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Training Quality as a Dynamic Construct: Longitudinal Evidence of Changing Effects on Vocational Competence Development

Viola Deutscher¹ · Beifang Ma² · Maximilian Kroetz¹ · Esther Winther²

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Abstract

Background Recent research has increasingly explored instructional quality in shaping Vocational Education and Training (VET) outcomes. However, how instructional quality in company-based training influences vocational competence development remains unclear, particularly regarding its dynamic effects at different training stages.

Aims This study examines how training quality criteria and individual trainee characteristics influence the development of general and domain-specific competence over two years of VET.

Sample The study followed 458 commercial trainees throughout their VET program.

Methods Training quality was assessed via questionnaires, and competence was measured using validated tests at three points: program start, midpoint, and end. Latent Growth Modeling (LGM) was used to analyze growth trajectories, incorporating time-invariant (e.g., prior education) and time-varying predictors (e.g., feedback).

Results Four training quality criteria (task relevance, autonomy, feedback, school-company cooperation) and four individual characteristics (age, prior education, literacy interest, desired occupation) significantly fostered competence development, albeit at varying stages.

Conclusions The findings emphasize the dynamic nature and varying impact of training quality on competence development and the critical importance of tailoring strategies to specific competence dimensions and training phases. Adopting a nuanced, adaptive approach to training design can significantly enhance outcomes in VET contexts. This requires accounting for individual characteristics, comprehensively addressing various aspects of training quality, and distinguishing clearly between different types of competence.

Keywords Workplace Learning Environment · Vocational Training · Quality · Competence · Sensitivity

Extended author information available on the last page of the article

Introduction

Learning and instruction are not limited to mere school education but extend to workplaces. Dual Vocational Education and Training (VET) systems, which integrate both school instruction and training at workplaces, have gained increasing traction worldwide as a key mechanism for producing a highly skilled workforce (European Union, 2018; Hanushek, 2012; OECD, 2019). These systems are valued for combining theoretical learning (mostly at VET schools) with hands-on experience (mostly in training companies), equipping trainees with academic knowledge and practical skills relevant to their professions. The growing adoption of these systems underscores their importance in meeting the demands of modern labor markets, where both academic and practical competencies are crucial. As the international emphasis on VET systems grows, so does the need for reliable and valid measures of training quality. Research into the quality of VET in this respect is critical at three distinct levels: the macro (national and international), meso (organizational), and micro (individual) levels. Each of these levels is interconnected and essential for understanding how training quality impacts both education systems and individual learners.

- *Macro-Level (National and International Perspective)*: At the macro level, VET systems are increasingly viewed as a critical solution to meeting the demands of modern labor markets (OECD, 2019). As VET systems are adopted globally, there is a growing need for reliable, standardized measures to assess the quality of training within and across different countries. The upcoming PISA-VET initiative (OECD 2024; Rausch et al., 2024) marks a significant milestone in this area, as it will, for the first time, apply standardized quality measures to generate large-scale international datasets. These datasets are expected to stimulate significant research in vocational competence assessment and VET quality evaluations and to provide novel insights into how varying levels of training quality impact the development of vocational competence across different countries and contexts. By establishing valid quality measures and empirical models, this branch of quality research in VET aims to refine our understanding of effective systems, thereby contributing to improvements in (inter)national educational standards.
- *Meso-Level (Organizational Perspective)*: On the organizational level, VET quality research is indispensable for human resource management and training personnel. It serves to identify the factors most conducive to optimal learning and skill acquisition to design training environments that not only meet industry standards but also maximize trainee performance. Through systematic evaluations, organizations can track the success of their training initiatives, ensuring that they align with desired trainee outcomes, such as improved vocational competence, job satisfaction, and retention. Regular assessments help organizations identify areas for improvement, making it easier to adapt training programs to evolving challenges. By using VET quality research as a continuous feedback loop, organizations can foster a culture of ongoing development and upskilling, ultimately enhancing their competitiveness and ability to meet future workforce demands.
- *Micro-Level (Individual Perspective)*: Finally, from the micro (individual trainee

or trainer) perspective, research into VET quality is vital for understanding how specific training environments and inputs affect individual outcomes, such as vocational competence, career readiness, and dropout intention on an individual level. Trainee-related outcomes are deeply influenced by the quality of the training they receive, both in terms of instructional content and the support provided by trainers. By investigating how training factors such as instructional design, mentorship, and feedback influence trainees on an individual level, research can identify which elements are most conducive to positive learning outcomes and personal development.

Despite the significance of VET quality research, there remain significant gaps in the literature, particularly regarding the relationship between training quality and vocational competence development pertaining to all these three levels. Deutscher & Winther, (2018) argue that while vocational competence is widely regarded as the central goal of VET programs in policy frameworks on a macro level, there is insufficient empirical research exploring how this competence is developed over time in real-world training contexts. More precisely, existing studies at the meso- and micro-level often report inconsistent associations between training quality and competence outcomes, with many relying primarily on trainees' self-evaluated competence (e.g., Löfgren et al., 2023; Pineda-Herrero et al., 2015; Rausch et al., 2014). However, they typically lack longitudinal modeling approaches based on objectively measured competence (e.g., standardized tests) that incorporate both static and time-varying predictors to capture dynamic changes in training quality and vocational competence over time. Moreover, predictors of training quality are only rarely embedded in robust theoretical frameworks of workplace learning (for exceptions, see Böhn & Deutscher, 2019; Böhn & Deutscher, 2021; Deutscher & Braunstein, 2023; Löfgren et al., 2023; Wijga et al., 2025), which limits both the explanatory depth and the comparability of the findings.

The current study aims to fill this gap by investigating how different aspects of in-company training quality influence the development of domain-specific vocational competence over a two-year period referring to the domain of business VET, which is the most often chosen branch of VET. Using validated objective tests to assess vocational competence, the study examines the impact of 15 training quality criteria, theoretically embedded in a 3P-framework, including both static (e.g., resources, infrastructure) and dynamic (e.g., feedback, mentorship) factors on vocational competence. Additionally, the study controls for 10 individual trainee characteristics to isolate the effects of training quality. By adopting a longitudinal design, this research will provide insights into how different dimensions of training quality contribute to vocational competence development at various stages of the training process. This is critical for both research and practice. Theoretically, it can deepen our understanding of how dynamic mechanisms within training environments influence learning and skill acquisition in VET settings. Practically, unlike static individual factors like IQ or personality traits, which are largely unchangeable, training quality is an adaptable element of the educational environment. By optimizing training conditions, we can markedly enhance vocational competence outcomes, providing actionable insights for improving specific aspects of the training process.

