Integrating Multiple Intelligences and I-TRIZ

A Framework for Developing Individualized Problem-Solving Skills in Vocational Training

Norikatsu Fujita
Ability Development Dept
The Polytechnic University of JAPAN
Tokyo, Japan
e-mail: fujita@uitec.ac.jp

Sho Aoki
Electronics and Information Systems Dept
Shikoku Polytecnic College
Kagawa, Japan
e-mail: Aoki.sho@jeed.go.jp

Abstract - **The paper proposes an integrated pedagogical approach to develop individualized problem-solving skills in vocational training, specifically addressing the growing number of trainees with special needs, such as developmental disabilities. The proposed approach integrates a framework of "fundamental skills," derived from Gardner's Multiple Intelligences (MI) theory, with I-TRIZ, a structured problem-solving methodology. Using interviews with vocational trainers and the Steps for Coding and Theorization (SCAT) method, we redefined the "fundamental skills" as 26 practical skills, which were then categorized under six intelligences from MI theory. This paper illustrates the framework's potential through a hypothetical case study in welding training, demonstrating how trainees with disabilities can strategically apply these skills at each stage of the I-TRIZ process to acquire effective and autonomous problem-solving abilities. Ultimately, this integrated framework offers a promising pathway for developing individualized support and fostering self-regulated problem-solving skills in vocational training.**

Keywords-Multiple Intelligences(MI)Theory; Ideation-TRIZ; Developmental disabilities; Self-Regulated Learning; Polytechnic science.

I. INTRODUCTION

Practical problem-solving skills, such as addressing workplace challenges and adapting flexibly to change, are essential for sustained career success in a world of rapid technological innovation and globalization [2].

In vocational training, the need for individualized instruction is growing due to the increasing number of trainees requiring special support—including those with developmental disabilities—and the diversification of trainee backgrounds. This paper is a substantially extended version of research originally presented at an international conference [1]. Trainees exhibit diverse attributes—such as vocational history, educational background, and age—as well as significant variations in learning styles, prior knowledge, and skill levels. Therefore, it is crucial to cultivate general-purpose problem-solving skills that leverage individual strengths and prepare trainees to manage unexpected situations, ensuring all can achieve independence and success.

Conventional instruction in vocational training has faced three major challenges [3]. First, instruction often relies on heuristic, case-specific methods rather than established systematic approaches. Second, it is difficult to tailor instruction to the unique characteristics and learning needs of each trainee. Third, excessive support from instructors may inadvertently hinder the development of trainee independence. Therefore, even if trainees overcome challenges during training, they may fail to develop the ability to think and solve problems independently, leading to subsequent difficulties after employment. While indicators for assessing individual characteristics exist in other fields [4], there is a notable scarcity of such indicators developed from a pedagogical perspective suitable for adaptation to vocational training environments.

Gardner's multiple intelligences (MI) theory [5], which views human intelligence from multiple perspectives, has potential for addressing this situation. However, the abstract nature of MI theory makes it difficult to translate into concrete instructional practices or to quantitatively measure its educational effectiveness in vocational training contexts [6].

To address these challenges, this study proposes a pedagogical approach that integrates MI theory with the I-TRIZ methodology to foster both individualized instruction and general-purpose problem-solving skills. This integrated approach is designed to directly counteract the identified challenges. Specifically, the MI-based framework provides a systematic basis for tailored instruction, addressing Challenge #2. Simultaneously, the I-TRIZ process establishes the systematic, non-heuristic methodology that conventional instruction lacks, thereby addressing Challenges #1 and #3. This approach is centered on the concept of "fundamental skills," which are derived from MI theory to address the unique strengths and challenges of individual trainees. By using I-TRIZ [7], a structured problem-solving methodology, it becomes possible to better support trainees in mastering the process of identifying root causes and devising concrete solutions. The "fundamental skills" were defined through a detailed analysis of 192 problematic behaviors observed in vocational training settings [8], allowing us to translate the abstract nature of MI theory into concrete, applicable instructional components.

The proposed approach builds on a history of pedagogical development at Polytechnic University, which has offered training focused on fundamental skills since 1998. This long-standing program has consistently integrated methods aligned with MI theory and was updated in 2022 to refine its framework from 32 to 26 core skills, addressing issues of redundancy and granularity. This continuous adaptation underscores the sustained significance of this pedagogical model in vocational education.

This paper is structured as follows. Section II outlines the theoretical foundations of the proposed approach, integrating MI theory and I-TRIZ. Section III details the methodology used to redefine the fundamental skills. Section IV presents a hypothetical case study to illustrate the practical application of the framework. Section V provides a broader discussion, positioning the contribution within the context of prior and related work. Section VI acknowledges the study's limitations and suggests directions for future research. Finally, Section VII offers concluding remarks.

II. Theoretical Framework and Proposed Approach

This section outlines the theoretical underpinnings of the proposed pedagogical approach, drawing upon Gardner's Multiple Intelligences (MI) theory and the I-TRIZ problem-solving methodology. It defines "fundamental skills" within the context of MI theory and explains how these skills are integrated with I-TRIZ to facilitate individualized learning and problem-solving in vocational training.

A. MI Theory and Fundamental Skills

Gardner's MI theory posits that human intelligence is not a single, uniform ability, but rather a collection of independent intelligences. Gardner initially proposed seven intelligences (linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal, and intrapersonal), and later added naturalist intelligence. Other candidate intelligences, such as existential intelligence, have also been considered by Gardner [9]. These intelligences reflect humans' diverse approaches to processing information and solving problems.

Within Gardner's Multiple Intelligences (MI) theory, an "intelligence" refers to an innate biopsychological potential for an individual to solve problems or create products that are valued within a particular cultural setting. In contrast, a "skill" in this study is defined as the observable mastery of a specific behavior, which emerges from this latent potential and is developed through training and experience. In other words, a skill is a tangible manifestation of an intelligence, measurable and evaluable in a practical context.

