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The DISC model for digital competence development in TVET: A mixed-methods evaluation

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Abstract: This study introduces the DISC Model as a practice-oriented framework for developing digital competence among technical and vocational education and training (TVET) instructors and examines pre–post changes associated with its initial implementation. The four pillars address data-driven pedagogy, Industry 4.0 tool integration, simulated and augmented learning environments, and continuous and customized upskilling. An exploratory sequential explanatory mixed-methods design combined a single-group pre-test/post-test evaluation with qualitative evidence. Thirty-five instructors completed a 12-week blended capacity-building program from 10 February to 28 April 2025; the post-test and focus groups took place on 5 May 2025. Competence was measured using the 40-item self-report Digital Intelligence Competency Scale (DICS). Overall scores increased from 2.81 (SD = 0.49) to 3.92 (SD = 0.44), with a mean paired gain of 1.11 (95% CI [0.93, 1.29]), $t(34) = 12.47$, $p < .001$, and paired-sample $d_z = 2.11$. All four pillar scores increased. Focus groups and journals described greater confidence and institutional barriers. Paired lesson plans documented changes in planned instruction, including dashboard-based feedback and simulator-supported guided practice.

Keywords: TVET; teacher digital competence; DigCompEdu; Industry 4.0; professional development; one-group pre–post study

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1. Introduction

Digital transformation changes the technologies, information flows, and practical tasks that technical and vocational education and training (TVET) instructors must address. This creates a professional-development challenge at the intersection of pedagogical assessment, occupation-specific digital tools, simulated practice, and continuing upskilling. DigCompEdu organizes educators' digital competence across professional engagement, digital resources, teaching and learning, assessment, learner empowerment, and facilitation of learners' digital competence (Redecker, 2017). However, an implementation-oriented TVET program must also specify how educators practise interpreting learner-performance information, using workplace-relevant systems, facilitating simulation activities, and planning subsequent professional learning. The DISC Model organizes these activities into four complementary domains: Data-driven Pedagogy (D), Industry 4.0 Tool Integration (I), Simulated and Augmented Learning Environments (S), and Continuous and Customized Upskilling (C). The macro-, meso-, and micro-level framing identifies policy context, institutional and occupational requirements, and classroom practice as levels of concern; it does not constitute evidence that the present study measured gaps or improvements at all three levels. The empirical evaluation instead examines paired changes in instructors' self-reported competence and qualitative accounts of implementation. Claims about employer feedback, curriculum–job mismatch, institutional audits, and graduate employment outcomes are

not treated as findings of this study because these outcomes were not measured. The study asks:

(RQ1) How can digital competence for TVET instruction be organized into a coherent, practice-oriented professional-development framework?
(RQ2) What within-participant changes in DICS scores were observed between the pre-test and post-test?
(RQ3) What implementation experiences and constraints are reflected in the focus-group discussions, reflective journals, and lesson-plan records?

2. Literature review and conceptual foundations

This section defines the study's key constructs, situates the proposed model within educator-competence and vocational-education scholarship, and develops the rationale for its four domains.

2.1 Digital literacy, competence, and intelligence

Digital literacy encompasses the ability to access, interpret, evaluate, and participate through digital information and media. Digital competence places these capacities within situated tasks and includes knowledge, skills, and dispositions. Educator digital competence adds instructional responsibilities: selecting resources, organizing learning, assessing progress, and supporting learners. DigCompEdu articulates these responsibilities across professional engagement, digital resources, teaching and learning, assessment, learner empowerment, and facilitation of learners' digital competence (Redecker, 2017). In the present study, Digital Intelligence denotes a study-specific operational construct: TVET instructors' self-reported readiness to interpret learning evidence, integrate workplace-relevant digital applications, facilitate simulated practice, and sustain professional upskilling. The DICS measures perceived competence in these domains; it does not establish independently observed instructional proficiency.

Conceptual boundaries and operationalization. In this article, "Digital Intelligence" is an author-defined umbrella label for a set of vocational instructors' perceived digital teaching capabilities; it is not used as a synonym for general intelligence, psychometric intelligence, or a universally established construct. The label is operationalized through four proposed practice domains: interpreting instructional evidence to adapt teaching (D), selecting and using occupation-relevant digital tools (I), designing digitally simulated practice with feedback (S), and identifying and pursuing continuing professional-learning needs (C). These domains connect the pedagogical emphasis of DigCompEdu (Redecker, 2017) to the vocational demands and contextual constraints documented in TVET research (Cattaneo et al., 2022; Xin et al., 2024). The framework is a design and professional-development proposition: the DICS questionnaire samples self-perceptions across the four domains but does not, on its own, demonstrate that they form four empirically distinct latent factors or that "Digital Intelligence" is a validated higher-order construct.