Theory

In-Company Training Quality

Assessing training quality presents two key challenges: defining what constitutes quality and clarifying the perspective from which it is assessed. Despite a long tradition of research, there is no universally accepted definition of VET quality or a standardized set of criteria and instruments to measure it. We adopt a broad definition for VET quality. In this context, quality is understood as the individual perception of training characteristics that support key outcomes. This approach acknowledges that different stakeholders, such as trainees and trainers, may prioritize and evaluate processes and outcomes of quality differently based on their roles. E.g., Heid (2000) notes that quality is not an observable property but the result of an evaluation process, meaning that both the perception of relevant aspects as well as their evaluation are subjective.

In this work, we focus on the perspective of trainees to analyze the effects of training quality on vocational competence development. According to Tynjälä's 3-P model of workplace learning (Tynjälä, 2013), learning outcomes (Products) are shaped by both the initial conditions (Presage) and the actual learning activities (Process). A key characteristic of this model is an additional factor between the presage and process components. This element is the learner's *interpretation of presage factors*. In other words, Tynjälä argues in line with the constructivist view of learning and based on previous authors (von Glasersfeld 1995; Prosser and Trigwell 1999) that the presage factors do not affect the learning process directly but rather through the learner's interpretation. Transferred to our field of research, this would mean that training quality as such does not directly determine learning. Instead, the determining factors are how they perceive the affordances of their workplace. Therefore, the model explicitly recognizes that individuals' interpretations and experiences of the learning environment play a mediating role in how they engage with learning activities. Based on this model, we assume that training quality comprises several objectively existing facets that are subjectively perceived by trainees and, together with individual factors, exert short- and long-term effects on a range of trainee-related outcomes. Figure 1 provides a conceptual framework for the operationalization of training quality criteria on the input and process level.

The model's input dimension comprises company frameworks that already exist prior to the trainees' entrance into the in-company training and remain relatively stable throughout the training period. These factors, together with constant personal factors such as demographic factors and traits, construct time-invariant explanatory variables. The process dimension subsumes daily activities during training and is divided into the areas of work tasks, social interaction, and educational mediation as subdimensions. The area of work tasks is again subdivided into task characteristics like overload, structure, and the variety, relevance, and complexity of tasks. Social Interaction focuses on different types of trainee involvement. Educational mediation reflects more pedagogical aspects such as mentoring, feedback, and instructions. These factors, which change over time and vary in the day-to-day interactions and experiences of the trainees, along with individual states, represent dynamic or

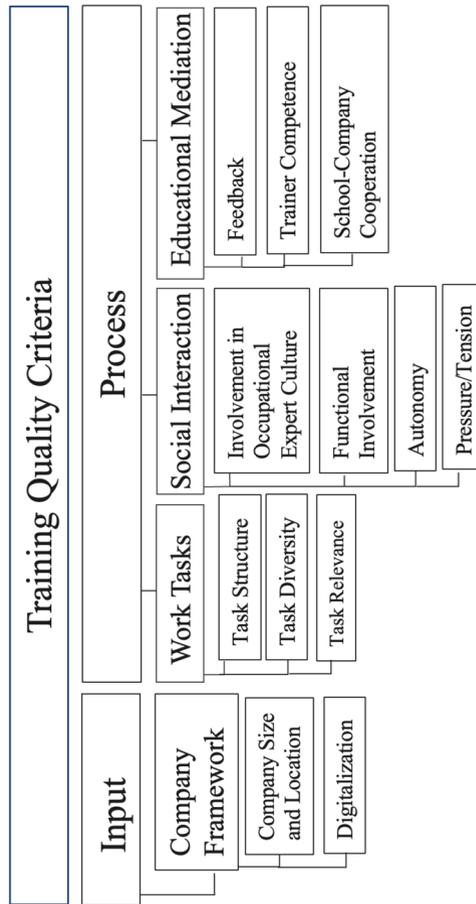


Fig. 1 Operationalization of Training Quality

time-varying variables. As trainees progress through their training, these factors may evolve, thereby dynamically impacting their development and the outcomes of the training program. The output dimension comprises trainees' short- and long-term outcomes of vocational training, such as satisfaction, vocational identity, and competencies. Those are target variables of VET that change as a result of the values in the input- and process dimension. In this manuscript, we solely focus on vocational competence as an educational outcome.

Vocational Competence in VET

According to Klieme et al. (2008), competence is conceptualized as a cognitive disposition that enables vocational learners to perform effectively in specific vocational domains. The scope of these domains can range from narrowly defined, occupation-specific competencies to more broadly conceived key competencies. Building on Gelman and Greeno (1989), we first distinguish between domain-linked and domain-specific item content as two fundamental forms of representing cognitive demands. Domain-linked content refers to decontextualized, foundational aspects that are broadly relevant across a wider vocational field, whereas domain-specific content reflects highly contextualized requirements tied to concrete occupational practices, guidelines, and action principles (Deutscher & Winther, 2018).

Applied to the business domain as an illustrative example, domain-linked content encompasses generic yet essential prerequisites—such as fundamental literacy and numeracy skills (Deutscher & Winther 2018)—that support problem solving across many business-related contexts. In contrast, domain-specific content captures the particular knowledge and procedures that characterize specific business occupations. A practical illustration of domain-linked ability is the calculation of exchange rates at the workplace. These calculations require no specialized vocational knowledge but instead rely on the application of general mathematical principles, such as the "rule of three," often learned in general education. In contrast, domain-specific knowledge and skills are directly tied to specific jobs or enterprise functions (Oates, 2004). For instance, in accounting, the ability to prepare a balance sheet involves specialized rules and processes that are typically acquired during vocational training.

Both types of knowledge and skills are essential for solving workplace tasks. Together, they equip individuals to navigate the complexities of vocational environments effectively (for sample items, see Appendix A3). However, empirically distinguishing between these two competence dimensions is crucial for our research, as studies have demonstrated that domain-linked and domain-specific competencies develop at different rates and with varying intensity over the course of VET training (e.g., Rosendahl & Straka, 2011). Ignoring these distinct growth dynamics could obscure important effects of VET quality on vocational competence development and lead to incomplete or misleading conclusions.