This study focuses on six intelligences from the MI theory (linguistic, logical-mathematical, spatial, bodily-kinesthetic, interpersonal, and intrapersonal) that are most relevant to vocational manufacturing training. In our framework, we operationalize these intelligences through a set of "fundamental skills," which are concrete, observable behaviors that manifest from an individual's latent potential. Rather than treating each intelligence as a broad, overarching concept, we defined four to five specific "fundamental skills" corresponding to each of the six intelligences. For example, "understanding instructions (using demonstratives)" is a fundamental skill related to linguistic intelligence, while "identifying 2D shapes" is a skill related to spatial intelligence. These fundamental skills are measurable behavioral indicators. Defining them allows for a more detailed understanding of each trainee's abilities and enables more practical, individualized instruction. This approach could be particularly beneficial for learners with developmental disabilities, who often have uneven profiles of cognitive strengths and weaknesses [10]. This approach can teach them to leverage their strengths to compensate for their weaknesses. It also promotes self-regulated learning by enabling trainees to understand their own learning styles and choose strategies that best suit their needs.

This principle is exemplified by a case study [11] of an individual with developmental disabilities who had a deficient body image. This condition hindered his coordinated movement. For this individual, logical-mathematical instruction (e.g., verbalizing the cause-and-effect of movements) was used to overcome challenges related to bodily-kinesthetic intelligence. This approach enabled the individual to understand movement mechanics and ultimately master complex athletic skills, demonstrating that learners can leverage strengths in one intelligence to compensate for difficulties in another.

B. Utilizing I-TRIZ and Fundamental Skills for Problem-Solving

While MI theory provides the crucial lens for understanding individual cognitive differences ('what' to focus on), it does not offer a structured process for problem-solving. Conversely, while I-TRIZ provides a systematic process ('how' to solve), it does not inherently account for individual learner characteristics. Therefore, the synergy of these two theories is essential to our approach, as it creates a comprehensive pedagogical model that integrates individualized diagnosis with systematic problem-solving. The proposed approach uses I-TRIZ, a simplified version of TRIZ, as a structured problem-solving methodology. TRIZ is a theory derived from the analysis of a vast number of patents to extract common patterns of invention. I-TRIZ retains the core principles of TRIZ and consolidates TRIZ's 40 inventive principles into nine key principles, enabling a simpler, more practical approach to problem-solving. This study adapts a problem-solving process based on I-TRIZ, consisting of the following steps:

1. Define Objectives and Constraints: Clearly define the problem to be solved and understand the goals to be achieved, the current situation, the ideal outcome, and constraints (time, budget, resources, etc.).

2. Model the Problem: Visualize the problem and its related factors using tools such as diagrams, and identify the root cause through methods like repeated questioning. At this stage, fundamental skills related to logical-mathematical intelligence, such as "Subdivision of information," and those

related to interpersonal intelligence, such as “understanding others’ intentions,” are important.

3. Generate Ideas: Utilize I-TRIZ’s nine inventive principles (segmentation, extraction, local quality, asymmetry, combination, universality, nesting, prior action, and counteraction/inversion). These principles provide structured pathways for creative problem-solving across diverse domains [12]. The strategic application of a trainee's fundamental skills can significantly enhance their ability to use these principles. By mapping specific skills to each inventive principle, instructors can guide trainees to leverage their cognitive strengths.

For example, the principle of Segmentation involves dividing a system or problem into smaller, independent, or more manageable parts. This directly engages Skill 7: Subdivision of information (Logical-mathematical), which is the ability to break down complex information. Additionally, visualizing how a physical object can be taken apart or how distinct modules can be formed relies on Skill 11: Identifying 3D shapes (Visual-spatial). If the segmentation involves physically manipulating components, Skill 14: Hand dexterity (Bodily-kinesthetic) becomes crucial.

The principle of Extraction focuses on identifying and separating a necessary part/property or removing an interfering one. To apply this, a trainee might use Skill 9: Understanding of priorities (Logical-mathematical) to determine which elements are essential or detrimental. If the part to be extracted is visually distinct (e.g., color-coded), Skill 12: Identifying color (Visual-spatial) would be beneficial. Furthermore, deciding to remove a long-standing but problematic feature might require Skill 25: Emotional control (Intrapersonal) to overcome attachment to existing designs.

Consider Prior Action, which means performing a required change or action in advance. This principle encourages foresight and planning. Trainees strong in Skill 23: Understanding future prospects (Intrapersonal) can more readily anticipate future needs or steps, making prior actions intuitive. Executing these preparatory steps often involves understanding and following sequences, supported by Skill 3: Understanding instructions (Linguistic-verbal), and in a workshop context, preparing materials might involve Skill 6: Basic arithmetic operations (Logical-mathematical) for measurements or counting.

The principle of Combination involves merging or assembling different elements or functions. This can be effectively utilized by trainees who excel at Skill 8: Completion of unclear points (Logical-mathematical), as they can see how disparate parts might fit together to form a complete solution. If combining ideas from multiple team members, Skill 21: Understanding of others' intentions (Interpersonal) is key. For a trainee with strong Skill 24: Relating to similar experiences (Intrapersonal), they might combine current ideas with solutions from past, analogous problems.

These examples demonstrate that the effective application of I-TRIZ principles is not a purely abstract exercise but can be significantly enhanced by consciously engaging relevant fundamental skills. By understanding these connections, an instructor can guide a trainee to focus on principles that align with their cognitive strengths. For instance, a trainee strong in Visual-Spatial intelligence might be particularly adept with principles like Nesting or Asymmetry (requiring Skill 10 & 11), while one with strong Logical-mathematical intelligence might find Segmentation or Prior Action more accessible (utilizing Skill 7 & 9). This strategic application transforms the inventive principles from an abstract list into a personalized toolkit for innovation, drawing upon a wide range of intelligences.

4. Develop Solution Plans: Evaluate and select multiple ideas under realistic constraints (cost, time, technology, human resources, etc.) and develop them into an executable plan. The optimal solution is determined by comprehensively considering feasibility, effectiveness, risks, and the trainee’s own characteristics and abilities.

5. Evaluate Results: Evaluate the achievement level of the implemented solution from multiple perspectives, including numerical targets, feedback from stakeholders, and self-reflection. Based on the evaluation, identify areas for improvement and review the entire process.

