? *J. Appl. Psychol.*, 102(3):421–433, March 2017.

[11] G. T. Doran. There's a s.m.a.r.t. way to write management's goals and objectives. *Management Review*, 70(11):35–36, 1981.

[12] M. Gagne´ and E. L. Deci. Self-determination theory and work motivation. *Journal of Organizational Behavior*, 26(4):331–362, 2005.

[13] E A Locke and G P Latham. Building a practically useful theory of goal setting and task motivation. *American Psychologist*, 57(9):705–717, 2002.

[14] J Lave and E Wenger. *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press, 1991.

11. EMOTIONAL INTELLIGENCE

11.1 EMOTIONAL INTELLIGENCE IN WORKFORCE DEVELOPMENT

Emotional Intelligence (EI), as illustrated in Figure 11), is defined as the ability to perceive, understand, and manage one's own emotions as well as the emotions of others, a concept initially proposed by Salovey and Mayer [1]. It includes a variety of competencies, such as emotional recognition, expression, and management, which are crucial for interpersonal interactions and decision-making. As the fifth industrial revolution, or Industry 5.0, focuses on human-centric approaches within technological frameworks, the demand for soft skills, particularly EI, becomes increasingly clear [2]. With workplaces becoming more dynamic, the importance of EI rises, especially in industrial settings.

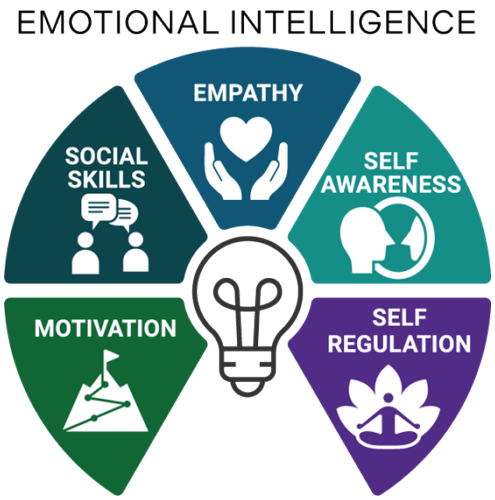

Figure 11. Emotional Intelligence. *Image Credit* [3].

Research indicates that individuals with high emotional intelligence exhibit greater adaptability and durability, which are essential for navigating complex social dynamics and collaborating within diverse teams [4, 5]. EI plays a significant role in job satisfaction and overall well-being, suggesting that emotionally intelligent employees are more likely to nurture positive workplace relationships and contribute to a harmonious work environment [6]. Furthermore, high emotional intelligence enhances adult learners' communication, problem-solving, and decision-making skills, thereby improving organizational performance [7] and positively impacting various aspects, including task, contextual, and adaptive performance [4]. Therefore, incorporating emotional intelligence training into industrial workforce development programs is not only beneficial but also essential, considering the evolving demands of today's workplace.

11.2 PRACTICAL APPLICATION OF EMOTIONAL INTELLIGENCE

Research consistently shows that emotional competencies, such as emotional management and interpersonal skills, are linked to positive organizational outcomes, including higher employee satisfaction and reduced turnover rates [4, 5]. EI plays a vital role in workforce development training programs by enhancing employees' abilities to manage relationships and resolve conflicts in the workplace. By promoting emotional intelligence in these training programs, organizations can cultivate a durable and effective workforce capable of thriving amid rapid technological advancements and shifting organizational structures [4, 6]. The intentional integration of EI into these training programs not only improves teamwork and adaptability among employees but also significantly boosts individual

performance and the overall success of the organization, leading to a more efficient and harmonious workplace environment.

- By incorporating emotional intelligence into training initiatives, organizations can develop targeted modules that focus on practical skills like emotional recognition and expression. This allows employees to recognize their own emotions as well as those of their colleagues [8].

- Role-playing scenarios that simulate workplace conflicts can help employees practice expressing their feelings and responding to others' emotional states, fostering a culture of open communication and collaboration.

- Training sessions that introduce techniques for emotional regulation, such as mindfulness practices, equip employees with tools to stay calm in stressful situations, which is crucial for effective problem-solving.

11.3 STRATEGIES FOR EMOTIONAL INTELLIGENCE IN WORKFORCE DEVELOPMENT

11.3.1 Integrating Emotional Intelligence

Incorporating EI into workforce development training programs can foster a versatile workforce capable of navigating the challenges of modern industrial environments. Program trainers can accomplish this by employing strategies to enhance emotional competencies among adult learners.

- **Prioritize Self-Awareness**: Encourage learners to develop self-awareness by incorporating reflective practices such as journaling. This helps them understand their own emotions and reactions, which is foundational for emotional intelligence.

- **Facilitate Empathy Development**: Use tools like empathy mapping to help learners understand and appreciate the perspectives and feelings of their colleagues. Design scenarios that reflect real workplace challenges to make the learning experience relevant and impactful.

- **Create a Supportive Development**: Foster a classroom atmosphere that values openness and vulnerability. Instructors should reassure learners that sharing their insights from reflections or role-plays is safe and confidential, promoting a culture of trust.

- **Highlight the Impact of Emotional Intelligence**: Share case studies or examples of how emotional intelligence has positively influenced workplace outcomes, such as improved safety, enhanced teamwork, or increased morale, to motivate learners to engage with the content.

- **Adapt to Individual Needs**: Recognize that learners come with diverse backgrounds and emotional experiences. Tailor your approach to meet individual needs and encourage personal growth in emotional intelligence.

11.3.2 Implementation

- One effective approach is immersive workshops that simulate realistic workplace scenarios, such as handling a dispute or leading a team meeting with conflicting viewpoints. These interactive sessions allow participants to practice identifying emotional cues, managing stress, and resolving conflicts within a controlled and encouraging environment [7].

- Reflective exercises like structured journaling prompts—where learners document their emotional reactions to specific situations—and guided group discussions offer a platform for profound exploration of personal emotional responses. This sharing fosters a sense of community and helps learners glean valuable insights from each other's experiences [4].

11.4 EXAMPLES

11.4.1 Empathy Mapping

1. **Description**: Empathy mapping is a visual tool that helps learners understand the perspectives and feelings of their colleagues. It encourages them to consider how others experience workplace challenges, which fosters emotional intelligence.

2. **Implementation**: Divide learners into small groups and provide them with a template that includes sections for "What They Think," "What They Feel," "What They Say," and "What They Do." Each group selects a scenario relevant to the industrial setting, such as a safety incident or a team project. They fill out the map based on their insights and perspectives about the individuals involved.

