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Modular, Adaptive, and Controlled: A Practice-Informed Design Framework for the Responsible Use of Generative AI in Continuing Vocational Education and Training in the Skilled Trades



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Modular, Adaptive, and Controlled: A Practice-Informed Design Framework for the Responsible Use of Generative AI in Continuing Vocational Education and Training in the Skilled Trades

1 Introduction

Vocational continuing education and training (CVET) in Germany is increasingly shaped by digitisation, structural changes in the labour market (cf. OECD 2021, p. 3), and an acute shortage of skilled workers (cf. SACHVERSTÄNDIGENRAT 2022, pp. 279–283).¹ These developments place increasing pressure on the skilled trades, understood here as regulated, practice-oriented occupations in crafts and technical services that are characterised by formal vocational qualifications and strong workplace integration, where new technologies continuously reshape task profiles and qualification requirements (cf. EBBINGHAUS et al. 2017, p. 9). Learning processes must therefore be flexible, workplace-oriented, and tailored to heterogeneous target groups that vary widely in experience and familiarity with digital education.

In this context, traditional methods of learning material development reach their limits. Producing high-quality, contextually relevant materials is time-intensive, especially when modularised and target group-oriented training structures require multiple variants of the same content. Artificial Intelligence (AI), and in particular Generative Artificial Intelligence (GenAI) based on Large Language Models (LLMs), offer new opportunities for scaling content production, enabling the rapid creation of texts, illustrations, and multimedia assets (cf. BAIDOO-ANU/OWUSU ANSAH 2023; CEDEFOP 2015).

This paper examines these challenges through the empirical lens of the “TraFuSMS – Training for Future Skills in Sustainable Mobility Solutions” project, which develops a modular continuing training programme covering battery diagnostics in electric vehicles, hydrogen systems and sustainable energy technologies, as well as innovation and process management for the skilled trades. While TraFuSMS is implemented in a CVET setting, the framework tar-

1 During the preparation of this manuscript, the authors used a number of AI-assisted tools to translate, edit the language and critically review the text. These tools were used exclusively to support linguistic quality and to identify potential issues in clarity, structure, or argumentation. No text passages were automatically generated or adopted without author verification. Translation and linguistic refinement: DeepL Translator, DeepL Write (DeepL SE, web version, accessed 13 January 2026). Review of grammar, spelling, academic style, clarity of expression, and the internal consistency of the manuscript: ChatGPT (OpenAI, GPT-4.1 / GPT-4o, accessed 13 January 2026) and Perplexity AI (Perplexity AI Inc., web interface, accessed 13 January 2026).

gets pedagogical control and governance mechanisms that are relevant across contexts of Vocational Education and Training (VET), including initial training and continuing education.

The project is described in more detail in chapter 3. Against this background, the paper addresses the following research questions:

- ▶ How can GenAI be used to support modular learning materials in heterogeneous target groups?
- ▶ What new roles and competencies are required of educational personnel when GenAI is embedded in content development?

By answering and synthesising these questions, a pedagogical framework is developed that supports educators by using GenAI as an assistive tool in Vocational Education and Training (VET) systems. The framework outlines when and how GenAI may be applied by educators and where its use must remain restricted as contexts require expert review.

2 State of Research and Technology

2.1 Characteristics of Vocational Continuing Education in Skilled Trades

CVET in the skilled trades is subject to structural conditions that fundamentally shape the requirements for learning materials. These determine the use of GenAI and its limitations. Vocational education research consistently highlights modular structuring, workplace embeddedness and learner heterogeneity as central determinants of pedagogical design in the skilled trades (cf. BIBB 2021; RAUNER 2004).

Modularisation and Flexibility

The shift towards modular training formats allows learning content to be broken down into clearly defined, self-contained units that target specific competencies (cf. BIBB 2021; PILZ 2005). This increases flexibility but leads to a growing number of content variants for different learner groups (cf. SEVERING/WEISS 2014). This creates a strong need for learning materials that can be created quickly, follow a consistent structure and can be updated easily (cf. ALBRECHT et al. 2014). In this context, GenAI can serve as a useful supporting tool to meet these requirements (cf. LUCKIN 2016).