In problem-solving and creative activities, it is crucial to understand which of a trainee's "fundamental skills" to use and how to use them effectively. This requires strong intrapersonal intelligence—the ability to accurately understand the trainee’s own emotions, motivations, strengths, weaknesses, and goals, and to use this understanding to guide their actions. However, individuals with certain developmental disabilities often face challenges in developing intrapersonal intelligence [13] [14], which can hinder their ability to engage in effective self-reflection and, consequently, impact their problem-solving capabilities. This focus on self-awareness is critical throughout the problem-solving process. Therefore, the proposed approach provides concrete support for developing these crucial skills through strategies such as promoting self-questioning (e.g., asking "why" repeatedly to oneself), incorporating feedback from others, and utilizing self-assessment checklists. These methods aim to foster objective self-review of actions and behaviors. For trainees with developmental disabilities who may struggle with self-reflection, instructors play a vital role by facilitating this process through guided questioning, structured feedback, and assistance in identifying and articulating their own strengths and weaknesses. It also promotes collaborative learning, in which trainees observe each other’s work, exchange opinions, and provide advice, thus deepening their learning from multiple perspectives.

III. REDEFINING FUNDAMENTAL SKILLS

This section details the process of redefining the fundamental skills derived from MI theory, making them more concrete and applicable to vocational training contexts. It outlines the methodology used, including semi-structured interviews with vocational trainers and the application of Steps for Coding and Theorization (SCAT) for qualitative data analysis. The section culminates in the presentation of the 26 redefined fundamental skills, categorized under six

MI intelligences, and explains how these skills were refined from the initial 32 skills.

A. Methodology

We conducted semi-structured interviews, each lasting approximately one hour, with 11 novice vocational trainers. All interviews were recorded and detailed transcripts were created. Novice instructors were chosen for this study because they are more likely to face instructional challenges. Consequently, they are expected to be more acutely aware of the fundamental skills required to address these challenges than their experienced counterparts. For each fundamental skill, interviewees were asked to imagine trainees with extremely high and extremely low levels of that skill and describe their specific behaviors in detail (e.g., during practical exercises, break times, interactions with others).

This method was designed to clarify the specific behavioral range associated with each skill and eliminate overlaps or inconsistencies.

This study used SCAT [15], a qualitative data analysis method, to redefine the 32 fundamental skills identified in previous research [16] to better suit the vocational training context. SCAT is a systematic method for extracting concepts from textual data, clarifying their relationships, and building a theory based on those relationships. For instance, its utility in structuring qualitative analysis to explore complex educational outcomes has been demonstrated by Kosaka and Nakawa [17] in their life story analysis of the long-term effects of a secondary education project in Kenya. Following this systematic approach, we applied the SCAT method, which proceeds along the following four steps:

1) Noteworthy Words: Identifying keywords and phrases related to trainees' difficulties (e.g., Explanation/safety part /misleading) from the interview transcripts.

2) Rephrasing: Converting these words into more general terms used in vocational training (e.g., Colloquialisms /points /not understood).

3) Explanatory Concepts: Assigning explanatory concepts to connect these phrases to the vocational training context (e.g., Practical training situations /safety management / trainee cases).

4) Themes and Concepts: Deriving the theme (constituent concept) of "understanding main points in spoken language" through this analysis.

Figure 1 illustrates the SCAT analysis process for redefining the fundamental skill "understanding key points from conversations and texts". The compositional concepts of the results of SCAT of the 11 interviews about "Understanding key points from spoken and written language" are shown in Figure 2. These elements, identified through our SCAT analysis, were derived from interviews where 11 instructors described the behaviors of trainees with extremely high or low proficiency in this skill. The analysis revealed that these 13 elements—such as understanding oral explanations, comprehending information from context, and misunderstanding colloquialisms—collectively define the scope of this fundamental skill and the concrete behaviors it encompasses.

Notably, the difficulties identified by instructors varied, with some emphasizing the inability to grasp main points while others focused on misunderstanding colloquial language. This variation underscores the need for individualized instruction tailored to each trainee's specific challenges. The overarching goal of this study was to identify a comprehensive set of fundamental skills, including the one detailed here, that could collectively explain the 192 problematic behaviors identified in our previous research. Ultimately, the goal of this iterative process was to create a refined set of skills that was not only comprehensive in its explanatory power but also practical and relevant for vocational training instructors.

B. Redefined Fundamental Skills

Figure 3 illustrates the 26 fundamental skills redefined through the SCAT analysis and instructor interviews, as described in Section III.A. These skills represent a refinement of the 32 skills identified in previous research [15], with modifications based on the specific needs and challenges observed in vocational training settings. These 26 skills are categorized under six of Gardner's Multiple Intelligences (MI): Linguistic-Verbal, Logical-Mathematical, Visual-Spatial, Bodily-Kinesthetic, Interpersonal, and Intrapersonal. This categorization is based on the observed behaviors and cognitive processes associated with each skill, as identified through the qualitative data analysis. The figure provides the MI category, skill name, and examples of specific vocational training situations where each skill is

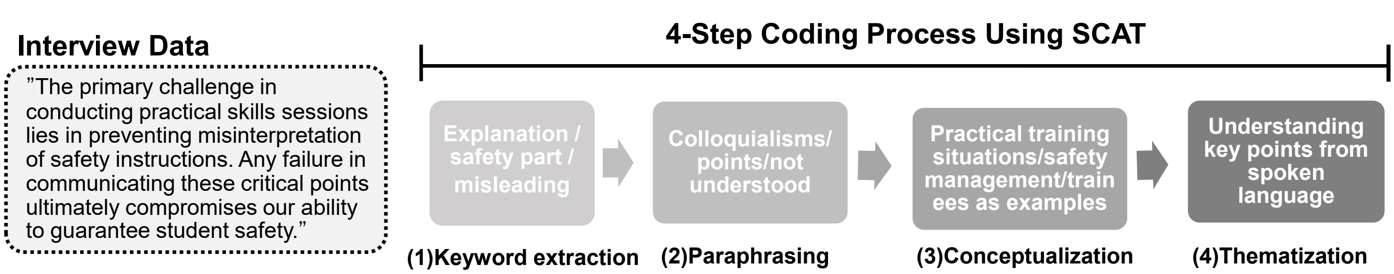

Figure 1. The SCAT analysis process for redefining the fundamental skill "understanding key points from conversations and texts"