3. **Support the Learner**: Instructors can facilitate discussions by guiding groups to share their maps and encouraging reflection on how understanding different emotions can improve teamwork and communication. They can also provide feedback on the maps to deepen learners' insights.

11.4.2 Role-Playing Scenarios

1. **Description**: Role-playing allows learners to practice responding to emotionally charged situations in a controlled environment, enhancing their interpersonal skills and emotional regulation.

2. **Implementation**: Instructors should prepare specific scenarios that are common in the industrial work setting, such as conflict resolution between team members or dealing with a high-pressure situation. Have learners role-play these situations in pairs or small groups, switching roles to experience different perspectives.

3. **Support the Learner**: Instructors can observe the role-plays and provide constructive feedback on the emotional responses exhibited. They can also facilitate a debriefing session afterward to discuss what strategies worked, how emotions influenced the interactions, and what could be learned from the experience.

11.5 KEY BENEFITS

By incorporating these specific strategies into training programs, organizations can cultivate a workforce that is not only proficient in technical skills but also rich in emotional intelligence. This can, in turn, improve workplace dynamics, foster collaboration, and enhance overall performance [6].

- **Enhanced Collaboration**: Emotional Intelligence training enhances interpersonal skills, allowing team members to communicate effectively, exchange ideas, and resolve conflicts, which is essential in diverse teams.

- **Increased Adaptability**: Employees with high emotional intelligence are more adept at adapting to change, allowing organizations to navigate transitions seamlessly, such as implementing new technologies or undergoing restructuring.

- **Enhanced Decision-making**: Emotional Intelligence promotes awareness of the emotional influences on decision-making, resulting in more thoughtful and balanced choices that take into account both rational and emotional factors.

- **High job Satisfaction**: Employees with emotional intelligence often foster positive relationships with their colleagues, leading to a more fulfilling and supportive work environment.

- **Effective Problem-solving**: High emotional intelligence enables individuals to tackle challenges with a clear awareness of their own emotions and those of others, promoting innovative solutions to complex problems.

- **Adaptability in the Face of Change**: EI Training prepares employees to handle stress and setbacks more effectively, promoting a culture of adaptability within the organization.

11.6 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

11.7 REFERENCES

[1] P Salovey and J D Mayer. Emotional intelligence. imagination. *Cognition and Personality*, 9(3):185–211, 1990.

[2] Yanytska, L. The rise of human-centric manufacturing in the industry 5.0 era. Int J Adv Manuf Technol 139, 5067–5077 (2025).

[3] Daniel Gnanaprakasam. Emotional Intelligence. https://www.protouchpro.com/guest-posts/emotional- intelligence-4/.

[4] Susan Tee Suan CHIN. Influence of emotional intelligence on the workforce for industry 5.0. *J. Hum. Resour. Manag. Res.*, pages 1–7, September 2021.

[5] D Varshney and N K Varshney. Workforce agility and its links to emotional intelligence and workforce performance: A study of small entrepreneurial firms in India. *Global Business and Organizational Excellence*, 39:35–45, 2020.

[6] J Mohd and H Abid. Critical components of industry 5.0 towards a successful adoption in the field of manufacturing. *Journal of Industrial Integration and Management*, 5(3):327–348, 2020.

[7] B Radha and A B Shree. Impact of emotional intelligence on performance of employees and organizational commitment in software industry. *International Academic Research Journal of Business and Management*, 6(2):17–28, 2017.

[8] F Farnia and F M Nafukho. Emotional intelligence research within human resource development scholarship. *European Journal of Training and Development*, 40(2):90–110, 2016.

12. TECHNOLOGY INTEGRATION IN ADULT LEARNING

12.1 EXPLORING APPLICATIONS OF EMERGING TECHNOLOGY IN WORKFORCE DEVELOPMENT TRAINING

Workforce development focuses on enhancing employee skills to keep pace with evolving job demands. Technology plays a vital role in this area by offering scalable, personalized, and immersive learning experiences (Figure 12). Integrating technology in adult training and education is crucial for benefiting both adult learners and the stakeholders involved. Trainers and adult educators are essential to implementing training programs that effectively utilize technology to improve the skills and competencies of adult learners [1].

Technologies such as Artificial Intelligence (AI), Virtual Reality (VR), and microlearning platforms now effectively bridge skill gaps, helping align with organizational and economic demands. Training, for instance, incorporates digital adoption, highlighting remote and hybrid models, as noted in Deloitte's 2021 report on learning trends [2]. Research on technology integration in adult education [3] underscores the significance of incorporating digital tools to enrich learning experiences. By integrating technology, training professionals can create interactive and personalized learning environments that cater to adult learners' needs, fostering engagement and knowledge retention in a workforce development context.

Additionally, Storey and Wagner examine the opportunities and challenges of integrating AI into adult education, illustrating the potential for advanced technologies to enhance training programs and improve learning outcomes [4].

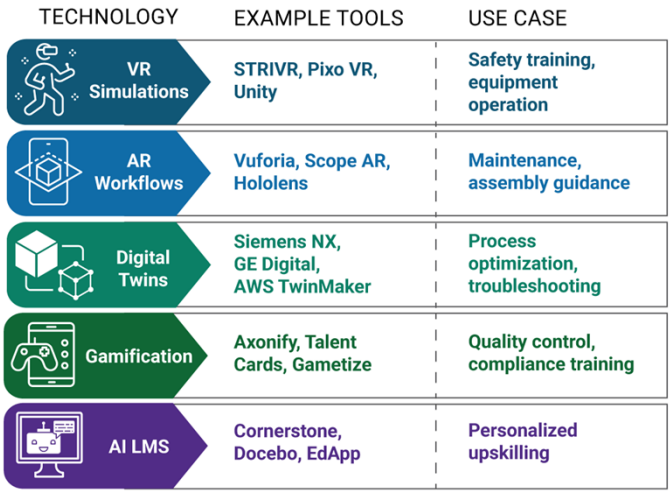

Figure 12. Overview of the Technology Applications.

12.2 THEORETICAL FOUNDATIONS

- **Andragogy** emphasizes self-directed learning. Technology facilitates this by utilizing adaptive learning platforms (e.g., Coursera) that allow employees to select paths tailored to their roles [5].

- **Experiential Learning** such as VR/Augmented Reality (AR) simulations (e.g., Oculus-based safety training) provide hands-on experience and reinforce learning through reflection and application [6].