Workplace as the Central Learning Site

In vocational education within the skilled trades, learning processes are embedded in real contexts of production, concrete work tasks, tools, and organisational regulations, which fundamentally shape the development of competencies (cf. GÖSSLING/OSTENDORF 2021, p. 22; KMK 2021). As a result, learning materials must be directly applicable to operational practice and aligned with workplace realities rather than remaining abstract or decontextualised (cf. BILLET 2014).

Heterogeneous Learners and Competence Profiles

Continuing vocational education and training in the skilled trades often involves mixed cohorts, ranging from first-year apprentices to experienced master craftspeople, each with distinct learning needs, prior knowledge, and specific digital skills. Adaptive learning materials therefore require differentiated complexity and tailored examples (cf. SEVERING/WEISS 2014). AI systems can support such adaptivity, provided that the outputs generated by these systems are carefully curated and validated (cf. LUCKIN et al. 2016).

2.2 GenAI as Media Assistance in Vocational Education

GenAI is increasingly used as a tool to accelerate the production of learning media rather than as a substitute for educational staff (cf. UNESCO 2023, p. 24f.). This includes the generation of simplified or alternatively worded texts, the creation of schematic visual representations, and the development of multimodal designs for videos, quizzes, and other interactive learning formats (cf. KASNECI et al. 2023; UNESCO 2023).

These functions can substantially reduce production time and provide scalable content variations for diverse learner groups.

GenAI can speed up media production in VET (cf. UNESCO 2023, p. 24f.), but it also introduces well-known risks, as Large Language Models (LLMs) predict plausible text rather than verify facts. In safety-sensitive areas, decontextualised or inaccurate guidance can cause equipment damage or injury. AI-generated content is therefore not reliable by default (cf. BENDER et al. 2021, p. 616f.). Its application requires clear pedagogical steering in the design and deployment of learning materials, expert review, and defined accountability before AI-generated content is released for educational use (cf. BENDER et al. 2021; KASNECI et al. 2023).

Typical types of mistakes include factual errors, misleading assumptions, incorrect terminology, security-relevant mistakes, and fabricated statements (hallucinations) (KASNECI et al. 2023). For VET providers, quality assurance and human oversight remain non-negotiable.

Pedagogical Control Requirements

Prompts require accurate delineation, accompanied by explicit pedagogical objectives. Human validation is integral to ensuring the technical accuracy and contextual relevance of the content under review. It is essential to ensure that there is alignment with the curricular requirements. Transparent documentation of AI-generated content is imperative (cf. UNESCO 2023, p. 19).

Research has converged on the view that GenAI can support, but not replace, the pedagogical expertise necessary to develop safe, contextually grounded learning materials (cf. KONG/YANG 2024).

3 Methodological approach and presentation of the TraFuSMS Project

This study combines theoretical analysis with practice-oriented development. Research on modular vocational education, target-group heterogeneity and the pedagogical media requirements of GenAI forms the conceptual framework for examining AI-supported content production in the skilled trades. The project TraFuSMS provides the empirical setting to test and refine these requirements in a real continuing education context.

3.1 Sample, Data Collection and Analysis

The empirical findings are based on an exploratory qualitative design embedded in the TraFuSMS piloting phase. Data were collected from a heterogeneous group of learners participating in CVET modules.

Data sources included learner feedback that was collected via short post-session questionnaires with open-ended response fields, guided group discussions conducted during pilot phases, and documented expert reviews carried out as part of the quality assurance workflow. The material was analysed using qualitative content analysis, focusing on recurring patterns related to perceived usefulness, comprehension, acceptance of AI-generated media elements and formats, coherence of learning sequences and validation effort.

3.2 The TraFuSMS Project Context

TraFuSMS develops a modular, workplace-oriented training programme for the automotive sector in three areas: battery diagnostics, hydrogen and sustainable energy systems, and innovation and process management. These modules are organised into short learning units that allow participation without extended workplace absences and support a heterogeneous learner group with varying levels of experience, digital affinity and learning needs. This structure makes it possible to analyse how content depth, complexity and format need to be adapted for different learner profiles.