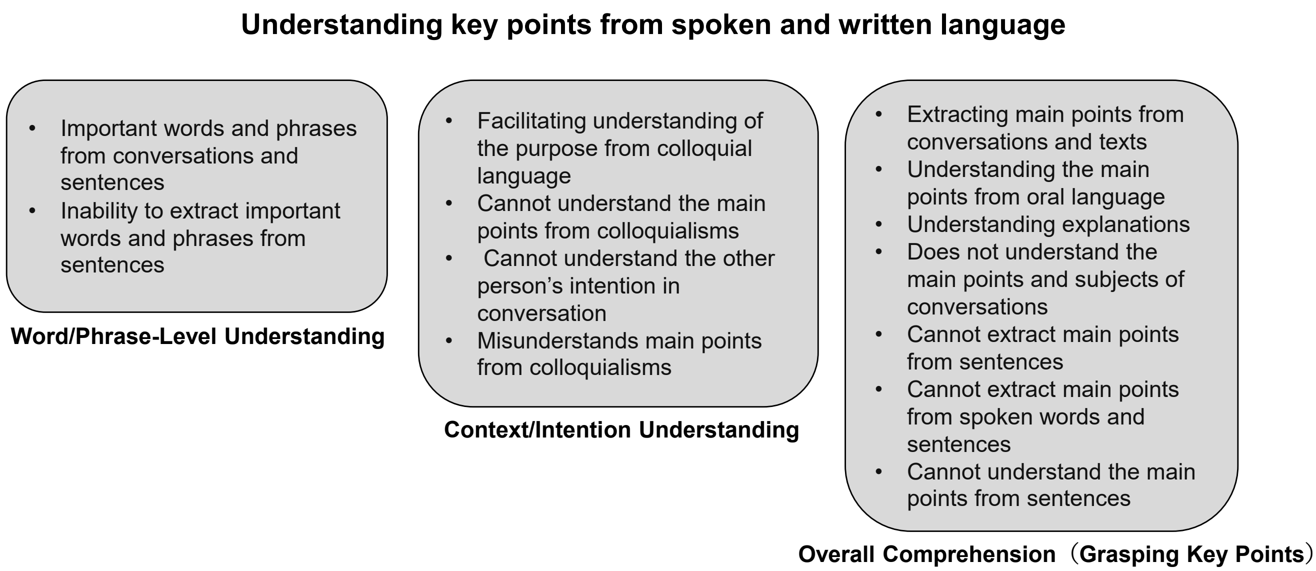

Figure 2. Compositional Concepts of the results of SCAT of the 11 interviews about "Understanding key points from spoken and written language"

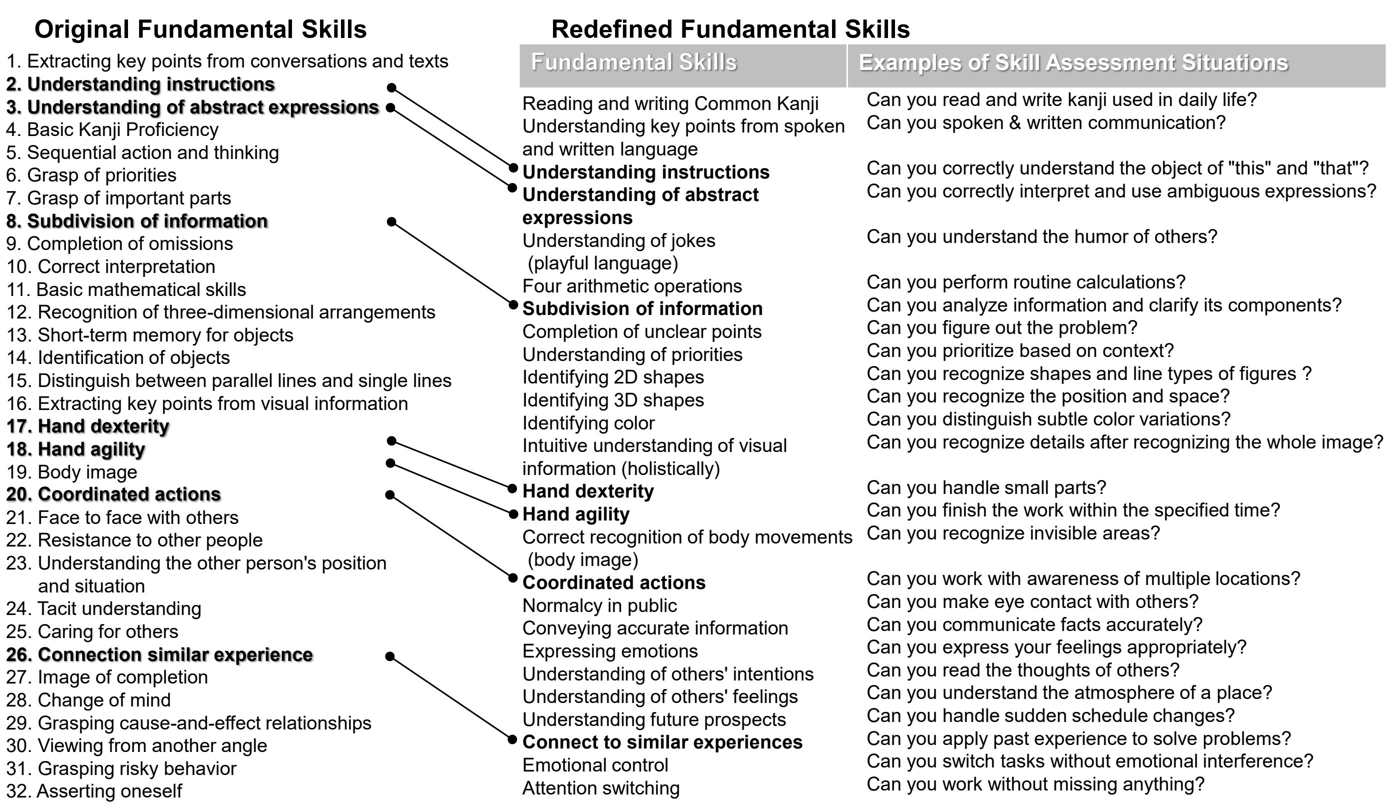

Figure 3. The original and redefined fundamental skills using SCAT analysis

Table 1. Modifications in redefining fundamental skills (changes, integrations, deletion, and additions)