- **Social Learning Theory** states that collaborative tools like Microsoft Teams or LinkedIn Learning foster peer interaction and knowledge sharing [7].

12.3 KEY TOOLS FOR MANUFACTURING TRAINERS

Table 2 provides examples of technologies used by trainers for manufacturing training programs.

Table 2. Example Technology for Manufacturing Trainings.

Technology	Example Tools	Use Case
VR Simulations	STRIVR, Pixo VR, Unity	Safety training, equipment operation
AR Workflows	Vuforia, Scope AR, Hololens	Maintenance, assembly guidance
Digital Twins	Siemens NX, GE Digital, AWS TwinMaker	Process optimization, troubleshooting
Gamification	Axonify, Talent Cards, Gametize	Quality control, compliance training
AI LMS	Cornerstone, Docebo, EdApp	Personalized upskilling

12.4 PRACTICAL APPLICATION OF TECHNOLOGY INTEGRATION

12.4.1 Current Technologies in Training

- Learning Management Systems (LMS): Platforms like Moodle and Cornerstone offer tracking and personalized content.
- Immersive Technologies: VR (e.g., STRIVR for Walmart's employee training) and AR (e.g., Boeing's assembly guidance) enhance technical and safety skills.
- AI and Analytics: Tools like EdCast provide personalized recommendations, while chatbots offer just-in-time support.
- Gamification: Platforms like Kahoot! increase engagement, as seen in Salesforce's Trailhead modules.
- Microlearning: Apps like Duolingo deliver bite-sized content, ideal for busy professionals.

12.4.2 Example 1: AI-Integrated LMS Platforms for Upskilling

1. **Description**: Personalizing training for diverse roles (e.g., machine operators vs. supervisors). Implementing online learning platforms can also provide a centralized and accessible hub for training materials, resources, and assessments.
2. **Technology**: AI-powered LMS like Cornerstone or Docebo to engage in self-paced learning, access training modules anytime, anywhere, and track their progress.

3. **Benefits**: Most LMS platforms offer features such as discussion forums, virtual classrooms, and multimedia content to boost engagement and collaboration among learners, foster a dynamic training environment, and reduce formal training time.

Tools for Trainers:

- Use **EdApp** for free AI-driven microlearning templates.
- Integrate **ChatGPT** into LMS for instant Q&A support.

12.4.3 Example 2: Virtual Reality (VR) Simulations

1. **Description**: Training employees on hazardous scenarios (e.g., chemical spills, equipment malfunctions) without exposing them to real danger.

2. **Technology**: VR simulations using platforms like **STRIVR** or **Talespin**.

3. **Benefits**: VR simulations can improve hands-on training, enhance decision-making skills, and offer a safe environment, thereby reducing workplace injuries for employees.

Tools for Trainers:

- Use **Unity** or **Unreal Engine** to create custom VR scenarios.
- Partner with VR vendors like **Pixo VR** for industry-specific modules.

12.4.4 Example 3: Gamified Microlearning for Quality Control/Performance Support

1. **Description**: Reinforce quality inspection standards without lengthy classroom sessions. Utilizing performance support tools, such as mobile apps or interactive job aids, can provide on-the-job guidance and resources to employees as they work.

2. **Technology**: Gamification platforms like **Axonify** or **TalentCards**. These tools offer quick access to troubleshooting guides, procedural checklists, and relevant information, reducing the need for intensive training sessions and improving defect detection accuracy.

3. **Benefits**: Trainees can apply their learning immediately and continuously improve their skills in real-time work situations. **Procter & Gamble (P&G)** gamifies SOP quizzes, using leaderboards to foster competition among factory teams.

12.5 STRATEGIES FOR EFFECTIVE TECHNOLOGY INTEGRATION

- **Needs Analysis**: Use surveys and analytics (e.g., LinkedIn Learning's 2023 report on in-demand skills) to identify gaps.

- **Blended Learning**: Combine VR modules with instructor-led sessions for holistic experiences.

- **Interactive Design**: Incorporate quizzes (Articulate 360) and scenario-based simulations.

- **Accessibility**: Ensure mobile compatibility (e.g., Degreed's app) and multilingual support.

- **Continuous**: Leverage LMS analytics to refine content and offer microcredentials for motivation.

- **Social Learning**: Integrate forums or Slack channels for peer collaboration.

12.5.1 Strategies for Implementation

1. **Start Small**: Pilot VR/AR modules with a single production line before scaling.

2. **Leverage Subject Matter Experts (SMEs)**: Partner with engineers to create accurate simulations (e.g., CAD models for digital twins).

3. **Blend Modalities**: for instance, combine VR with instructor-led debriefs to reinforce learning.

4. **Measure Return on Investment (ROI)**: Track metrics like reduced downtime, error rates, or time-to-competency.

12.6 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

12.7 REFERENCES

[1] Athman Haruna and Onesmo Amos. Effectiveness of teaching technology integration in the adult learning process in selected higher learning institutions in Tanzania. *International Journal of Education Humanities and Social Science*, 07(04):316–332, 2024.

[2] Deloitte Global Human Capital Trends. The social enterprise in a world disrupted: Leading the shift from survive to thrive. Technical report, Deloitte, 2021.

[3] Chih-Wei Wang, Amanda D Sainz, Glenda L Rose, and Mary V Alfred. Program directors' perspectives on technology integration in adult education and literacy classrooms. *Adult Literacy Education: The International Journal of Literacy, Language, and Numeracy*, 6(2):4–17, August 2024.

[4] Valerie A Storey and Amiee Wagner. Integrating artificial intelligence (AI) into adult education. *International Journal of Adult Education and Technology*, 15(1):1–15, May 2024.

[5] Malcom Shepherd Knowles. *The adult learner: a neglected species*. Gulf Publication Company, Houston, TX, 4th edition, 1990.

[6] D. A. Kolb. *Experiential learning: Experience as the source of learning and development*. Prentice Hall.

[7] A Bandura. *Social learning theory*. Prentice Hall, 1977.

13. BLENDED LEARNING IN THE WORKPLACE

13.1 EXPLORING BLENDED LEARNING AND ITS APPLICATIONS FOR WORKPLACE TRAINING

Blended learning (Figure 13) as an instructional approach integrates traditional face-to-face learning experiences with online components, creating a multifaceted learning environment that caters to the diverse needs of adult learners [1, 2]. It has emerged as a pivotal educational paradigm for adult learners in contemporary workplace settings, particularly in light of the seismic shifts prompted by the COVID-19 pandemic [3].