GenAI is used as a pedagogically guided media assistance that contributes draft texts, visualisations, explanatory elements, and components for interactive modules. All AI outputs undergo iterative expert review to ensure accuracy and pedagogical coherence. These processes make it possible to examine the boundary between automated content generation and human quality control, including requirements for transparency and responsibility.

The development, piloting, and validation of materials take place in cooperation with automotive workshops, apprentices, and inter-company training centres. Iterative testing cycles ensure that practical feedback is systematically incorporated. This facilitates the identification of requirements for learning formats, pedagogical steering, and the evolving role of educational personnel. Integrating materials into a digital learning platform also offers insights into technical scalability and linguistic accessibility.

The combination of analytical work and practical implementation in TraFuSMS helps identify pedagogical, technical and organisational requirements under real-world conditions. The resulting insights form the basis for the analysis in chapter 4 regarding adaptive learning

materials, changing professional roles, and a governance framework for the responsible use of GenAI in vocational education.

4 Research Findings

This chapter brings together the theoretically derived potentials of GenAI (Chapter 2) and the empirical findings from the TraFuSMS project. It contrasts the requirements identified in educational research with the specific needs of the skilled trades and with the conditions observed during the practical use of AI-assisted learning materials in the project. On this basis, the chapter develops a pedagogical governance framework for the use of GenAI in VET and examines it using empirical evidence from the CVET context of TraFuSMS.

4.1 Adaptive Learning Materials and Target-Group Heterogeneity

Within TraFuSMS, GenAI was applied in different variants of content production and evaluated with a heterogeneous group of learners. The empirical findings presented below are derived from qualitative analysis of learner feedback, guided group discussions and documented expert reviews conducted during the piloting of AI-supported learning materials. They reflect recurring patterns that were identified across multiple training iterations rather than isolated individual assessments.

Finding 1: GenAI performed well in terms of linguistic diversification. It produced simplified variants of complex explanations and improved accessibility for the different learner groups, from first-year apprentices to master craftspeople. However, reliability decreased when GenAI was used for technical elaboration, including both visual representations and their accompanying textual explanations.

For example, GenAI was used to generate a standard current-voltage characteristic curve of a fuel cell and an accompanying explanatory description for instructional purposes. Although the resulting diagrams appeared plausible, an expert review revealed that the characteristic curves were technically incorrect. The inaccuracies could not be identified without domain-specific expertise, thus making expert validation indispensable.

Finding 2: Visual aids, distinguishably generated by GenAI, were well received and supported understanding. However, audiovisual formats such as photo-realistic avatars showed low acceptance among the test group.

Figure 1: Screenshots of the avatars from the various trial runs of the training: realistic version and comic style version



Source: left: HeyGen, Avatar III, 14.08.2025; right: OpenAI, ChatGPT (Version 4.1), 19.09.2025

The photo-realistic avatar on the left of Figure 1 was perceived as inauthentic due to synchronisation issues, the comic-like avatar on the right was preferred by the test group.

The avatars were perceived as inauthentic, and inaccuracies in pronunciation, intonation and timing disrupted comprehension and undermined trust in the content being conveyed.

Finding 3: The application of GenAI increased efficiency and accelerated the creation of initial drafts but did not produce coherent learning paths. Outputs tended to be additive and lacked the curricular progression required for the development of competencies. In practice, GenAI generated discrete content elements such as isolated explanations, examples, or quiz items in response to individual prompts. However, these elements were not automatically aligned across learning units and lacked references to prior knowledge or subsequent learning objectives. As a result, educators had to manually restructure, sequence, and connect AI-generated materials to establish a coherent curricular progression.

Finding 4: The use of GenAI enabled the rapid production of multiple content variants from shared source materials. In our workflow, the systematic versioning and documentation of generation parameters (e.g., models, prompts, and input data) were not consistently supported by the available tools and had to be handled manually. This limited the reproducibility and traceability of generated learning materials, although such metadata are essential for quality assurance and iterative improvement.