State of Research on the Relation Between Vocational Competence and Training Quality

The research on the relationship between vocational competence and training quality has so far shown only weak or inconsistent effects. For example, Rausch et al. (2014) investigated the self-evaluated competence of trainees and found no significant effect of pedagogical professionalization of in-company trainers on trainees' self-evaluated competence. In contrast, Baethge-Kinsky et al. (2016) investigated the objectively measured competence of industrial management trainees and found a significant effect. Pineda-Herrero et al. (2015) found that mentoring by the company's tutor significantly influenced the self-reported workplace learning efficacy of Spanish trainees in various occupations. Löfgren et al. (2023) focused specifically on domain-general competencies and found that social support from educators, equal treatment, a positive climate, and recognition were all positively associated with Finnish trainees' self-reported competence. Regarding the effect of the training tasks provided, Dietzen et al. (2014) found no effect of training tasks, while Baethge-Kinsky et al. (2016) emphasized the impact of the structural quality of training tasks. Rausch (2011) found that tasks which are challenging, involve interaction with colleagues, and provide an interesting experience are perceived by trainees as enhancing their perceived learning. Likewise, Lüthi et al. (2021) demonstrate that exposure to challenging workplace tasks is a key driver of apprentices' learning and competence development. In Dietzen et al. (2014), eight quality criteria (learning enhancing tasks, scope of action, relevance of tasks, feedback, overload, trainer competence, solicitude of the trainer, support by colleagues) had no direct effect on the objectively measured vocational competence of mechatronics and IT specialists. Nickolaus et al., (2009, 2015) found correlations of overload, social involvement, and complexity with trainees' objectively measured procedural knowledge of automotive mechatronics, while the majority of quality criteria (work climate, transparency, expert culture, variety of tasks, autonomy, relevance of tasks) remained non-significant. Towards the end of training, only correlations with the relevance of tasks and overload were found (Nickolaus et al., 2015), pointing to the important role of dynamic measurements. When controlling for individual general characteristics like mathematical competence or intelligence (IQ), these correlations disappeared (Nickolaus et al., 2009, 2015). Likewise, Siegfried et al. (2019) confirmed an effect of autonomy, interaction climate, instruction, and structural task quality on commercial trainees' knowledge application (.10 –.16). However, in holistic models run by Siegfried et al. (2019) which controlled for personal factors like cognitive dispositions, training quality again played no significant role anymore, demonstrating the utmost importance of control variables when analyzing the effects of training quality on vocational competence. Another noteworthy finding is reported by Findeisen (2025), who combined objective measures of professional knowledge with a longitudinal design across three measurement occasions and demonstrated a significant effect of task quality, operationalized as the variety of tasks.

Summing up, the selected aspects of training quality so far researched showed sometimes inconsistent and often weak effect sizes in their relation to vocational competence and (perceived) vocational learning compared to the effects of indi-

vidual non-cognitive characteristics or general competencies on the development of vocational competence. For example, mathematical skills have been found to be a strong predictor of vocational competence development (e.g., Abele, 2014; Dietzen et al., 2014; Frank et al., 2017; Nickolaus et al., 2009; Seeber, 2008, 2014). Also, prior knowledge or educational level (e.g., school-leaving qualification, final grade) are confirmed predictors of vocational competence (e.g., Baethge-Kinsky et al., 2016; Seeber, 2014; Siegfried et al., 2019).

But does that really mean that the learning environment plays no or just a very minor role? Given the existing research on the effects of training quality on various other educational outcomes (e.g., dropout or vocational identity development), the limited impact on vocational competence development is somewhat unexpected. For instance, aspects of training quality have been shown to predict the development of vocational identity, robustly with small to medium effect sizes (see Wuttke, 2024 for a comprehensive summary of studies and robust empirical evidence). Similar observations have been made in the explanation of vocational dropout, where training quality repeatedly showed small to medium-sized effects on dropout intention (Krötz & Deutscher, 2022; Braunstein et al., 2024). Rather it seems at least possible that the lack of consistent and significant findings regarding the relationship between training quality criteria and vocational competence may be due to several conceptual and methodological problems:

- **Limited Focus of Previous Studies:** Earlier research has often focused on a limited subset of training quality criteria, which restricts the validity of the statistical designs and may obscure potential causal relationships. The omission of certain key quality dimensions, along with relevant personal factors, introduces a risk of bias, affecting the results of the variables that are examined. Conceptually, this is problematic because training quality is inherently multi-dimensional, and the various dimensions are empirically known to share variance. Ignoring this interconnectedness can lead to an incomplete understanding of how training quality influences outcomes, potentially underestimating the combined effects of multiple, interrelated factors.
- **Dynamic Nature of Training Quality:** Training situations and processes can evolve over the course of training (Nickolaus et al., 2015). However, there is a notable lack of studies that track the dynamic, contemporaneous influence of both input and process factors in a longitudinal framework. A notable recent study by Schauer et al. (2025) stands out as a rare example adopting a dynamic perspective to examine how input factors—such as cognitive resources, school-leaving certificates, and sociodemographic background—influence the development of problem-solving competence among automotive technician apprentices. Their findings highlight that applying a longitudinal approach reveals shifting effects of these input variables over time, underscoring the importance of temporal dynamics in competence development. However, their study did not consider instructional quality or training characteristics as influencing factors. In the present study, we similarly anticipate temporal effects, particularly regarding the role of instructional quality in shaping competence trajectories.
- **Measurement of Competence:** Objectively assessed vocational competence is

less frequently studied compared to subjectively evaluated competence. Subjective assessments are prone to biases such as social desirability and self-perception (Paulhus & Vazire, 2007), which could explain inconsistent findings. Moreover, studies rarely differentiate between distinct competence dimensions or explicitly examine clearly defined subcomponents of vocational competence (for a noteworthy exception, see Löfgren et al., 2023, who focused on domain-general competence).

These methodological shortcomings highlight the need for more comprehensive, longitudinal research that considers a broader range of training quality criteria to assess their influence on vocational competence development.

Research Aim, Research Question and Research Model

To evaluate the impact of in-company training quality on vocational competence development, we conceptualize training quality as Opportunity to Learn (OTL). Following Polikoff (2010), we hypothesize that, beyond curricular validity, pedagogy plays a crucial role implying instructionally sensitive assessments. Accordingly, valid assessments of vocational competence must be instructionally sensitive, capturing variation in pedagogical quality rather than reflecting curricular exposure alone. To test this assumption, we adopt a comprehensive and dynamic approach based on Tynjälä's (2013) adaptation of Biggs' 3-P model for workplace learning. This framework allows us to address two key research questions:

1. Which training quality criteria significantly influence vocational competence after accounting for individual factors?
2. How can training quality criteria at the input level (as time-invariant predictors) and at the process level (as time-varying predictors) jointly explain the trajectories of vocational competence development?