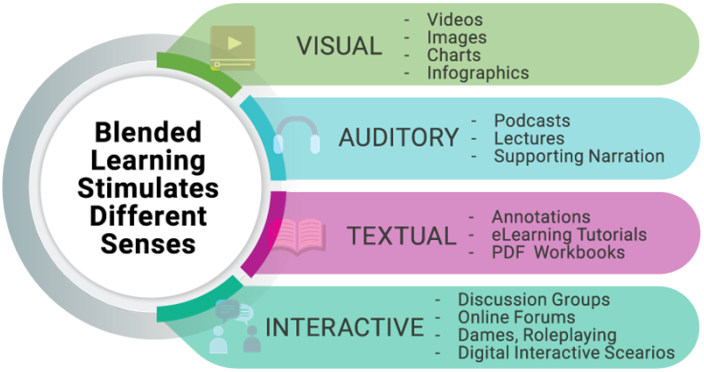

Figure 13. Blended Learning Stimulates Different Senses. *Image Credit* [1].

Although the pandemic necessitated a rapid transition to remote work, it compelled organizations to rethink their training methodologies [3]. Rapid advancements in technology for various learning methods have enabled this transition and spurred the adoption of numerous digital tools, including asynchronous e-learning modules, live webinars, podcasting, and virtual collaboration platforms—within a structured pedagogical framework. As a result, employees can engage in self-paced learning while benefiting from the advantages of synchronous, in-person interactions when feasible [3].

Blended learning highlights several essential principles of adult and continuing education, including self-directed learning, contextual relevance, and ongoing assessment and feedback.

Adult learners often value autonomy in their educational journeys, enabling them to customize their learning experiences to meet personal aspirations and professional goals [4]. Furthermore, incorporating collaborative projects and peer interactions in an online setting nurtures a sense of community that is vital for effective learning. By embracing these fundamental concepts, blended learning not only improves knowledge retention and skill development but also fosters a culture of lifelong learning that is crucial for navigating the complexities and uncertainties of today's rapidly changing work environment [4].

13.2 PRACTICAL APPLICATION OF BLENDED LEARNING ADULT EDUCATION

A blended approach allows employees to engage with the material at their own pace while fostering opportunities for hands-on practice, peer engagement, and immediate feedback, ultimately facilitating a more effective and personalized learning experience. Incorporating blended learning into today's workplace training demands a thoughtful approach that caters to the unique needs of adult learners. Integrating technology into existing programs can be challenging [3], as many organizations may confront outdated systems or resistance from employees who prefer traditional methods. To implement this approach effectively, Diep et al. recommend that organizations first assess their employees' skills and

learning preferences, ensuring the selected technology aligns with those needs [5]. Once these requirements are identified, they can create a curriculum that combines online learning with in-person instruction, making sure the materials are relevant and engaging. Measuring learner motivation and engagement throughout the process is vital, as understanding what drives employees can help tailor the program for improved outcomes.

13.2.1 Strategies for Incorporating Blended Learning

- **Online Learning Platforms with In-person Check-ins**: Trainees can complete courses at their own pace, while trainers hold monthly meetings to address questions, provide additional resources, and facilitate discussions about the content and connections among peers.

- **Collaborative Projects with Virtual Tools**: Encourages blended learning by assigning collaborative projects that enable teams to work together to complete tasks online. Instructors can facilitate this process by offering ongoing feedback and support through virtual platforms.

- **Mobile Learning Resources with Performance Support**: Developing or using existing mobile learning apps that enable trainees to access training materials and quick reference guides while on the job, with trainers promoting its use during team meetings and outcomes reviews.

13.3 IMPLEMENTING BLENDED LEARNING IN WORKFORCE TRAINING

13.3.1 Example 1: E-Learning Modules with Face-to-Face Workshops

1. **Description**: An organization creates a series of e-learning modules on project management principles that employees can complete at their own pace.

2. **Application**: After completing these modules, employees participate in a one-day in-person workshop where they apply the concepts they have learned through group activities and case studies.

3. **Benefits**: This approach enables learners to gain theoretical knowledge online and apply it right away in a practical setting, boosting retention and confidence in their skills.

13.3.2 Example 2: Virtual Training with Peer Collaboration

1. **Description**: A training program implements a virtual training program focused on certain types of new or updated skills, utilizing video conferencing tools for live sessions.

2. **Application**: During these sessions, employees break into smaller virtual groups to role-play and then reconvene to discuss experiences and insights.

3. **Benefits**: This approach encourages active participation and collaboration, fosters a sense of community, and enables learners to improve their skills through peer feedback in a supportive environment.

13.3.3 Example 3: Mobile Learning with On-the-Job Application

1. **Description**: An organization offers access to mobile learning apps that provide quick, bite-sized lessons on compliance training and regulatory updates.

2. **Application**: Employees can utilize these resources during their workday and immediately implement the knowledge acquired into their daily tasks or decision-making processes.

3. **Benefits**: The availability of learning materials keeps employees informed and compliant, while enabling just-in-time learning, which increases relevance and application in real-world situations.

13.4 KEY TAKEAWAYS

- **Blend Online and In-Person Learning**: Employ a combination of online resources and in-person instruction to create a comprehensive learning experience. This approach enables learners to take in information at their own pace while enjoying the interpersonal benefits of face-to-face interactions.

- **Understand Learner Needs**: Conduct a thorough assessment of your adult learners' skills and learning preferences. This understanding will guide the curriculum design to meet their unique needs and enhance engagement.

- **Embrace Flexibility**: Create blended learning programs that can adapt to change. So, make sure your program can accommodate various learning environments and unforeseen challenges.

- **Integrate Technology Thoughtfully**: While technology can enhance learning, it can also pose challenges. Select tools and platforms that are user-friendly and offer adequate support to assist learners in transitioning smoothly from traditional methods to blended approaches.

13.5 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

13.6 REFERENCES

[1] GP Strategies. Blended Learning: What It Is and Why It Works So Well. https://www.gpstrategies.com/blog/blended-learning-what-it-is-and-why-it-works-so-well/.

[2] Anh Diep, Chang Zhu, Celine Cocquyt, Maurice Greef, Minh Hien Vo, and Tom Vanwing. Adult learners' needs in online and blended learning viewed through the lens of existence, relatedness and growth (erg) theory. *Australian Journal of Adult Learning*, 59:224–255, 07 2019.