Finding 5: The effectiveness of GenAI depends on the type of content being produced. Factors such as risk, structure, desired level of competence, target audience, and pedagogical purpose influence suitability. Standardised definitions and technical terms with low risk of error were particularly well suited for GenAI, while content requiring nuanced judgement or high accuracy was less reliably generated.

The findings from theTraFuSMS project show that AI can support adaptive learning by producing linguistic variants, visuals and draft materials. However, an effective adaptation relies on human-led design, contextualisation and quality control. GenAI is most effective as an assistive tool for generating raw content, while pedagogical structuring, technical accuracy and authenticity remain the responsibility of educators.

4.2 Transformation of the Teaching Role and Competence Requirements

The integration of GenAI into vocational education reveals a marked shift in the professional role of teaching staff. Rather than functioning primarily as authors of learning materials, educators increasingly assume responsibilities related to steering, validating and curating AI-generated content. These observations align with the structural characteristics of vocational education outlined in chapter 2 and emerge directly from the practical application scenarios analysed in the project.

Theoretical Role Shift: From Author to Curator

Within TraFuSMS, teaching staff no longer developed learning materials exclusively through independent authorship. Instead, AI-generated drafts served as a starting point that required interpretation, critical assessment and targeted revision. The role of educators shifted toward defining pedagogical intentions, specifying prompts, evaluating AI outputs and integrating selected content into coherent instructional sequences. Responsibility thus moved away from text production toward maintaining pedagogical coherence, practical relevance and contextual accuracy.

Empirical Specification: The Teacher as Validating Expert

The findings from TraFuSMS further indicate that the use of GenAI increases the demand for subject-specific expertise. The implementation of AI necessitates a high degree of specialisation to identify errors, the assessment of plausibility, and the assurance of practical relevance.

Four areas of expertise are central to this:

- ▶ **Competence in prompt engineering:** Educators are tasked with the responsibility of translating pedagogical intentions into precise prompts. The creation of effective educational materials necessitates the delineation of the learner profile, the context, the complexity level, and the instructional purpose.
- ▶ **Validation competence:** Given that GenAI does not ensure precision and correctness, educators must be able to identify factual inaccuracies, distortions, and contextual inconsistencies. This is important to circumvent the presence of potentially hazardous or deceptive content, a matter of particular significance in domains that pertain to safety.

- **Curatorial competence:** GenAI has the capacity to generate content expeditiously and in substantial quantities. Educators must curate AI-generated texts, examples, and media elements, selecting only those components that align with learning objectives, as reduction and prioritisation are more critical than further expansion of content.
- **Editorial and processing competence:** Draft texts or other material produced by GenAI generally necessitate refinement. Educators must modify the wording, structure, and examples to ensure alignment with learner needs and workplace conditions.

These areas of competence form part of a professional profile that has not yet been systematically developed in existing teacher training. Targeted qualification formats will be necessary to prepare educators for the development of AI-supported content. They require clear guidelines for authorship, to maintain transparency regarding the production process and to define the responsibilities for content release. Educational institutions must determine who carries final responsibility for AI-assisted materials and determine the adaptation of quality assurance procedures. Such structures are imperative for maintaining legal compliance, ensuring accountability, and upholding the quality standards of VET.

The transformation of the competence profile can be systematised in the following matrix.

Table 1: Transformation of the competence profile of educators for the use of GenAI

Competence Area	Competence Shift (AI)	Development Need
Text production	Prompting & refinement	Training in prompt design
Media production	Multi-format selection	Media selection skills, AI tool and copyright knowledge
Target-group alignment	AI-supported differentiation	Diagnostic skills for assigning variants
Quality assurance	Accuracy and safety validation, hallucination checks	Advanced subject knowledge, risk competence
Documentation	Process and authorship documentation	Knowledge of metadata, transparency standards, AI labelling

4.3 Synthesis: A Pedagogical Governance Framework for the Production of AI-Based Content

From the systematic comparison of the theoretically-derived requirements (cf. chapter 2) and the empirical findings on adaptive learning materials (cf. 4.1), as well as the observed role transformations (cf. 4.2), a governance framework is derived. The framework consists of six dimensions that guide decisions on the use of GenAI in content production. The dimensions were derived from the five empirical findings. They capture the conditions under which GenAI proved effective or problematic, particularly with regard to content risk, standardisation, learner diversity, pedagogical purpose, efficiency effects and targeted levels of competence. Each dimension includes evaluation categories that determine the permissible degree of AI

autonomy and were validated through experiences from the TraFuSMS project. In order to translate these conditions into actionable guidance, the framework is structured along six steering dimensions.