MI	Fundamental Skills	Scope	Reason for improvement	Refined Skills name
Linguistic-verbal	Extracting key points from conversations and texts	・Smoothly understand the purpose from colloquial language. ・Inability to understand the other person's intention in conversation.	**Change:** Focus on any spoken, not just conversational, language.	Understanding key points from spoken and written language
	Basic Kanji Proficiency	・Cannot comprehend Kanji characters at the vocational level. ・Can read and write daily life level Kanji characters.	**Change:**Vocational training level within compulsory education scope	Reading and writing of kanji for common use
			Addition: Difficulty conveying jokes in conversation.	Understanding of jokes (playful language)
Logical-mathematical	Sequential action and thinking	・Can work according to the established sequence. ・Deviates from work procedures.	**Integration:** Includes "Understanding of priorities".	Understanding of priorities
	Grasp of priorities	・Can determine priorities based on efficiency. ・Cannot determine priorities based on deadlines.	**Integration:** Includes "Understanding of priorities".	Understanding of priorities
	Grasp of important parts	・Can grasp the important parts of things. ・Can understand the important parts of multiple tasks.	**Integration:** Includes "Understanding of priorities".	Understanding of priorities
	Completion of omissions	・Can understand the lack of processing and improve it. ・Does not have the knowledge to accomplish the objectives.	**Change:** Based on instructor feedback ("unclear points").	Completion of unclear points
	Basic mathematical skills	・Can perform four arithmetic operations including fractions. ・Can perform the four arithmetic operations.	**Change:** Based on instructor feedback ("Four arithmetic operations").	Four arithmetic operations
	Correct interpretation	・Make sense of numbers by calculation. ・Interpret the significance of things correctly.	**Integration:** Includes "Suddivision of information".	Suddivision of information
Visual-spatial	Recognition of three-dimensional arrangements	・Inability to perceive three-dimensional distance and depth. ・Cannot visualize three-dimensional shapes.	**Change:** Separated into 2D and 3D skills.	Identifying 3D shape
	Short-term memory of objects	・Cannot memorize numerical values in the short term. ・Can memorize the shape of objects in the short term.	**Delete:**Memory is not included in the MI categories.	
	Distinguish between parallel lines and single lines	・Understanding of line types is a prerequisite. ・Cannot distinguish shapes.	**Addition:** Separated into 2D and 3D skills.	Identifying 2D shape
	Distinguish between Objects	・Cannot distinguish colors close to the primary color. ・Cannot distinguish colors.	**Change:** Requires color identification, alongside 2D and 3D skills.	Identifying Color
	Extraction of key points from visual information	・Cannot focus on hazardous areas. ・Cannot focus on important points.	**Change:** Added holistic, intuitive visual understanding.	Intuitive understanding of visual information (holistically)
Body-kinesthetic	Body image	・Imitates the body movements of others. ・Does not have proper awareness of body range.	**Change:** "Body image" to clearer term.	Correct recognition of body movements (body image)
Interpersonal	Face to face with others	・Inability to use appropriate body language. ・Inability to express appropriate emotions.	**Change:** Based on instructor feedback (a lot of conversation and body language).	Conveying accurate information
	Resistance to other people	・Is uncomfortable in conversation. ・Cannot establish positive rapport with new acquaintances.	**Change:** Focus on attitude	Normalcy in public
	Understanding the other person's position and situation	・Cannot anticipate the feelings of others and act accordingly. ・Cannot understand the other person's situation.	**Change:** Focus on intentions	Understanding of others' intentions
	Tacit understanding		**Change:** Focus on feelings	Understanding of others' feelings
	Caring for others	・Can build good relationships. ・Has difficulty in building good relationships.	**Change:** Emphasizes emotional expression.	Expressing emotions
Intrapersonal	Image of completion	・Clearly defines the target quality. ・Can grasp the process from the image of completion.	**Change:** Supports intuitive visual understanding.	Understanding future prospects
	Change of mind	・Can switch from break to work quickly. ・Cannot let a bad event drag on.	**Change:** Requires diverse emotional control.	Emotional control
	Grasp of cause-and-effect relationships	・Cannot investigate the cause of work failure. ・Cannot understand the structure of equipment.	**Integration:** Includes "Connection to similar experiences".	Connection to similar experiences
	Viewing from another angle	・Flexible in dealing with problems instead of sticking to existing methods. ・Cannot consider multiple means to solve a problem.	**Integration:** Includes "Understanding future prospects".	Understanding future prospects
	Grasp of risky behavior	・Can predict and avoid hazards. ・Can anticipate danger.	**Change:** Includes "Attention switching".	Attention switching
	Asserting oneself	・Cannot express physical condition. ・Needs to improve the work environment.	**Integration:** Includes "Normalcy in public".	Normalcy in public(Interpersonal)

utilized and can be evaluated. This figure serves as a key reference point for understanding the individual strengths and weaknesses of trainees, and for tailoring instruction to meet their specific needs within the I-TRIZ problem-solving framework.

Table 1 shows the process of redefining the Fundamental Skills. To more comprehensively address the 192 problematic behaviors identified in the previous research and align the skills with the needs of vocational training, we implemented the following modifications:

Skill Changes (n=17): Seventeen skills underwent revisions to their names, definitions, or scope. These changes aimed to enhance clarity, precision, and practical relevance to vocational training. A representative example is the modification of "Understanding instructions" (Linguistic-verbal) to "Understanding key points from spoken and written language." This change acknowledges the primary modes of information delivery to trainees (spoken explanations and written materials) and moves away from an emphasis on interactive conversation. Other modifications included broadening skill scopes, refining terminology, and refocusing skills on practical application (e.g., emphasizing the use of related past experiences).

Skill Integrations (n=6): Six skills were merged into broader, encompassing skills. This consolidation was based on conceptual overlap and shared practical applications within the vocational context. For instance, "Grasp of priorities" and "Grasp of important parts" (both Logical-mathematical) were combined into a single skill: "Grasp of priorities (integrated skill)."

Skill Deletion (n=1): The skill "Short-term memory of objects" was removed. The rationale for this removal was that memory is considered a general cognitive function ratherthan a distinct intelligence within Gardner's MI framework.

Skill Additions (n=2): Two new skills were incorporated to address identified gaps in the original framework: "Understanding of jokes (playful language)" (Linguistic-verbal) and " identifying 2D shapes" (Visual-Spatial).