[3] Esinam Afi Kayi. Transitioning to blended learning during covid-19: Exploring instructors and adult learners' experiences in three Ghanaian universities. *British Journal of Educational Technology*, 55(6):2760–2786, November 2024. Publisher Copyright: © 2024 British Educational Research Association.

[4] H F B Mubayrik. The present and future state of blended learning at workplace-learning settings in adult education: A systematic review. *Journal of Social Studies Education Research*, 9(4):247–273, 2018.

[5] Anh Diep, Chang Zhu, Celine Cocquyt, Maurice Greef, Minh Hien Vo, and Tom Vanwing. Adult learners' needs in online and blended learning viewed through the lens of existence, relatedness and growth (ERG) theory. *Australian Journal of Adult Learning*, 59:224–255, July 2019.

14. EXPERIENTIAL LEARNING

14.1 WHAT IS KOLB'S THEORY OF EXPERIENTIAL LEARNING PROCESS?

Experiential learning in adult education is a dynamic process in which individuals acquire knowledge, skills, and competencies through direct engagement with experiences rather than traditional didactic teaching methods. This approach is grounded in the premise that learning is most effective when it involves active participation and reflection on one's experiences [1] (Figure 14).

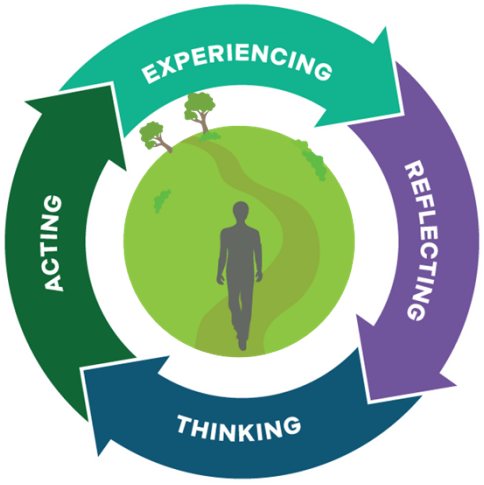

Figure 14. Kolb Experiential Learning Profile. *Image Credit* [2].

The experiential learning process encompasses four key stages:

1. **Concrete Experience:** Engage in a specific activity or event that serves as the foundation for learning.

2. **Reflective Observation:** Reflect on the experience to understand what occurred and the implications behind those actions.

3. **Abstract Conceptualization:** Formulate theories or concepts based on the reflections derived from the experience.

4. **Active Experimentation:** Apply the new concepts in practical situations to evaluate their effectiveness [3].

This cyclical process enhances critical thinking and problem-solving skills while promoting personal growth and self-directed learning. It is especially relevant for adult learners who bring a wealth of prior experiences to educational settings.

By engaging in experiential learning, adults can more effectively connect theoretical knowledge with practical application, resulting in a deeper understanding of how to apply new skills in various real-world situations. This learning process enhances retention of information and improves problem-solving and decision-making capabilities [4].

14.2 APPLICATION OF EXPERIENTIAL LEARNING

Experiential learning in the workplace, grounded in Kolb's Experiential Learning Theory, emphasizes learning through direct experience and reflection [1]. This approach can be implemented through on-the-job training, where employees learn under supervision, aligning with Bandura's Social Learning Theory on observational and hands-on skill development [5]. Role-playing exercises, which build communication and decision-making skills, resonate with Dewey's philosophy of "learning by doing" [6]. Workshops and simulations, as discussed in Schön's reflective practice framework, create safe environments for experimentation by mirroring real-world challenges. Project-based assignments, which foster ownership and practical understanding, reflect Lave & Wenger's Situated Learning Theory, emphasizing authentic tasks within communities of practice [7, 8].

Mentorship programs, informed by Kram's research, promote knowledge transfer through observation and feedback [9]. Regular feedback sessions, critical for continuous improvement, draw on London's work on performance evaluation, while job rotation (a widely recognized HR practice) broadens perspectives by exposing employees to diverse roles [10]. Collectively, these methods enhance engagement, retention, and skill mastery.

14.3 EXAMPLES OF APPLYING EXPERIENTIAL LEARNING

14.3.1 Example 1: Job-Shadowing

To implement experiential learning through job shadowing, begin by identifying critical roles or tasks that benefit from hands-on learning. Pair less experienced employees with seasoned professionals for observation, while establishing clear learning objectives and desired outcomes. Schedule specific times for shadowing, ensuring both parties are committed.

Following each session, conduct a debrief to discuss observations and insights, facilitating reflection and effective knowledge transfer.

14.3.2 Example 2: Problem-Solving Workshops

For problem-solving workshops, initiate by selecting a genuine workplace challenge or process requiring enhancement.

Organize employees into diverse groups to foster various perspectives and facilitate discussions where teams brainstorm solutions and formulate action plans. Permit teams to test their proposed solutions in a pilot phase, then rigorously evaluate the outcomes. This iterative process promotes continuous improvement and the practical application of problem-solving skills.

14.3.3 Example 3: Project-Based Learning

In project-based learning, choose projects that align with organizational goals and necessitate practical application. Clearly define roles and responsibilities within the project team, equipping them with the requisite tools, materials, and support. Regularly monitor progress, providing constructive feedback and guidance to maintain project alignment. Upon completion, conduct a comprehensive review session to discuss successes and lessons learned, reinforcing the learning experience and identifying opportunities for future enhancement.

14.4 KEY TAKEAWAYS

- **Engagement**: Experiential learning actively involves learners, which enhances engagement and retention. Trainers should create opportunities that are interactive and relevant

- **Reflection**: Encourage learners to reflect on their experiences. Reflection helps solidify learning and promotes critical thinking.

- **Real-World Application**: Design activities that simulate real-world scenarios. This helps learners apply skills directly to workplace situations, increasing the relevance and impact of the training.

- **Feedback**: Provide timely and constructive feedback. This supports continuous improvement and helps learners identify areas for growth.

- **Adaptability**: Be flexible and adapt learning experiences to meet diverse learner needs and styles. This ensures inclusivity and maximizes learning effectiveness.

- **Collaboration**: Foster a collaborative environment where learners can share insights and learn from each other, enhancing teamwork and communication skills.