The Six Steering Dimensions: Systematic Classification

The framework comprises six dimensions designed to regulate the degree of AI autonomy. Specific levels are correlated to defined steering strategies. The resulting matrix provides a guideline for deciding when to automate, when to assist, and when to rely exclusively on human expertise (see Table 2).

- ▶ **Content Risk:** Degree to which incorrect content may lead to professional errors or safety hazards.
- ▶ **Standardisation Potential:** Extent to which content can be standardised and processed independently of situational context.
- ▶ **Learner Heterogeneity:** Degree of heterogeneity in learner profiles and specific learning requirements.
- ▶ **Target Competence:** Predefined objectives of competence that learners are expected to achieve through the learning content.
- ▶ **Pedagogical Function:** Specific instructional role (e.g., information, reflection) that a learning element fulfills within the process.
- ▶ **Efficiency Gain:** Potential for AI to save time and resources in production of content.

The dimensions were derived from the empirical findings, with individual findings informing more than one dimension of governance simultaneously.

The matrix illustrates that a classification of Low Content Risk combined with high Standardisation Potential correlates with a high AI Integration Level (●), allowing automated generation. Content characterised as High Risk or context-sensitive necessitates a steering strategy of exclusion (○), requiring full human creation. In the context of TraFuSMS, this governance logic successfully distinguished between foundational knowledge, eligible for automation, diagnostic modules, and requiring mandatory expert review.

Table 2: Governance Framework for the use of GenAI in VET

Dimension	Level/Category	Exemplary Content	AI Integration Level	Steering Requirements/ Strategy
Content Risk	High	Generation of synthetic or dummy data; Safety instructions	○	Full human creation; Dual-control (Four-eyes) principle; Legal review
	Medium	Diagnostics; Process descriptions	●	AI drafts allowed; Mandatory expert review
	Low	General theory; Definitions; Glossaries	●	Automated generation; Sampling check
Standardisation Potential	Complex / context-sensitive	Case studies; Customer scenarios; Soft skills	○	Human contextualisation required; AI for inspiration only
	Standardized	Step-by-step procedures; Manuals	●	AI-generated variants; Human logic check
	Simple	Vocabulary lists; Definitions	●	High automatisisation; Outlier review
Learner Heterogeneity	High	Individual learning paths; Multilingual needs; level of linguistic complexity	●	Expert parameter definition; AI translation/simplification
	Medium	Distinct roles/experience levels	●	AI adaptation of core content; Human fit-gap analysis
	Low	Generic information	●	Automated delivery; Minimal review
Target Competence	Meta-competence	AI understanding; Critical reflection	●	Human-designed reflection methodology
	Subject competence	Technical skills; Application	●	Pedagogical embedding required
	Basic knowledge	Facts; Terminology	●	Automated delivery
Pedagogical Function	Reflection	Open-ended tasks; Ethics; Transfer cases	○	Human creation; AI for inspiration only
	Simulation	Virtual/diagnostic simulations	●	Expert design; AI-generated variants
	Practice	Quizzes; Drills; Flashcards	●	AI-generated variants; Human verification
	Information	Definitions; Visualisations (e.g. avatars)	●	Monitor factual accuracy (hallucination check)
Gain of Efficiency	Routine	Repetitive tasks; Standard items	●	Prioritise automation to release resources
	Medium	Moderately complex tasks	●	Assisted production; Validation required
	Low	Creative/specialised tasks	○	Manual creation; AI setup time exceeds benefit

The level of AI integration is categorised into Suitable = ●, Restricted = ●, and Excluded (not suitable) = ○ and labelled accordingly.