Our research model (Fig. 2) divides the research variables into:

- *Time-invariant predictors*, including training quality criteria at the *input level* (e.g., company framework), as well as individual factors (e.g., demographic and biographic factors, personal traits).
- *Time-varying predictors*, encompassing training quality criteria at the *process level*, such as social interaction, educational mediation, and the quality of learning environments.

This framework enables us to analyze both static and dynamic influences on vocational competence development, providing a nuanced understanding of how in-company training quality shapes vocational competence development.

Time-varying training quality criteria at the process level in the model include three scales related to Work Tasks. *Task Structure*, representing how well learning tasks are pre-structured and organized, *Task Diversity*, reflecting the variety and nov-

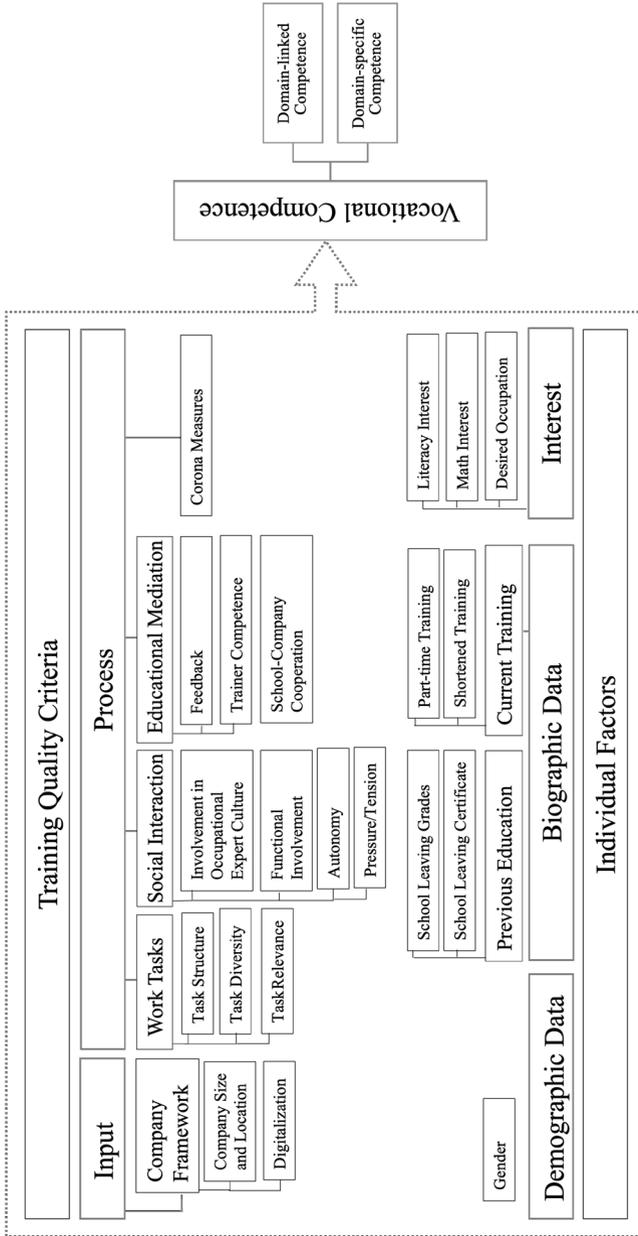


Fig. 2 Research Model

elty of tasks and *Task Relevance*, capturing the importance, responsibility, and real-world applicability of tasks. Another dynamic aspect of training quality is Social Interaction, which is partially grounded in Self-Determination Theory (SDT). This category emphasizes *Autonomy* and social involvement as key factors for self-development (Ryan & Deci, 2000), contrasting with experiences of *Pressure and Tension* within group settings. It encompasses perceptions of *Involvement in Expert Cultures* and *Functional Involvement* into operative work processes. The category Educational Mediation highlights the central role of *Feedback* in educational processes (Hattie & Timperley, 2007; Shute, 2008). It also includes Trainer Competence, which captures trainees' perceptions of their trainers' professionalism, clarity, problem-solving skills, explanatory ability, facilitation of learning opportunities, and enthusiasm. A unique feature of dual training environments is *School-Company Cooperation*, evaluated through measures such as the practical relevance of school learning for workplace tasks and the integration of specialized knowledge into classroom instruction.

Time-invariant variables in the model include quality criteria at the input level as well as individual factors. Quality criteria at the input level pertain to the Company Framework, which considers factors such as *Company Size*, *Location*, and the level of *Digitalization*. Basic Demographic Data, including *Gender*, *Age*, and spoken *Language*, serve as important control variables for analyzing competence development. Additionally, Biographic Data on previous education and current training are included. This encompasses the *School-Leaving Certificate*, *School-Leaving Grades*, and whether trainees are currently enrolled in *Part-Time Training* or *Short-Term Training* programs. Empirical evidence highlights the importance of Interests as motivational predictors of vocational competence development. Specifically, mathematical and language interest (Winther, 2010), as well as occupational (mis-)matches in vocational training (Holtmann & Solga, 2023; Michaelis & Findeisen, 2022) referring to situations in which a trainee's interests, abilities, or expectations do not align with the demands, tasks, or learning opportunities of the chosen occupation, have demonstrated predictive value. As a result, variables such as *Math Interest*, *Literacy Interest*, and the trainee's interest in their current training occupation as their *Desired Occupation* are included as key time-invariant predictors in the model.

Methods

Sample

Data on training quality and competence were collected at three stages throughout the training process in Germany: autumn 2019 (T0), autumn 2020 (T1), and autumn 2021 (T2). The sample included 458 economic trainees who completed both the survey and competence tests at each of these time points. We fully assessed all classes from ten participating VET schools from the south to the north of Germany, with schools being randomly selected. Participation was voluntary, but data collection took place during regular school hours, and apprentices were offered individual feedback on their test performance, which all of them used as a trial preparation for their final examinations—an incentive that strongly supported voluntary participation, since

the final examinations are of high personal importance for VET students. Within the sample, 64% of trainees were female, closely mirroring the gender distribution in the statistical population (58.4% female; BMBF, 2020). The average age at T0 was 19.66 years, with a range from 15 to 31 years, aligning closely with the statistical population's average age of 19.7 years at the start of training (BIBB, 2020). Most trainees (75.9%) reported living in German-speaking households, which is a typical distribution for commercial trainees in Germany (BMBF, 2020).