Focusing on these aspects, trainers can create effective and meaningful experiential learning experiences. It is crucial to engage learners through interactive activities, encourage reflection, and design real-world applications. Providing timely feedback and adapting to diverse needs ensure inclusivity and maximize effectiveness. Additionally, fostering collaboration allows learners to share insights and learn from each other, enhancing teamwork and communication skills. These strategies collectively contribute to a dynamic and impactful learning environment.

14.5 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

14.6 REFERENCES

[1] D. A. Kolb. Experiential learning: Experience as the source of learning and development. Prentice Hall, 1984.

[2] A Y Kolb. The Kolb experiential learning profile: A guide to experiential learning theory. Psychometrics and Research on Validity, pages 1–154, 2021.

[3] D. A. Kolb. Experiential learning: Experience as the source of learning and development. Pearson Education, Inc., 2nd edition, 2015.

[4] S. B. Merriam and L. L. Bierema. Adult learning. Linking theory and practice. Jossey-Bass, San Francisco, CA, 2014.

[5] A Bandura. Social learning theory. Prentice Hall, 1977.

[6] J Dewey. Experience and education. Macmillan, 1938.

[7] D. A. Schön. The reflective practitioner: How professional think in action. Basic Books, 1983.

[8] J Lave and E Wenger. Situated Learning: Legitimate Peripheral Participation. Cambridge University Press, 1991.

[9] K E Kram. Mentoring at work: Developmental relationships in organizational life. Scott Foresman, Glenview, IL, 1985.

15. ACTIVE LISTENING IN WORKFORCE DEVELOPMENT PROGRAMS

15.1 EXPLORING HOW ACTIVE LISTENING CAN FACILITATE CHANGE IN ADULT LEARNING PROGRAMS

Active listening (Figure 15) is a conscious process that involves fully engaging with the speaker to comprehend, interpret, and respond to their message [1]. Unlike passive hearing, which occurs involuntarily, active listening requires the listener to pay thoughtful attention, analyze both verbal and non-verbal cues, and provide appropriate feedback [2]. This multifaceted skill includes several cognitive components, such as sensing, encoding, evaluating, and responding [3]. Effective active listening is crucial for fostering meaningful communication and interaction, as it enables individuals to distinguish relevant information from irrelevant details, comprehend the speaker's intentions, and cultivate a purposeful, reciprocal adult learning environment [4]. By practicing active listening, learners not only improve their understanding but also foster stronger interpersonal relationships, which are vital for effective learning, dialogue, and collaboration in manufacturing training settings.

Figure 15. Active Listening. *Image Credit* [5].

In today's workforce development context, active listening is essential for promoting adult continuing education and skill development [1]. As lifelong learners, adults must continuously adapt to changing workplace demands, and effective listening is crucial to this process [6]. The European Commission highlights that communication skills, including active listening, are key competencies for lifelong learners, enabling them to interact positively and responsibly within their professional environments [7]. Furthermore, active listening creates an inclusive atmosphere where diverse perspectives are acknowledged and valued, thereby enhancing teamwork and collaboration [8]. By incorporating active listening practices into workforce training programs, trainers can greatly enhance learners' engagement, information retention, and overall success in their professional endeavors [9].

15.2 PRACTICAL APPLICATION OF ACTIVE LISTENING IN ADULT EDUCATION

Active listening promotes open communication and collaborative learning by fostering an environment where participants feel heard and understood. This approach not only strengthens interpersonal relationships among team members, but it also encourages the sharing of diverse perspectives, which can promote innovative problem-solving and improve team dynamics effectiveness. As Spataro and Bloch emphasize, active listening goes beyond simply hearing words; it requires engaging with the speaker

through reflection and inquiry, ultimately fostering a deeper understanding of the issues at hand [10]. Therefore, incorporating active listening into training programs can create a more inclusive and productive workplace culture.

15.3 STRATEGIES FOR ACTIVE LISTENING IN WORKFORCE DEVELOPMENT PROGRAMS

15.3.1 Types of Strategies for Applying Active Listening

To effectively implement active listening in workforce development programs, trainers can employ several strategies to encourage participant engagement and skill development.

- Incorporating interactive exercises such as role-playing scenarios or group discussions creates opportunities for participants to practice active listening in a supportive environment [10].

- Utilizing multimedia resources like video clips that demonstrate active listening behaviors improves understanding and retention of the concepts being taught.

- Instructors can also promote self-assessment activities, enabling learners to evaluate their listening styles and pinpoint areas for improvement [10].

- Offering continuous feedback and promoting a culture of reflection motivates participants to consistently hone their active listening skills, thus improving their overall effectiveness in the workplace.

15.4 IMPLEMENTATION EXAMPLES

15.4.1 Reflective Listening

1. **Description**: Reflective listening involves restating or paraphrasing what a speaker has said to confirm understanding and encourage further dialogue. This strategy helps learners feel valued and ensures clarity in communication.

2. **Implementation**: Instructors can practice reflective listening by actively engaging during discussions or training sessions. When a learner shares an idea or concern, the instructor can respond by summarizing the key points, saying something like, “What I hear you saying is that you find the new equipment challenging to operate. Is that correct?” This approach not only validates the learner’s input but also clarifies any misunderstandings.

3. **Supporting Learners**: Instructors should encourage learners to express their thoughts openly and remind them that their contributions are important. They can create a welcoming environment where learners feel safe to share their perspectives, reinforcing the idea that every opinion matters.

15.4.2 Open-Ended Questioning

1. **Description**: Using open-ended questions allows learners to elaborate on their thoughts and feelings, promoting deeper discussion and understanding. This strategy encourages critical thinking and helps uncover valuable insights from participants.

2. **Implementation**: Instructors can incorporate open-ended questions during training sessions or group discussions. Instead of asking yes-or-no questions, they could ask, “What are some

challenges you've faced when using this machinery, and how did you overcome them?" This prompts learners to provide more detailed responses and fosters an atmosphere of exploration.

3. **Supporting Learners**: Instructors should model open-ended questioning by encouraging peers to respond to each other's contributions. They can also provide prompts or examples to guide learners in formulating their responses, helping them articulate their thoughts more clearly.

15.4.3 Group Listening Circles

1. **Description**: Group listening circles create a structured environment where participants can share their thoughts and experiences without interruption. This strategy promotes attentiveness and respect among group members.

2. **Implementation**: Instructors can organize listening circles by seating participants in a circle and establishing ground rules for respectful listening. Each person takes turns sharing their thoughts while others listen attentively. To facilitate this process, instructors can provide a talking piece (e.g., a ball or a stick) that the speaker holds while talking, ensuring that only they have the floor.