These modifications, taken together, constitute a significant revision of the Fundamental Skills framework, resulting in a model that is more precisely aligned with the specific demands and observed challenges of the vocational training context."

IV. Case Study

To illustrate the application and potential benefits of this approach, this section presents a hypothetical case study, developed for instructional purposes, focusing on a trainee, "A," undergoing welding training.

A. Trainee A's Profile and Challenges

Trainee A, a student diagnosed with a developmental disability affecting self-regulation, consistently produces welding defects, including uneven beads and insufficient penetration. This performance is not random but is directly attributable to a critical mismatch between his cognitive and motor skill profiles.

Cognitive Profile: The primary limiting factor is a profound deficit in 3D spatial recognition (Skill 11: Identifying 3D shapes). While highly capable of interpreting 2D blueprints (related to Skill 10: Identifying 2D shapes), he cannot perceive the changing geometry of the molten weld pool in real-time. This failure of visual feedback renders him unable to identify errors as they occur, making technical adjustments impossible.

Motor Profile: This perceptual deficit is exacerbated by his motor skills. He lacks the fine-motor dexterity (Skill 14: Hand dexterity)—the steady, precise control essential for quality welding. Conversely, he possesses significant hand agility (Skill 15: Agility), meaning his movements are quick and rapid.

Core Conflict: The central issue is a dysfunctional synergy. Trainee A’s agility is untempered by dexterity, and his rapid hand movements are unguided by the necessary real-time visual data. This combination of uncontrolled speed and perceptual blindness directly accounts for his consistent failure to produce a sound weld.

B. Application of the Proposed Approach within the I-TRIZ Framework

The following five stages illustrate how instruction, utilizing the redefined fundamental skills, was applied within the I-TRIZ problem-solving framework.

1. Define Objectives and Constraints: The instructor initiated a diagnostic dialogue with Trainee A, to facilitate self-reflection. The instructor prompted him to shift his focus from the immediate task to his internal state and past experiences. This intervention was designed to leverage intrapersonal intelligence, specifically 'Attention switching' (Skill 26)." This collaborative assessment, combining the trainee's articulation with the instructor's observations, revealed a core conflict: while Trainee A excelled at interpreting static 2D diagrams (a strength in skill 10), he struggled to perceive the dynamic, three-dimensional weld pool. This deficit, linked to a weakness in skill 11: Identifying 3D shapes, impeded real-time adjustments and was identified as the primary cause for inconsistent torch control (skill 14: Hand dexterity). Based on this diagnosis, a concrete, measurable goal was established: achieving consistent, defect-free welds with uniform beads and appropriate penetration.

2. Model the Problem: To deconstruct the challenge, the instructor and trainee co-created simplified diagrams on a whiteboard, breaking the welding process into discrete steps and identifying key variables (skill 7: Subdivision of information). This leveraged the trainee's 2D strengths to build a shared understanding (skill 21: Understanding of others' intentions). The critical intervention here was the use of smartphone video recordings. This method transformed the uncontrollable, real-time 3D phenomenon into a controllable, analyzable learning resource. By analyzing paused video frames (static 2D images), the trainee could objectively critique his own form. This technique acted as a powerful cognitive scaffold, leveraging his 2D proficiency (skill 10) to indirectly cultivate the spatial reasoning required for the dynamic 3D task.

3. Generate Ideas: Leveraging I-TRIZ principles and the trainee's profile, the instructor facilitated the formulation of targeted interventions. The Segmentation principle was first applied to decompose the complex skill acquisition. Practice was divided into two distinct, independently masterable units: 1) Motor-Only, to convert his innate agility (skill 15: Hand agility) into controlled dexterity (skill 14) by practicing torch movements with the welder off; and 2) Perception-Only, to refine his mental model by analyzing slow-motion videos of ideal welds, leveraging his 2D shape identification strength (skill 10). Subsequently, the Extraction principle was applied to mitigate cognitive overload during the live weld. A temporary jig was designed to 'extract' the interfering variable of maintaining torch angle. This intervention freed the trainee's cognitive resources to focus exclusively on observing the weld pool and regulating travel speed, thus transforming a multi-variable challenge into a manageable, single-variable task.

4. Develop Solution Plans: The generated ideas were then integrated into a structured, individualized training plan. The cornerstone was a standard instructional checklist, heavily modified to reflect the trainee's specific learning objectives. Vague items like "Evaluate weld quality" were replaced with concrete, observable questions tied to the new practice methods (e.g., "1. Bead uniformity: Is the width as consistent as the guideline we drew?"). This modification process itself involved subdivision of information (skill 7) and establishing clear evaluation criteria by prioritizing observable metrics over vague overall assessments (skill 9: Understanding of priorities). The plan also integrated a peer-suggested tactic: drawing guidelines on the workpiece, which exemplifies the plan's flexibility to incorporate collaborative problem-solving and address skill 8: Completion of unclear points. The resulting plan structured Trainee A's practice around the segmented drills and specified the use of video feedback for regular self-critique, connecting performance with past experiences (skill 24: Connect to similar experiences).

5. Evaluate Results: Evaluation was an iterative, multi-faceted process. Trainee A performed self-evaluations against the modified checklist, quantitatively tracking his progress in bead uniformity and defect reduction, which directly addressed his initial weakness in identifying 3D shapes (skill 11). This was supplemented by qualitative feedback from both the instructor and Trainee B. This structured loop of action and reflection significantly promoted his metacognitive awareness and attention switching (skill 26). His progress was documented in a learning journal, where he not only recorded results but also began to autonomously plan future practice sessions, demonstrating a tangible development in skill 23: Understanding future prospects and connecting experiences (skill 24). The process resulted in a quantifiable improvement in weld quality and, more importantly, in the trainee's autonomous problem-solving capabilities. He learned to synthesize insights from multiple sources by interpreting key points from verbal advice (Skill 2) and understanding the underlying intentions of feedback from his instructor and peers (Skill 21).

C. Outcomes and Evaluation

This iterative process, guided by the redefined fundamental skills and the structured I-TRIZ framework, is designed to result in significant and observable improvements in Trainee A's welding performance. In this hypothetical scenario, he demonstrates increased control over torch angle and speed, leading to more uniform bead formation and a reduction in defects such as insufficient penetration and burn-throughs. This improvement reflects not only the acquisition of technical welding skills but also the development of crucial metacognitive and self-regulatory abilities.