Practical Validation and Implementation Guidance

The governance framework was applied to selected learning materials during pilot training sessions in the TraFuSMS project. AI-assisted materials were used in both low-risk introductory units and, for example, in safety-critical electric-vehicle high-voltage systems training and reviewed in instructional practice. Evaluation was based on learner feedback from open-ended questionnaire responses and guided group discussions, as well as documented expert reviews conducted as part of the quality assurance workflow. Automated generation proved suitable for standardised, low-risk content when combined with sample-based review, whereas diagnostic and context-rich materials required structured expert review.

The iterative cycle of prompting, AI generation, expert review and approval proved workable, and effective implementation depended on learning management system (LMS) functions such as metadata and version control to support adaptive delivery.

Based on these insights, several steps are essential for successful institutional adoption:

- ▶ **Qualify teaching personnel** in prompt design, validation and risk assessment, with a focus on safety-critical and domain-specific content.
- ▶ **Ensure technical infrastructure**, particularly LMS systems with metadata, access control and adaptive delivery based on learner profiles and content variants.
- ▶ **Establish standardised workflows** for generation, review, approval and documentation of AI-generated content, prompts, model versions, and validation decisions.
- ▶ **Safeguard legal compliance**, including data protection, copyright and transparency regarding the use of AI-generated materials.
- ▶ **Evaluate and update processes** based on feedback from learners, educators and validation outcomes to maintain quality and support innovation.

These measures help institutions improve efficiency while preserving the human oversight required for technical accuracy, contextual relevance and pedagogical responsibility.

5 Conclusion and Outlook

This study demonstrates that GenAI can meaningfully support vocational continuing education when it is embedded within a clear pedagogical and organisational framework. Based on the empirical insights gained from the TraFuSMS project, GenAI proved particularly effective as an assistive tool for producing draft materials, linguistic variants and visual elements. These contributions can increase the flexibility and scalability of learning materials, especially in modular and heterogeneous training settings. At the same time, the findings consistently show that core quality dimensions remain dependent on human expertise. Technical accuracy, workplace relevance, pedagogical coherence and safety-related reliability could not be ensured through the use of GenAI alone.

The developed governance framework provides a structured approach to deciding where the use of AI is appropriate and where full human responsibility is required. The framework

helps differentiate between low-risk, standardisable content and complex learning materials, thereby linking technological potential with pedagogical accountability. In this context, technical possibilities of GenAI should not drive decisions, but pedagogical purpose and practical relevance should.

The results of this study are based on a limited number of contexts of application within a specific vocational domain. The automotive and mobility domain is characterised by a high degree of safety relevance, rapidly evolving technologies and strict regulatory requirements. Compared to other vocational domains, such as commercial or administrative training, inaccuracies in learning materials may have more immediate physical and safety-related consequences. These characteristics increase the importance of expert review and limit the degree of permissible automation, which may differ in less safety-critical occupational fields.

While the governance framework is designed to be transferable, its validation so far relies primarily on qualitative evidence from the automotive and mobility-related training environment (open-ended questionnaire responses, guided group discussions, and documented expert reviews). Moreover, the study focuses on content development and governance processes rather than on long-term learning outcomes or comparative studies on effectiveness. In addition, the rapid development of GenAI technologies means that specific tools and capabilities may change over time. The findings therefore reflect the state of practice at the time of implementation; hence, future technological changes should be considered. Hereby, ethical, legal and sustainability aspects are to be taken into account additionally.

Future research should extend the application of the governance framework to additional occupational fields to further test its generalisability. Empirical studies examining learning outcomes, motivation and competence development in AI-supported learning environments are particularly needed. Future research should also examine the systematic qualification of educational personnel, especially regarding prompt design, validation practices and risk assessment.

Finally, there is considerable potential in the development of AI-supported validation and error-detection tools that can assist educators in quality assurance processes without replacing professional judgement (cf. DELL'ACQUA et al. 2023). Continued empirical evaluation will be essential to refine the framework and to support a responsible, pedagogically grounded integration of GenAI in vocational continuing education.

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