2.2 Competence frameworks and the TVET context

TVET differs from general educational settings because instruction must connect pedagogical decisions with occupational procedures, workplace tools, and opportunities for safe practical rehearsal. Reports describe changes in the nature and role of vocational education and training in Europe (Cedefop, 2017) and highlight the implications of digital transformation for vocational skills (UNESCO, 2021). These sources support examining professional learning that integrates teaching practice and workplace technology, without assuming that technology adoption itself improves student outcomes. DigCompEdu provides a broad educator-competence reference point, but it is

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not a prescribed sequence of TVET-specific instructional modules (Redecker, 2017). DISC translates selected educator-competence priorities into four linked vocational professional-development domains: interpreting learner-performance evidence (D); engaging with industry-relevant applications and processes (I); organizing simulation, feedback, and debriefing for practical learning (S); and planning continuing professional learning (C). The contribution is an instructional organization of these domains, not a claim that existing frameworks omit them or that DISC has established superiority over them. Empirical evidence from vocational education identifies both teacher-level competence and contextual constraints. A survey of 1,692 Swiss vocational teachers examined digital competence and associated personal and contextual factors, including workload (Cattaneo et al., 2022). A study of 2,514 Chinese TVET teachers used a context-specific digital-competence system encompassing attitudes, knowledge and skills, teaching, support, and collaboration (Xin et al., 2024). These studies justify attending to occupational context and professional conditions, but their observational assessments do not establish that a particular training sequence causes improvement.

Intervention evidence is more directly comparable to the present evaluation. A school-based TVET teacher-training program in China was evaluated using pre- and post-training measures and participant feedback (Diao & Qu, 2024). Their work supports the feasibility of studying structured TVET professional development, while the present study's uncontrolled design and study-specific self-report scale prevent direct comparison of intervention efficacy or effect sizes. A conceptual study instead proposes a competency-based whole-institution approach involving leaders, teachers, and learners (Zhong & Juwaheer, 2024). Their conceptual analysis highlights organizational support as a consideration for implementation; it is not evidence that the present intervention produced institution-wide change. Together, these four studies sharpen the DISC research gap: existing work offers vocational competence assessments, evidence on contextual factors, an evaluated teacher-training program, and an institutional framework, whereas the present exploratory study examines a four-domain instructional sequence through matched self-reports and explanatory qualitative materials. DISC is therefore presented as a context-specific program organization and preliminary evaluation, not as the first vocational digital-competence model or a validated alternative to established frameworks.

2.3 Program theory and research gap

The literature provides complementary rather than identical explanations for the four domains. DigCompEdu emphasizes the pedagogical use of evidence and assessment, supporting the rationale for Data-driven Pedagogy (D) (Redecker, 2017). Changes in vocational work and digital skills demands motivate Industry 4.0 Tool Integration (I), in which instructors practice with occupationally relevant software and processes (Cedefop, 2017; UNESCO, 2021). Simulated and Augmented Learning Environments (S) address the pedagogical need to structure practical rehearsal and feedback when direct workplace practice may be costly, constrained, or unsafe; this is a proposed instructional mechanism, not an outcome established by the present study. Continuous and Customized Upskilling (C) addresses the ongoing professional-learning demands associated with changing technologies and occupational expectations (Redecker, 2017; UNESCO, 2021). Together, the domains describe a sequence of supported exposure, practice, reflection, and planning. The study evaluates associated changes in instructors' DICS self-ratings and examines their accounts and lesson-plan documents; it does not test whether these mechanisms mediate change or establish system-level effects.

The specific research gap addressed here is therefore the limited evidence presented in this manuscript on a single, integrated four-domain professional-development program for TVET

instructors, assessed with matched domain-specific self-reports and explanatory qualitative materials. This is a focused contribution claim rather than an assertion that no prior studies have combined digital pedagogy, workplace tools, simulation, and continuing learning. Research on language teaching, flipped classrooms, and science visualization is not treated as direct evidence for the intervention unless its instructional relevance is specifically established. Research on immersive tools illustrates the distinction between designing a digital resource and preparing instructors to teach with it. One review mapped the vocational education literature on augmented and virtual reality (Fortuna et al., 2024), while another examined applications and implementation challenges across educational settings (Samala et al., 2024). At the classroom level, a study examined an augmented-reality flipbook in relation to vocational students' critical thinking (Sabitri et al., 2024). These studies inform the Simulated and Augmented Learning Environments pillar but address questions distinct from instructor professional development. DISC focuses on how instructors select a simulation for an occupational task, guide practice, and use the activity to structure feedback and debriefing.

3. The DISC framework

The DISC framework translates the study's conceptual rationale into four linked areas of instructor professional development. Table 1 summarizes each domain, its instructional focus, and the intended proximal outcome.