3. **Supporting Learners**: Instructors can guide discussions by encouraging participants to reflect on what they heard after each turn. They may ask, "What insights did you gain from listening to your colleagues?" This encourages the synthesis of ideas and reinforces the value of active listening within the group.

15.5 KEY TAKEAWAYS

- **Prioritize Reflective Listening**: Encourage an environment where trainers actively restate and summarize learners' contributions. This practice clarifies understanding and fosters a sense of validation and respect among participants.

- **Use Open-Ended Questions**: To foster deeper discussions, transition from closed questions to open-ended ones. This strategy encourages learners to share their thoughts and experiences more fully, boosting critical thinking and engagement.

- **Create Organized Listening Circles**: Arrange group listening circles in which participants share their insights while others listen attentively. By setting ground rules for respectful communication, everyone feels heard and valued, fostering a collaborative learning environment.

- **Model Active Listening Techniques**: Instructors should demonstrate active listening behaviors, such as maintaining eye contact, nodding, and showing genuine interest in learners' responses. This demonstration encourages participants to adopt similar practices in their interactions.

- **Encourage Reflection on Listening Experiences**: After discussions or training sessions, prompt learners to reflect on their listening experiences. Questions like "What did you learn from listening to others?" reinforce the importance of active listening and promote continuous improvement.

15.6 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

15.7 REFERENCES

[1] Tanju Deveci. Listening as a lifelong learning skill- what, why, and how. In *16th International Conference on Literature, Languages, Humanities and Social Sciences*, 10 2018.

[2] M Purdy. *Listening in everyday life: A personal and professional approach*. University Press of America, 1997.

[3] A. Rizvi. *Effective Technical Communication*. Tata McGraw Hill Education Private Limited, 2005.

[4] S. Duck and D.T. McMahan. *Communication in Everyday Life*. SAGE Publications, 2009.

[5] School for Ethical Education (SEE). Tri-Factor Model of Moral Functioning.

[6] P Jarvis. The Routledge international handbook of lifelong learning. pages 9–18, 2009.

[7] European Commission. *The key competencies for lifelong learning: A European framework*. Office for Official Publications of the European Communities, 2007.

[8] Alex Matveev. *Intercultural Competence in Organizations*. Springer International Publishing, 2017.

[9] M Pearse and M Dunwoody. *Learning that never ends: Qualities of a lifelong learner*. Rowman & Littlefield, 2013.

[10] S E Spataro and J Bloch. Can you repeat that?" teaching active listening in management education. *Journal of Management Education*, 42(2):168–198, 2018.

16. ETHICAL CONSIDERATIONS IN WORKPLACE TRAINING

16.1 ETHICAL CONSIDERATIONS IN ADULT LEARNING ENVIRONMENTS

Ethics is a crucial focal point in adult education, particularly within workforce development training programs, as it provides a framework for determining appropriate conduct in complex professional environments (Figure 16). In this context, ethics includes a set of moral principles that guide individuals in distinguishing right from wrong, which is essential as workplaces face challenges due to technological advancements, globalization, and increased competition [1, 2]. Adult education, especially professional training programs that effectively incorporate ethical training, enhances the moral reasoning of learners and addresses their holistic development needs, fostering an organizational culture characterized by integrity and accountability. For instance, when adult learners are equipped with tools to navigate ethical dilemmas, such as workplace harassment or conflicts of interest, they are less likely to engage in misconduct, thereby promoting a culture of ethical awareness [1]. Moreover, the ethics of care emphasizes relationality and empathy and encourages trainers and trainees to establish supportive environments that foster trust and collaboration among colleagues [3, 4].

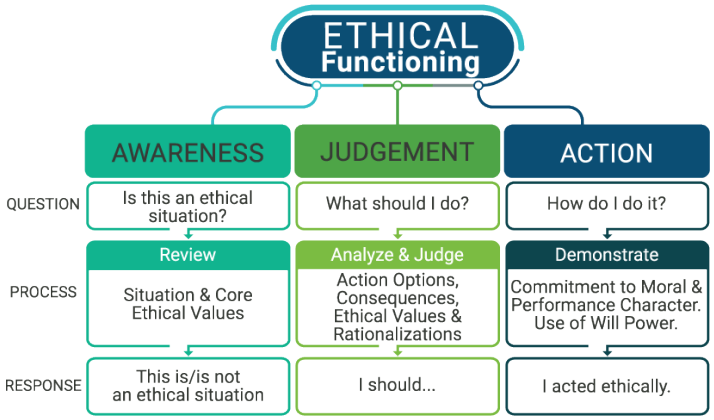

Figure 16. Tri-Factor Model of Moral Functioning. *Image Credit* [5].

Ethical training enables adult learners to engage in self-reflection and critical thinking, empowering them to assess the moral implications of their decisions in real-world scenarios, such as ethical sourcing and environmental responsibility [2]. Research shows that ethical considerations positively influence learners' ethical awareness and decision-making skills, effectively preparing them to navigate workplace challenges [4]. Therefore, integrating ethics into adult training programs not only enhances individual character development but also fosters a workplace culture that prioritizes ethical behavior, ultimately benefiting the organization by promoting an endurable environment for all employees [3].

16.2 PRACTICAL APPLICATION OF ETHICAL CONSIDERATIONS

By incorporating ethical case studies and scenarios into training modules, trainers can facilitate discussions that challenge employees to analyze their actions and understand their ramifications for team dynamics and community relations. This focused approach not only enhances accountability but also nurtures a culture emphasizing fairness, respect, and social responsibility [4]. Moreover, emphasizing the importance of ethical behavior in daily operations prepares employees to tackle real-world challenges, ensuring that their actions align with the organization's core values and ultimately enhancing the ethical climate for the organization's public image [1].

16.2.1 Integrating Ethical Considerations

- **Workplace Culture Enhancement**: Programs that emphasize ethics contribute to a culture of integrity, as employees are more likely to exhibit accountability and transparency.

- **Moral Decision-Making**: Ethics training helps employees make informed decisions in complex situations, such as resolving conflicts of interest, thus reducing misconduct.

- **Supportive Learning Environments**: The ethics of care fosters empathy among educators, enabling them to address the unique needs of diverse learners, which can lead to improved collaboration.