Notably, under a conventional approach, an instructor might simply have told Trainee A to 'practice more,' failing to diagnose the underlying metacognitive challenges and the specific weakness in real-time 3D shape identification (skill 11). In contrast, the case of Trainee A provides a model for how instruction tailored to individual cognitive characteristics (informed by MI theory), combined with a structured problem-solving approach, can effectively support the learning of trainees with developmental disabilities. The redefined fundamental skills offer a framework for identifying trainee strengths and weaknesses, allowing for focused instruction. The insights gained from this constructed example point the way towards broader validation and practical application, including larger-scale studies with diverse populations and the development of standardized assessment tools.

V. Discussion

The pedagogical framework at the heart of this paper is an evolution of our prior work. Our initial study analyzed 192 problematic behaviors to define a set of 32 fundamental skills [15]. This framework was subsequently refined into the current, more parsimonious 26-skill model. The development of this model was the primary contribution of our preceding conference publication [2]. This paper, in turn, substantially extends that initial work. Its principal contribution is not the 26-skill framework itself, but rather its deep theoretical positioning and articulation. We present this framework as a cognitivist advancement over structured learning models like Self-Regulated Strategy Development (SRSD), designed specifically to address future vocational demands.

Self-regulated learning (SRL) refers to learners' proactive management of their own learning processes and is widely considered a critical factor for academic achievement and lifelong learning [18]. Within the extensive research on SRL, Self-Regulated Strategy Development (SRSD) has emerged as a particularly robust instructional model, consistently demonstrating high efficacy and significant effect sizes in enhancing students' academic skills and self-regulation, especially for those with learning difficulties. Indeed, interventions that yield such substantial effect sizes are recognized as having a powerful impact on student outcomes in broader meta-analytic syntheses of educational effectiveness [19]. SRSD typically employs a structured, multi-step (six-step) pedagogical sequence. While its conceptual roots are predominantly behaviorist, focusing on the modeling, acquisition, and personalization of effective strategies for existing tasks, SRSD's pronounced success, particularly for learners with difficulties, can be partly attributed to Cognitive Load Theory (CLT) [20]. Its explicit procedural scaffolding likely minimizes extraneous cognitive load, thereby optimizing the cognitive resources available for learners to internalize complex strategies and achieve procedural fluency.

However, the justification for evolving beyond such behaviorist-centered models towards a more cognitivist framework is critically reinforced by the paradigm shift in expert skill, driven by AI and automation. The role of the human expert is transitioning from a primary focus on sensory-motor execution and procedural replication to a dual-competency model. This new model demands both high-level manual dexterity for complex, non-standard tasks (such as small-lot production or specialized repairs) and the systems-level expertise to manage, plan for, and collaborate with automated processes. Consequently, the primary challenge for future professionals is no longer just procedural mastery or the adaptation of known strategies within established parameters. Instead, it becomes inventive problem-solving when established procedures are inadequate, lead to contradictions, or when entirely new approaches are required for novel human-AI collaborative tasks. While behaviorist models like SRSD are highly effective for teaching established procedures, they are inherently less equipped to cultivate the *de novo* inventive capacity required for emergent, non-procedural challenges.

Our proposed MI/I-TRIZ framework is specifically designed to address this need for cognitivist, inventive skill development. It, too, utilizes a systematic structure—the I-TRIZ problem-solving process—complemented by individualized scaffolding through the MI-informed application of fundamental skills. This structured and personalized approach, akin to the architectural strengths of SRSD, similarly aids in managing cognitive load by minimizing extraneous load. Cognitive Load Theory posits that reducing such non-essential cognitive effort frees up finite working memory resources. These freed resources can then be invested in germane load—the productive mental effort required for deep understanding and schema construction. Critically, however, where SRSD primarily channels this available germane load towards the mastery of pre-defined strategies, the MI/I-TRIZ framework intentionally directs it toward systematic inventive thinking and the creative resolution of complex contradictions, employing I-TRIZ principles. The objective is thus to educate professionals who can function as expert problem-solvers, capable of inventing novel solutions whether working manually or managing automated systems—embodying a cognitivist approach to self-regulated, inventive learning tailored for the future of vocational expertise.

The practical application of this framework is illuminated by the case study of Trainee A. His difficulty was not a lack of potential, but a specific cognitive weakness—an inability to accurately perceive the changing 3D form of the weld pool (skill 11)—which prevented him from diagnosing his own errors. The key intervention—using diagrams and video feedback—was a direct application of the MI-based approach. It leveraged his documented strength in Identifying 2D shapes (a component of Visual-Spatial intelligence) to provide a concrete, external tool. This effectively translated the challenging dynamic 3D task into a series of manageable static 2D problems, enabling the self-reflection he struggled with internally. This specific example illustrates a central tenet of our approach: that by systematically identifying a trainee's strengths and weaknesses via the 26-skill framework, instruction can be tailored to build cognitive pathways around barriers, rather than attempting to confront them directly.

Beyond the individual level, implementing this integrated framework has profound practical implications for vocational training institutions. It necessitates a pedagogical shift, transforming the instructor from a traditional purveyor of knowledge into a diagnostic coach who can identify cognitive profiles and tailor strategies accordingly. Supporting this new role, in turn, would require a suite of validated diagnostic and instructional tools, which are essential for the scalable and consistent application of the framework.

Ultimately, the principles underpinning our framework are a practical extension of Gardner's core theory. A foundational tenet of MI theory is that all individuals possess a unique and uneven profile of intelligences. While this is universally true, these variations can be particularly pronounced in individuals with developmental disabilities. Therefore, the primary contribution of our work is not merely to acknowledge these individual profiles. Instead, we provide a systematic and replicable methodology—the 26 skills for diagnosis and the I-TRIZ framework for intervention—that empowers instructors to translate each unique intelligence profile into structured, effective pedagogical practice.

VI. Limitations and Future Work

The limitations of this study directly inform our agenda for future research. First, the redefinition of the 26 fundamental skills was based on semi-structured interviews with a small sample of 11 novice vocational trainers. Although this qualitative approach provided rich, detailed insights into the challenges faced in instructional settings, the small sample size restricts the generalizability of the findings.