Table 1. Four domains of the DISC framework and their instructional functions

Pillar	Operational competency	Example learning activity	Expected proximal outcome
D — Data-driven Pedagogy	Interpret learning/simulator data; adapt feedback	Analyze LMS or simulator performance and revise feedback	Higher perceived data-informed teaching capability
I — Industry 4.0 Tool Integration	Select and use relevant workplace technologies	Plan an ERP, IoT, AI or visualization-based task	Higher perceived industry-tool teaching capability
S — Simulated and Augmented Learning Environments	Design, facilitate, assess and debrief simulations	Develop a VR/AR/simulation scenario and debriefing guide	Higher perceived simulation facilitation capability
C — Continuous and Customized Upskilling	Identify gaps, seek credentials and evaluate tools	Prepare an individual professional-growth plan	Higher perceived continuing-development capability

The macro–meso–micro distinction is used to situate the framework rather than to claim demonstrated system-level impact. Macro-level technological change provides the broader rationale for ongoing instructor development; meso-level vocational programs and workplace expectations shape choices about industry-relevant tools and resources; and micro-level teaching decisions concern feedback, guided practice, simulation, and reflective improvement. These levels inform the proposed logic model, whereas the empirical evaluation focuses on instructors' immediate self-reported competence and qualitative accounts. The DISC domains are therefore not presented as one-to-one measures of macro-, meso-, or micro-level transformation.

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4. Methods

The methods are organized around the mixed-methods design, recruitment, program implementation, measurement, qualitative materials, and quantitative analysis. The procedures distinguish the intervention from the subsequent assessment and explanatory phases.

4.1 Design and setting

The study employed an explanatory sequential mixed-methods design. The quantitative phase consisted of a one-group pre-test/post-test assessment of 35 TVET instructors participating in the D.I.S.C. Capacity Building Program. The subsequent qualitative phase examined how instructors described the changes represented by the four DICS domains, the teaching practices reflected in their lesson plans, and the practical constraints they encountered. No comparison group was included.

4.2 Participants and recruitment

Participants were recruited through a voluntary open call circulated across TVET departments within the University of Applied Science and Technology system in Iran. Eligibility required full-time TVET teaching employment and at least two years of teaching experience. Recruitment records show 58 instructors reached, 47 expressions of interest, 42 eligible, 38 consenting, 37 completing the pre-test, 36 enrolling, and 35 completing the post-test. The analytical sample comprised the 35 instructors with matched pre-test and post-test data.

Table 2. Demographic and professional characteristics of participating TVET instructors

Characteristic	Category	n (%)
Gender	Male	22 (62.9%)
Gender	Female	13 (37.1%)
Age group	25-34	10 (28.6%)
Age group	35-44	15 (42.9%)
Age group	45-54	7 (20.0%)
Age group	55 or above	3 (8.6%)
Highest educational qualification	Bachelor's degree	6 (17.1%)
Highest educational qualification	Master's degree	19 (54.3%)
Highest educational qualification	Doctoral degree	10 (28.6%)
Years of TVET teaching experience	2-5 years	12 (34.3%)
Years of TVET teaching experience	6-10 years	13 (37.1%)
Years of TVET teaching experience	11-15 years	8 (22.9%)
Years of TVET teaching experience	More than 15 years	2 (5.7%)
Main teaching area	Engineering technology	14 (40.0%)
Main teaching area	Business management	10 (28.6%)
Main teaching area	Smart agriculture	5 (14.3%)
Main teaching area	Information technology	6 (17.1%)
Employment status	Full-time	35 (100.0%)
Previous digital-teaching training	Yes	16 (45.7%)
Previous digital-teaching training	No	16 (45.7%)
Previous digital-teaching training	Not sure	3 (8.6%)
Current digital-technology use	Never	2 (5.7%)
Current digital-technology use	Rarely	3 (8.6%)

Characteristic	Category	n (%)
Current digital-technology use	Sometimes	11 (31.4%)
Current digital-technology use	Often	12 (34.3%)
Current digital-technology use	Very often	7 (20.0%)

4.3 Intervention and implementation documentation

The D.I.S.C. Capacity Building Program comprised twelve scheduled weekly sessions from 10 February to 28 April 2025, followed by one post-test and focus-group meeting on 5 May 2025 (12 + 1 sessions). The program was organized around four domains: data-driven pedagogy (D), Industry 4.0 tool integration (I), simulated and augmented learning environments (S), and continuous and customized upskilling (C). Blended activities combined digital-resource exploration with applied teaching tasks, including learning-management-system data interpretation, ERP and IoT examples, VR/AR simulation and debriefing, and individual professional-development planning. Table 8 provides the session-by-session sequence.