Measurement and Descriptives on Vocational Competence Development

The assessment of vocational competence in this study was based on a two-dimensional test, capturing both domain-linked and domain-specific competence. The instrument was adapted from a prototype of official final examinations administered by the Chamber of Industry and Commerce (IHK) and has been validated with respect to reliability and construct validity (e.g., Klotz, 2015; Ma, et al., 2024). Measurement invariance across time points was established, ensuring that competence scores are comparable longitudinally (see Table A3 in the Appendix for details). Convergent validity was demonstrated through significant positive correlations between the test scores and external performance indicators such as concurrent grades in vocational school and evaluations from training companies.

The test placed participants in the role of employees in a simulated ceramic production company, requiring them to complete action-oriented tasks such as drafting a business email, performing profitability calculations, and converting currencies (see Appendix Fig. A1). Each item was designed to target either domain-linked or domain-specific competence exclusively.

The dimensional structure of vocational competence was modeled using a between-item multidimensional random coefficients multinomial logit model with correlated dimensions (Hartig & Höhler, 2009). This approach allows for the simultaneous estimation of both competence constructs, accounting for differentiated skill development across multiple domains. Further details regarding the modeling approach and computational procedures are provided in Authors (2024). A sample item and a description of the test setting can be found in Appendix AP 3.

Table 1 summarizes the development of vocational competence across three measurement points (T0, T1, and T2).

Domain-linked competence increased steadily from -0.410 at T0 to 0.294 at T2, although the growth rate slowed over time. In contrast, domain-specific competence, which started from a lower baseline (-0.902), showed a steeper and more rapid devel-

Table 1 Competence Levels in Domain-Linked and Domain-Specific Competence Across Time Points

	T0	T1	T2
Domain-linked Competence (M±SD)	-0.410 ± 1.06	-0.002 ± 1.20	0.294 ± 1.30
Domain-specific Competence (M±SD)	-0.902 ± 1.07	0.090 ± 1.16	0.866 ± 1.11

Competence scores are expressed on the logit scale, with higher values reflecting greater ability. Although logits formally represent log-odds, they can be interpreted in a manner analogous to standardized scores: positive values indicate above-average competence and negative values indicate below-average competence relative to the sample. To characterize score dispersion and measurement precision, we report means (M) and variances (SD)

opment. By T1, domain-specific competence had already surpassed domain-linked competence (0.090 vs. -0.002) and continued to grow substantially, reaching 0.866 at T2. These descriptive findings highlight distinct developmental patterns between the two competence dimensions that are theoretically plausible: learners typically enter VET with some general, domain-linked competence acquired during general schooling, while domain-specific competence is largely acquired during the course of vocational training. The stronger focus of vocational curricula on domain-specific skill acquisition explains the accelerated growth in this dimension.

Measurement and Descriptives on Training Quality

The assessment of training quality in VET was based on 13 constructs. At the input level, company size was measured by the question, “How many employees does your training company have?” Additionally, digital learning and working conditions at the training workplace were assessed using a self-constructed scale on digitalization (e.g., “I communicate with trainers on connected learning platforms”), which captures the degree to which digital tools and infrastructures are available and used within the training environment.

A multifaceted set of scales was used to evaluate the quality of training processes, each reflecting a critical aspect of the learning experience. *Task Structure* (e.g., “In the company, various teaching methods are used when learning”), *Task Diversity* (“In my company, work tasks are highly diversified”), *Task Relevance* (“In my company, I work on ‘real tasks’”), *Functional Involvement* (“I am well integrated into the company’s workflows in my work area”), *Feedback* (“The training personnel and my colleagues let me know whether I perform work tasks satisfactorily or not”), and *Trainer Competence* (“Those who train me on the job can explain well”) were measured via the publicly available VET-LQI instrument for training quality (Böhn & Deutscher, 2021). *Involvement in Occupational Expert Culture* (“I am involved in discussions about professional questions in the company”) was evaluated using scales from Eberle et al. (2015). *Autonomy* (“In my company, I can make many decisions myself in my work”) and *Pressure* (“When working in the company, I always feel under time pressure”) followed the scales of Wilde et al. (2009). *School-Company Cooperation* (“My training in the company is aligned with the instruction in vocational school”) was assessed according to Ma & Winther, (2025). As data were collected during the COVID-19 pandemic, we measured the adaptation of training companies to the COVID-19 pandemic with a self-constructed single item: “How satisfied are you with your company’s handling of the COVID-19 crisis in terms of the quality of your training?” A detailed overview of all scales and sources is provided in the appendix (AP 1).

Descriptive results for these training quality scales can be found in appendix table AP 2. Cronbach’s alpha coefficients ranged from 0.634 (Task Structure, T0) to 0.917 (Trainer Competence, T2), indicating acceptable internal consistency for almost all scales, with a threshold of 0.70 generally considered reliable. The scales *Task Structure* and *Transparency and Organization* remained slightly below this threshold at all measurement points. We attribute these lower values mainly to the limited number of items (three) within these scales, in line with research indicating that shorter scales

systematically reduce Cronbach's alpha even when items are conceptually sound (Hair et al., 2010). These scales were nevertheless retained to ensure comprehensive conceptual coverage.

All time-varying predictors of in-company training quality at the process level were evaluated by trainees at three key time points—beginning (T0), midpoint (T1), and end (T2) of training—using five-point Likert scales (0=strongly disagree; 4=completely agree). Time-invariant predictors, as well as digitalization at the workplace, were captured at T0, as significant changes over time were not anticipated for these variables. Detailed coding information and descriptive statistics are provided in Appendix Table A2.

Analytical Approach

To model the theoretical relationships proposed in Fig. 2, we employed two separate latent growth models (LGMs) for both domain-specific and domain-linked competence dimensions. The decision to estimate separate latent growth models (LGMs) for domain-specific and domain-linked competence stems from both theoretical and methodological considerations. First, the two competence dimensions reflect distinct developmental trajectories grounded in different types of competences. Second, from a methodological standpoint, separate LGMs allow for dimension-specific growth factors and variance structures, avoiding potential biases or misfit that could arise from forcing a joint growth trajectory on conceptually distinct constructs. This separation ensures that the model adequately captures the unique variance and structural dynamics of each competence dimension, which is critical when assessing the differential effects of training quality. In summary, separate LGMs honor the theoretical distinction and developmental logic of the two competence types while enabling clearer, more accurate estimations of the influence of training quality on each.