Second, the case study presented in this paper is hypothetical, designed for illustrative purposes to demonstrate the potential application of the proposed framework. While grounded in real-world observations, it does not provide empirical evidence of the approach's effectiveness.

Therefore, future research is essential to address these limitations. A larger-scale study with a more diverse population of trainees and instructors is needed to validate and refine the fundamental skills framework. Building on this, the empirical validity and efficacy of the proposed pedagogical approach must be rigorously investigated through subsequent empirical studies. Future empirical studies will involve implementing this pedagogical framework in educational practice, replacing conventional instruction. Its effectiveness will then be rigorously evaluated by systematically measuring key learning outcomes (such as skill acquisition, trainee satisfaction, self-efficacy, and performance metrics) and subsequently calculating effect sizes to quantify its practical impact.

VII. Conclusion

In conclusion, this paper articulated and theoretically grounded an integrated pedagogical framework combining MI theory and I-TRIZ.

Building upon our prior work which refined 32 fundamental skills into a practical set of 26, the primary contribution of this paper is the articulation of this integrated MI/I-TRIZ framework as a cognitivist evolution of structured self-regulated learning approaches. It leverages structural benefits analogous to highly effective models like SRSD to manage cognitive load. However, it uniquely directs these freed cognitive resources toward systematic inventive thinking via I-TRIZ principles. We therefore offer a pedagogical model designed to cultivate the adaptive, creative problem-solving capabilities essential for future vocational contexts.

As illustrated by the case study and supported by the discussion, this model offers a promising pathway for diverse learners, particularly those with special needs. This work, therefore, not only offers a practical methodology but also opens new avenues for research into scaffolds that cultivate, rather than merely guide, cognitive skills.

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References

[1] N. Fujita and S. Aoki, "Fundamental Skills for Learning Strategies Based on Multiple Intelligences Based on 192 Cases of Problematic Behavior in Vocational Training," in HEALTHINFO 2024: The Ninth International Conference on Informatics and Assistive Technologies for Health-Care, Medical Support and Wellbeing, 2024, pp. 26-31.

[2] World Economic Forum, "Future of Jobs Report 2023". Geneva, Switzerland: World Economic Forum, May 2023. [Online]. Available:

https://www3.weforum.org/docs/WEF_Future_of_Jobs_2023.pdf. [Accessed: Jun. 4, 2025].

[3] J. Williams, "Pedagogical approaches to vocational education," in Pedagogy for Technology Education in Secondary Schools: Research Informed Perspectives for Classroom Teachers, P. J. Williams and D. Barlex, Eds. Cham, Switzerland: Springer, 2020, ch. 14. doi: 10.1007/978-3-030-41548-8_14.

[4] P. D. Flanagan and A. S. Kaufman, "Essentials of WISC-IV Assessment," Hoboken, 2009.

[5] H.Gardner, "Multiple Intelligences: The Theory in Practice," Basic Books; Reprint Edition edition, 1993.

[6] M. Ferrero, M. A. Vadillo, and S. P. León, "A valid evaluation of the theory of multiple intelligences is not yet possible: Problems of methodological quality for intervention studies," Intelligence, vol. 88, p. 101566, 2021.

[7] B. Zlotin, A. Zusman, and F. Hallfell, "TRIZ to invent your future utilizing directed evolution methodology,"Procedia Eng.", vol. 9, pp. 126-134, 2011, doi: 10.1016/j.proeng.2011.03.106.

[8] Japan Organization for Employment of the Elderly, Persons with Disabilities and Job Seekers, "Effective vocational training examples for people with developmental disabilities" Research Report No. 119, Japanese, 2007.(in Japanese) "

[9] H. Gardner, "Frames of Mind: The Theory of Multiple Intelligences," Basic Books, 2011

[10] R. M. Joseph, H. Tager-Flusberg, and C. Lord, "Cognitive profiles and social-communicative functioning in children with autism spectrum disorder," J. Child Psychol. Psychiatry, vol. 43, no. 6, pp. 807–821, Sep. 2002.

[11] M. Komichi, "Atashi Kenkyu" [My research]. Creates Kamogawa, 2009 (in Japanese).

[12] V. Souchkov, "Breakthrough thinking with TRIZ for business and management: An overview," ICG Training & Consulting, Enschede, The Netherlands, 2007, Updated 2017. [Online]. Available: https://www.xtriz.com/TRIZforBusinessAndManagement.pdf

[13] C. F. Huggins, G. Donnan, I. M. Cameron, and J. H. G. Williams, "Emotional self-awareness in autism: A meta-analysis of group differences and developmental effects," *Autism*, vol. 25, no. 2, pp. 307-321, Feb. 2021, doi: 10.1177/1362361320964306.

[14] D. Reid and C. Green: Preference-Based Teaching: Helping People with Developmental Disabilities Enjoy Learning without Problem Behavior, Habilitative Management Consultants, Inc., 2005

[15] T. Ohtani, "SCAT: Steps for coding and theorization: Qualitative data analysis method with explicit procedure, easy to set about, and suitable for small scale data,"Kansei Engineering", vol. 10, no. 3, pp. 155-160, 2011. [in Japanese]. [Online]. Available: https://www.educa.nagoya-u.ac.jp/~otani/scat/index-e.html. [Accessed: Jun. 4, 2025].

[16] N. Fujita et al., "Developing a computer-based vocational training environment that complements the weak skills and career development of trainees," International Journal on Advances in Intelligent Systems, pp. 279-289, 2018.

[17] M. Kosaka and N. Nakawa, "Life Story Analysis of the Longer-term Effects of Kenya's Strengthening of the Mathematics and Science in Secondary Education Project on the Attitudinal and Behavioural Changes of Former Secondary Students," Afr. J. Res. Math. Sci. Technol. Educ., vol. 28, no. 1, pp. 1-12, 2024, doi: 10.1080/18117295.2024.2318539.

[18] B. J. Zimmerman and D. H. Schunk, Eds., "Handbook of Self-Regulation of Learning and Performance". New York, NY, USA: Routledge, 2011.

[19] J. Hattie and G. C. R. Yates, "Visible Learning and the Science of How We Learn". Abingdon, Oxon, UK: Routledge, 2014.

[20] J. Sweller, "Cognitive load theory, learning difficulty, and instructional design," Learning and Instruction, vol. 4, no. 4, pp. 295-312, 1994.