16.3 STRATEGIES FOR ETHICAL CONSIDERATION IN WORKFORCE DEVELOPMENT

Organizations can host dedicated training sessions that employ interactive methods, such as role-playing and small group discussions, to encourage employees to share their thoughts and learn from one another's experiences [6]. Additionally, it is crucial to foster an open environment where employees feel safe discussing ethical questions or concerns without fear of negative repercussions. Training programs can adopt a targeted approach to effectively integrate ethical considerations into workforce development programs, focusing on specific strategies that enhance both learning and application.

- Developing training materials that focus on specific ethical issues employees may encounter in their daily tasks, such as conflicts of interest or safety concerns, enables workers to explore real-life situations and think critically about appropriate responses [4].

- Establishing straightforward rules about expected behavior and clear ways to report unethical actions helps reinforce the importance of ethical behavior [7].

- Valuing and prioritizing ethical practices in their work will encourage employees to follow suit [3].

- Role-playing scenarios based on common ethical challenges within the industry, such as safety violations, resource allocation, or conflicts of interest.

16.4 IMPLEMENTATION EXAMPLES

16.4.1 Ethical Case Study Workshops

Ethical case study workshops can be integrated with other training programs.

1. **Description**: Develop workshops centered around case studies that present real-world ethical dilemmas relevant to the industry.

2. **Application**: Select case studies and incorporate real situations within the organization or industry. During the workshop, participants break into small groups to analyze the cases in assigned roles, identify ethical considerations, and discuss potential solutions based on professional and organizational ethical policies. Instructors facilitate discussions by promoting critical thinking and encouraging perspectives from diverse roles played.

3. **Benefit**: Enables employees to practice ethical reasoning in a safe environment, directly linking discussions to their roles. It encourages critical thinking and strengthens their capacity to navigate ethical challenges at work, ultimately aligning their decision-making with the organization's core values.

16.4.2 Structured Ethical Dialogues

1. **Description**: Create a framework for ongoing structured dialogues around ethics that can be embedded into regular training sessions.

2. **Application**: Allocate specific time during training sessions for facilitated discussions on ethical issues. Provide prompts or scenarios that encourage participants to reflect on their personal values and how they align with organizational standards. Finally, encourage storytelling, where participants can share experiences related to ethical practices or dilemmas.

3. **Benefit**: Promotes a culture of open communication and ethical reasoning among employees. It encourages participants to freely discuss ethical issues, enhancing their understanding and accountability in professional conduct. Regularly participating in these discussions can cultivate a more ethically aware workforce that prioritizes integrity in decision-making.

16.4.3 Reflective Ethical Leadership Training

1. **Description**: Develop training that emphasizes self-reflection on ethical beliefs and their influence on leadership styles and decisions.

2. **Application**: Create modules that encourage participants to assess their ethical beliefs and biases and how these influence their professional roles. To facilitate this reflection, instructors can use tools such as journals, peer feedback, guided discussions, or even online tools to leave messages unanimously. They can also incorporate role-playing scenarios in which participants must make decisions that reflect their ethical beliefs while considering organizational objectives.

3. **Benefit**: By engaging in self-reflection and understanding the interplay between personal ethics and professional responsibilities, employees are better equipped to lead with integrity. This training fosters a sense of accountability and empowers leaders to align their actions with both individual and organizational values, thereby enhancing the overall ethical culture in the workplace.

16.5 KEY TAKEAWAYS

- **Align Training with Organizational Values**: Ensure that the ethical principles integrated into the training align with the organization's values and industry standards. This alignment reinforces the importance of ethics in the workplace and enhances the credibility of the training program.

- **Establish Clear Ethical Guidelines**: Develop and communicate explicit guidelines and policies that outline ethical standards within industrial settings or specific organizational environments. These guidelines help reinforce accountability and create a culture of integrity among participants.

- **Reflect on Personal Values and Diversity**: Engage in self-reflection regarding own ethical beliefs and how they relate to the diverse backgrounds of adult learners. Acknowledging and addressing potential conflicts between individual aspirations and organizational goals can help create an inclusive environment that prioritizes learners' best interests.

- **Foster a Culture of Open Dialogue**: Create opportunities for open dialogue about ethics in the workplace. Regular discussions on ethical dilemmas enhance moral reasoning and contribute to a collective understanding of ethical practices within the organization.

- **Measure the Impact of Ethical Training**: Regularly evaluate the effectiveness of the ethical training initiatives through assessments, feedback, and performance metrics. This ongoing evaluation ensures that the training remains relevant and impactful.

16.6 AUTHORS AND ACKNOWLEDGMENT

This document was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725.

The efforts of the following contributors are appreciated for the content creation, review, and suggestions for this document: Dr. Qi Sun with University of Tennessee, Knoxville, Dr. Wei Guo, Paulomi Nandy, Kalie Miera, Ethan Guo, Dr. Melrose Pan, Thomas Wenning, and Dr. Sachin Nimbalkar with Oak Ridge National Laboratory, Dr. Crystal Bell and Ethan Rogers with US Department of Energy.

16.7 REFERENCES

[1] Amin Alizadeh, Khalil M. Dirani, and Shaoping Qiu. Ethics, code of conduct and ethical climate: implications for human resource development. *European Journal of Training and Development*, 45(8/9):674–690, December 2020.

[2] R.G. Brockett and R. Hiemstra. *Toward Ethical Practice*. Professional Practices Series. Krieger, 2004.

[3] N.E. Chalofsky, T.S. Rocco, and Michael Morris. *Handbook of Human Resource Development*. John Wiley Sons, 11 2014.

[4] David McGuire, Marie-Line Germain, and Kae Reynolds. Reshaping HRD in light of the COVID-19 pandemic: An ethics of care approach. *Advances in Developing Human Resources*, 23(1):26–40, 2021. eprint: https://doi.org/10.1177/1523422320973426.

[5] School for Ethical Education (SEE). Tri-Factor Model of Moral Functioning.

[6] https://www.ethicsed.org/tri-component model.html.

[7] Cam Caldwell and Louisiana State University, Alexandria. Understanding kindness—a moral duty of human resource leaders. *J. Values-Based Leadersh.*, 10(2), July 2017.

[8] Marilyn Y Byrd. Does HRD have a moral duty to respond to matters of social injustice? *Hum. Resour. Dev. Int.*, 21(1):3–11, January 2018.

ACKNOWLEDGMENT

This report was developed for US Department of Energy's Office of Critical Minerals and Energy Innovation as part of the Industrial Systems Energy Efficiency Development Collaborative by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725. The efforts of Dr. Crystal Bell and Ethan Rogers with US Department of Energy are appreciated for the review and suggestions for this report.