LGM provides a robust framework for analyzing longitudinal data by capturing individual trajectories of change while incorporating both time-invariant and time-varying predictors (Zheng et al., 2022). Time-invariant predictors, such as company size or individuals' prior educational experiences, are used to estimate the intercept (initial status) and slope (growth rate) of individual trajectories. However, they do not provide insights into how developmental dynamics evolve over time. A key limitation of time-invariant variables is that they do not allow for positioning (determining where an individual stands at a given point in the developmental process) or explaining trade-offs (how different influencing factors interact and are balanced over time). To address this methodological gap, we introduce time-varying variables (e.g., autonomy, feedback), which change over time and account for variability around the best-fit line at each time point. This allows for a more nuanced examination of developmental trajectories, capturing adjustments and compromises within the process. As a result, incorporating time-varying variables enhances the models' dynamism, enabling a more comprehensive analysis of individual development. Our methodological approach to modeling the effects of training quality on competence development is novel in this regard and builds upon the data analysis methods introduced by Raudenbush and Bryk (2002) and Singer and Willett (2003).

First, we establish a baseline growth trajectory without predictors to serve as a reference. Subsequently, we incorporate both time-invariant and time-varying predictors into the LGMs to assess their influence on baseline trajectories. This rigorous approach enables a detailed examination of both general growth patterns and the dynamic processes driving competence development. Recognizing the potential for small effect sizes based on existing empirical studies, we report a significance level of 0.1 (10%) in addition to the conventional 0.05 (5%) to minimize the risk of overlooking relevant relationships and to identify findings that warrant further investigation. All analyses were conducted using R.

For the competence tests (domain-linked and domain-specific), we included only those participants who completed all three measurement occasions (T0, T1, T2) for both the competence assessments and the questionnaire. This *balanced panel* represents a clean analytic option for our research questions, as longitudinal competence modeling requires complete within-person trajectories. Major longitudinal competence studies (e.g., PISA-L, NEPS) likewise rely on balanced panels. In the competence tests, omitted or skipped items were coded as incorrect, consistent with standard practice in large-scale educational assessment. For the questionnaire data, missing values were handled using Full Information Maximum Likelihood (FIML), implemented via the MLR estimator in *lavaan*. FIML incorporates all available information under the assumption of missing at random (MAR) and is recommended for longitudinal analyses with partial item nonresponse.

To evaluate whether the sample size was sufficient given the number of predictors, we conducted a Monte Carlo-based power analysis using the model structure of the latent growth models and the observed sample size. Small effects ($\beta=.10$) were specified in the population model, and 500 simulated datasets were generated. The results indicated that the study design provides adequate sensitivity to detect small-to-moderate effects, whereas possibly existing very small effects may not be reliably detected.

All analyses were conducted in R (Version 4.3.1; R Core Team, 2023) using the following packages: *lavaan*, *car*, *Hmisc*, *dplyr*, *tibble*, *readr*, and *writexl*. A full session information report (R version and package versions) is provided in the Appendix B.

Results

All descriptive results are summarized in Table A2. From a descriptive perspective, several training quality dimensions show substantial variation over the course of training. For example, *Pressure/Tension* increases noticeably over time, whereas perceived *Autonomy*, *Task Relevance*, the *Practical Relevance of School-based Learning*, and *Task Structure* tend to decrease. Other dimensions, such as *Transparency and Organization*, *Task Diversity*, *Feedback*, and *Competence of Trainers*, remain relatively stable over time when considered in relation to their standard deviations.

Before conducting the latent growth analysis, we assessed multicollinearity among the predictors by calculating Variance Inflation Factors (VIFs) separately for domain-linked and domain-specific competence across the three time points (T0, T1, and T2).

The results, presented in Table A4 of the Appendix, indicate that VIF values ranged from 1.024 to 1.810, well below the widely accepted threshold of 10. This confirms that multicollinearity is not a concern in the dataset and that the predictors meet the prerequisites for latent growth analysis, ensuring reliable parameter estimation. Correlation tables for all variables in the models across all time points are provided as supplementary files (Tables 1–4). The first step of the latent growth analysis involved comparing model fits between the baseline model (without predictors) and the full model (with predictors) for both the domain-linked and domain-specific dimensions. This comparison aimed to verify that including predictors enhances the models’ explanatory power. The model fit statistics for these comparisons are summarized in Table 2.

The fit indices reveal a clear improvement when transitioning from the baseline to the full models. In the full models, the RMSEA value remains low, particularly for the domain-linked dimension (0.039), indicating a strong fit between the models and the data. While the RMSEA value of 0 in the baseline model for domain-linked competence might seem ideal at first glance, it likely reflects an oversimplified structure that fails to capture the data’s complexity, underscoring the necessity of including explanatory variables. The RMSEA value in the full model for domain-specific competence suggests a more suitable balance between complexity and fit. Additionally, both baseline models show significant variance in the intercept parameters, emphasizing the importance of accounting for individual differences in longitudinal change. The lower AIC and BIC values for the full models further validate its superior complexity and generalization capabilities.

Following this, two rounds of latent growth analysis incorporating all predictors were conducted separately for domain-linked and domain-specific competence.

The results presented in Table 3 summarize the effects of time-invariant predictors (TIPs) and time-varying predictors (TVPs) on domain-linked and domain-specific dimensions of vocational competence. For TIPs, several significant findings emerge: gender differences reveal that males exhibit significantly higher initial lev-

Table 2 Model Fit and Trajectory Estimates for Vocational Competence Dimensions

	Vocational Competence			
	Domain-Linked Dimension		Domain-Specific Dimension	
	Baseline	Full Model	Baseline	Full Model
Model Fit				
AIC	4307.000	2085.454	4063.413	2076.155
BIC	4340.015	2351.562	4096.428	2324.630
RMSEA	0.000	0.039	0.085	0.055
SRMR	0.013	0.013	0.026	0.016
Trajectory				
Intercept	-0.396***	-0.415	-0.865***	-0.274*
Slope	0.355***	-1.925*	0.876***	-0.287
Var (intercept)	0.337*	0.288*	0.317**	0.306*
Var (slope)	0.111	0.045	0.105	0.050
Cov (intercept-slope)	-0.053	-0.074	0.007	-0.056

*** $p < 0.001$; ** $p < 0.01$

Table 3 Effects of Time Invariant Predictors (TIPs) and Time Varying Predictors (TVPs)

	Domain-Linked Competence				Domain-Specific Competence					
	Intercept	Slope	T0	T1	T2	Intercept	Slope	T0	T1	T2
TIPs										
Demographic Data										
Language	0.006	-0.028				0.094	0.093			
Gender	-0.052	-0.036				0.364**	0.021			
Age	-0.023	0.044*				0.005	-0.002			
Previous Education										
School Leaving Certificate	0.155	0.190**				0.221*	0.105			
School Leaving Grades	0.079	0.111*				0.155*	0.058			
Current Training										
Part-time training	-0.050	-0.075				-0.089	-0.113			
Shortened training	-0.097	0.001				0.011	0.015			
Personal Traits										
Math interest	0.006	-0.012				-0.081	0.010			
Literacy Interest	0.073	-0.102				0.182*	-0.025			
Desired occupation	-0.151*	0.076				-0.144+	0.086+			
Company Framework										
Company Size	0.046	-0.009				0.011	0.003			
Company Location	-0.113	0.032				0.038	0.038			
Digitalization	0.006	-0.003				-0.116	0.075			
TVPs										
Work Tasks										
Task Structure			-0.241*	-0.166	0.059	0.057	-0.164	0.001		
Task Diversity			-0.083	-0.052	-0.038	-0.011	-0.128	-0.067		
Task Relevance			0.011	0.288*	0.253+	0.165	0.208	0.050		
Social Interaction										
Autonomy			-0.011	0.176*	-0.183+	0.041	0.209**	-0.048		
Pressure/Tension			-0.237	0.050	-0.083	-0.149	0.128	0.103		

Table 3 (continued)

	Domain-Linked Competence			Domain-Specific Competence		
	Intercept	Slope		Intercept	Slope	
	T0	T1	T2	T0	T1	T2
Involvement in Expert Culture	0.002	-0.008	-0.048	-0.029	0.089	-0.060
Functional Involvement	0.043	-0.146	0.081	-0.129	-0.132	0.154
Educational Mediation						
Feedback	-0.141	-0.087	-0.051	0.017	0.085	0.218*
Trainer Competence	0.142	-0.017	-0.070	0.082	0.057	-0.025
School-Company Cooperation						
Relevance	0.350***	-0.121	-0.064	0.089	0.109	0.039
Integration	-0.122	0.076	0.019	-0.134	0.044	-0.009
Transparency	-0.083	-0.022	0.054	-0.034	-0.110	-0.049
Corona Measures		0.050	0.122		-0.090	0.060

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; + $p < 0.1$

Table 4 Adjusted Explained Variance (R^2) in the Domain-Specific and Domain-Linked Competence Models

	Intercept	Slope	T0	T1	T2
Domain-Linked Competence	13.66%	81.04%	36.86%	24.15%	25.32%
Domain-Specific Competence	30.61%	28.45%	35.91%	39.72%	47.46%

els of domain-specific competence compared to females. Age positively impacts the growth slope of domain-linked competence, indicating that older trainees show greater development over time. Prior educational attainment—including school-leaving certificates and grades—does play a role in competence development; however, its impact is limited to the growth trajectory of domain-linked competence, where a significant effect was observed. Interestingly, no such effect emerged for domain-specific competence development, suggesting that foundational academic qualifications are more closely associated with transferable skills than with the acquisition of task-specific vocational competences. Interestingly, trainees whose current occupation aligns with their originally desired career path demonstrate lower initial levels of competence in both dimensions. Additionally, a higher interest in German as a school subject correlates with higher initial levels of domain-specific competence.

For TVPs, the following effects are noteworthy: *Task Structure*, reflecting the instructional design of work tasks, shows a weak effect on domain-linked competence at the beginning of training. In contrast, *Task Relevance*, which measures the perceived importance and applicability of tasks, positively affects competence at midterm (T1) and final (T2) stages. Autonomy-supportive interactions during training, measured through the scale *Autonomy*, have a small, positive effect on both dimensions of competence at the midterm stage. Educational mediation, particularly *Feedback*, exhibits a weak positive effect on domain-specific competence at the final stage. Finally, within *School-Company Cooperation*, the practical relevance of school learning demonstrates a medium positive effect on domain-specific competence at the beginning of the training, highlighting the value of applying theoretical knowledge to practical tasks.

Table 4 presents the adjusted R^2 values from the latent growth analysis, reflecting the proportion of variance explained by the models for each time point and the latent factors.

For domain-linked competence, the predictors strongly explain the variance in competence growth (81.0%), indicating a robust capacity to account for changes over time, while the relatively low R^2 for the intercept (13.7%) suggests limited explanatory power for initial competence levels. For domain-specific competence, the R^2 values at each time point increase over time (from 35.9% at T0 to 47.5% at T2), indicating the model captures more variance as trainees progress through their training. Moderate R^2 values for both the intercept and slope highlight that while the model explains some variability in initial competence and growth, other factors not included in the analysis likely contribute to the development of vocational competence.

Discussion

Interpretation of Findings

The present study aimed to examine how training quality influences vocational competence development across a two-year VET program. Building on Tynjälä's (2013) 3-P model, we hypothesized that both time-invariant input factors (e.g., prior education, company characteristics) and time-varying aspects of instructional quality (e.g., feedback, autonomy, task relevance) would significantly predict growth in vocational competence. Additionally, we expected different patterns for two distinct dimensions of competence: domain-linked and domain-specific.

We found that the predictors—i.e., components of training quality—exhibited heterogeneous temporal dynamics: some increased over time (e.g., *Pressure/Tension*), others decreased (e.g., *Autonomy*), and some remained relatively stable (e.g., *Variety of Tasks*), depending on the specific dimension of training quality.

Beyond these findings, the study reinforces the significance of individual inputs, as highlighted in previous research, in shaping competence development—particularly those related to prior education (e.g., Baethge-Kinsky et al., 2016; Seeber, 2014; Siegfried et al., 2019).

A key contribution of this study lies in the conceptual and empirical differentiation between domain-linked and domain-specific competences—two dimensions that are often conflated. The results demonstrate that domain-linked competence development, characterized by transferable skills (e.g., Löfgren et al., 2023), is significantly influenced by prior educational attainment. In contrast, domain-specific competence, which is tied closely to immediate occupational demands, is more strongly shaped by training characteristics such as autonomy and feedback.

Notably, school-leaving certificates and grades show no predictive value for domain-specific competence growth beyond initial values, aligning with recent longitudinal findings by Schauer et al. (2025). These distinct developmental trajectories underscore the need for a more nuanced conceptualization of vocational competence when evaluating training quality. More broadly, they suggest that domain-specific competence can be effectively developed even in learners with less formal prior education—supporting the inclusion of more diverse educational backgrounds in vocational programs.

The study further underscores how training quality impacts competence differently over time. Unlike the cross-sectional results by Siegfried et al. (2019), which found training quality in the business domain to be insignificant once personal factors were controlled for in holistic models, our dynamic approach suggests that both learner characteristics and instructional quality exert meaningful—albeit partially modest—effects. In line with Siegfried et al. (2019) and Findeisen (2025), we confirm that the influence of training quality diminishes when controlling for personal background variables. Moreover, not all training quality indicators proved significant, and those that were showed differentiated effects depending on the training stage. These findings are consistent with Nickolaus et al. (2015), who argue that the impact of training quality varies across training phases. For instance, autonomy showed a delayed positive effect—its influence emerged clearly only at later stages

of training, when learners had developed orientation and foundational knowledge. In contrast, early autonomy may risk leaving trainees without sufficient guidance. Similarly, feedback gained in relevance over time, becoming a critical instructional lever in later stages. Conversely, efficient cooperation between schools and training companies was particularly effective early in the program, helping trainees integrate theoretical and practical content at a point when this link may not be intuitively clear. These temporal patterns underline the importance of timing in both empirical analysis and instructional practice and advocate for phase-sensitive pedagogical planning.

Interestingly, the analysis also revealed the counterintuitive effect of learners not training in their desired occupation showing more favorable growth in domain-specific competence. One explanation may be that lower initial intrinsic motivation leads to greater instructional responsiveness—especially when feedback and autonomy are high. This interpretation may highlight the value of responsive learning environments that can compensate for motivational deficits and support diverse learning trajectories. Likewise, it is possible, that with higher initial competence levels learners might take vocational training for granted or even as a transitional phase rather than an endpoint, while those with lower competence levels may feel a sense of accomplishment in securing their desired occupation. These dynamics suggest that the well-established scale of "desired occupation" in training quality research should be used with caution or interpreted carefully when applied to explain competence development.

Limitations

While the study provides new insights, several limitations warrant attention and invite further investigation. First, the reliance on subjective measures for assessing training quality introduces potential biases, such as social desirability and self-perception inaccuracies. This mismatch with the objectively tested competence measures may compromise the validity of findings. Future research should integrate independent observations, or also the perspective of multiple stakeholders (multi-perspective approach), which are of course still subjective, but would include diverse perspectives on training quality.

Second, the study's explanatory power is limited by the omission of key variables, particularly motivation, which dynamically interacts with competence development. Constructs such as self-efficacy and vocational identity are well-established influencers of learning trajectories but remain underexplored in this context. Including these variables in future studies would provide a more comprehensive understanding of competence development. Moreover, more recent aspects of training quality—such as digital learning conditions and remote work and learning, which increasingly shape workplace learning (Wijga et al., 2025)—are not yet sufficiently reflected in existing VET quality measurement instruments and were therefore omitted from the analysis.

Moreover, the results of the Monte Carlo power analysis indicate that the available sample size provides insufficient statistical power to reliably detect small effects. In particular, effects of approximately $\beta \approx .10$ have a low probability of being detected as statistically significant. Accordingly, although constructs such as *Pressure/Tension* and *Trainer Competence* showed effects of this magnitude, these effects did not reach

statistical significance given the limited power of the present sample, implying an increased risk of Type II error.

A further methodological constraint relates to the treatment of time-varying predictors. With only three measurement points, we could not reliably apply a within-between decomposition (centered-within-cluster/centered-between-cluster) to distinguish stable between-person differences from momentary within-person fluctuations. Such decompositions require several measurement occasions per person to obtain stable cluster means. Consequently, we modeled the time-varying predictors in their observed wave-specific form. Future research employing designs with more repeated assessments—such as diary methods, experience-sampling approaches, or higher-frequency longitudinal measurements—would enable a more fine-grained decomposition of within-person dynamics and allow for more precise modeling of how training quality varies over time and relates to competence development. Moreover, such more granular measurement designs could offer concrete guidance on the optimal frequency and level of granularity needed to capture meaningful fluctuations in training quality. Capturing processual data at shorter intervals—such as weekly or monthly—could yield deeper insights into the dynamic interplay between inputs, instructional processes, and outcomes. In particular, Harteis and Gruber's (2018) *iPPP model* emphasizes the bidirectional relationships among these dimensions, proposing that outcomes such as competence development may also function as predictors.

Conclusion and Practical Implications

Despite these limitations, we are confident that the study's findings highlight the need to move beyond viewing training characteristics as static attributes. Instead, a deeper understanding is required of how the dynamic interplay between learners' backgrounds and instructional quality shapes vocational competence development. The results also emphasize the necessity of differentiated assessment and instructional strategies that are responsive to the diverse developmental pathways of vocational learners. While this study was not initially guided by a specific pedagogical theory, its recommendations for practice align with well-established scaffolding and fading strategies (Collins et al., 1989) frequently endorsed in workplace learning literature and practice:

1. Start with Stronger Guidance

Provide structured instructional support and a clear task structure particularly during the early phases of training to establish a solid foundation and minimize learner uncertainty.

2. Promote Autonomy as Learners Progress

Gradually increase opportunities for self-directed learning and encourage learner independence as trainees gain confidence and competence, especially in the later stages of the program.

3. Establish Ongoing Feedback Routines

Implement regular, high-quality feedback practices—such as weekly reflective check-ins or structured peer evaluations—from the outset and maintain these routines, as feedback tends to have increasing impact as learners advance through their training, particularly on domain-specific competence development.

4. Link Theory and Practice Early

Integrate classroom instruction with workplace-based tasks right at the start of the training program, since learners—particularly in the early phase—often find it difficult to establish connections between their prior domain-linked knowledge and practical applications on their own.

5. Broaden Access to Training

When recruiting, it is important to avoid the uncritical exclusion of candidates with weaker academic backgrounds. The findings suggest that these learners are capable of achieving significant growth in domain-specific competence—provided that instructional quality is sufficiently high. In this sense, high-quality training can serve a compensatory function, helping to offset earlier disadvantages in learners' educational biographies.

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Data Availability The data of this study are not publicly available as it contains sensible information (competence data) of the participants and participating schools (instructional quality). However, interested researchers may obtain access to the anonymized data upon written request submitted to the Ministry of Culture, Education and Sports of Baden-Württemberg. Access will be granted subject to compliance with applicable ethical regulations and subject to a data handling agreement.

Declarations

Ethics Approval and Consent to Participate The study received ethical approval from the authors' institutional ethics boards and the responsible federal authority of anonymous. Informed consent was obtained from all individual participants included in the study. No research involving animals was conducted as part of this study.

Competing Interests The authors declare no competing interests.

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