4.4 Digital intelligence competency scale (DICS)

The Digital Intelligence Competency Scale (DICS) was developed for this study by selecting and adapting educator digital-competence concepts from DigCompEdu and operationalizing them within the four D.I.S.C. domains. It is not an official European Commission instrument. The 40 self-report items comprise 10 items per domain: Data-driven Pedagogy (D, Items 1–10), Industry 4.0 Tool Integration (I, Items 11–20), Simulated and Augmented Learning Environments (S, Items 21–30), and Continuous and Customized Upskilling (C, Items 31–40). All items use a five-point agreement scale (1 = strongly disagree to 5 = strongly agree), with no reverse-coded items. Domain scores are the arithmetic means of their 10 items, and the overall DICS score is the arithmetic mean of all 40 items; higher values indicate greater self-perceived digital competence. The complete item wording is reproduced in Appendix A. The same item wording and scoring were specified for both assessments. Three experts reviewed the content for relevance and clarity; the available documentation does not include quantitative expert ratings or a content-validity index. Internal consistency at both assessment occasions is reported in Table 3.

Table 3. Internal consistency of DICS domains in the main study

DICS score	Pre-test α	Post-test α
Data-driven Pedagogy	0.907	0.829
Industry 4.0 Tool Integration	0.925	0.786
Simulated/Augmented Environments	0.905	0.869
Continuous/Customized Upskilling	0.863	0.679
Overall DICS	0.945	0.929

Instrument structure and scoring. The DICS comprises 40 positively keyed statements rated from 1 (strongly disagree) to 5 (strongly agree), with ten items allocated a priori to each domain. Domain scores are the arithmetic means of their ten items, and the overall score is the mean of all 40 items; no reverse scoring or weighting is applied. Consequently, a higher score denotes stronger perceived competence rather than observed performance. The full item wording and response anchors are reproduced in Appendix A to support scrutiny and replication.

Development and validity boundaries. The questionnaire documentation describes adaptation of educator-competence concepts, review of item clarity, and a pilot administration with 15 TVET

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instructors outside the main sample. Two items were revised for clarity after piloting. The final instrument contained 40 items. The pilot Cronbach's $\alpha = .89$ applies to the 42-item draft. Because alpha depends on the number of items and how their responses covary, the pilot estimate cannot be transferred to a different item set. Table 3 reports separate internal-consistency estimates for the 40-item instrument in the main sample. No factor analysis, convergent or discriminant validity study, measurement-invariance test, or external performance-based criterion validation is documented. Accordingly, the four-domain allocation is theory-led and exploratory, not an empirically confirmed factor structure; the pilot alpha alone cannot establish construct validity.

Main-sample reliability and interpretation. Internal-consistency coefficients are reported separately for pre-test and post-test scores, for each domain and the overall scale, in the main-study reliability table. The post-test alpha for Continuous and Customized Upskilling was .679, indicating comparatively weaker internal consistency and warranting particular caution when interpreting that domain. Reliability coefficients describe score consistency in these samples; they do not demonstrate that the intervention improved competence, that the domains are distinct, or that score differences are free of response-shift bias. Scoring followed the questionnaire protocol: a domain mean could be computed with one missing item but not with two or more; an overall mean could be computed with up to four missing items but not five or more. All 35 matched pairs had complete item responses; no imputation was required. The reliability estimates are presented in Table 3.

4.5 Qualitative materials and analytic procedures

The explanatory qualitative phase was conducted on 5 May 2025, following the post-test, with the 35 instructors from the paired quantitative sample organized into five focus groups of seven participants each. The qualitative corpus includes 320 focus-group transcript turns, 140 reflective-journal entries (four per instructor), and 70 lesson plans (35 before and 35 after the program). Participant identifiers were used to link these sources to the four DISC domains while presenting findings without personal names. The qualitative material was organized around participants' accounts of instructional change, implementation constraints, and professional confidence. The reported thematic categories were Pedagogical Mindset Shift, Navigating Barriers, and Empowerment and Increased Self-Efficacy. Focus-group, journal, and lesson-plan material was compared with the corresponding DICS domain changes to explain how participants interpreted the observed self-report shifts; agreement across sources was treated as contextual corroboration, not evidence of causation. Participant codes are used in published excerpts. Qualitative analytic transparency. The three reported themes are presented as descriptive thematic categories derived from the focus-group, reflective-journal, and lesson-plan materials. The analysis organized focus-group, journal, and lesson-plan evidence into three descriptive thematic categories. Interpretation was based on the reported themes and participant-linked excerpts; formal inter-coder reliability and saturation were not used as evidence of thematic validity.

4.6 Quantitative analysis

Five paired-samples t-tests evaluated within-participant change in the overall DICS mean and four domain means (post-test minus pre-test; possible score range 1–5). Difference-score distributions were evaluated using Shapiro–Wilk tests and standardized difference scores were screened for potential outliers (absolute $z > 3$). Because normality was not supported for every outcome, two-sided Wilcoxon signed-rank tests were used as sensitivity analyses. For each paired comparison, Cohen's d_z was computed as the mean paired difference divided by the sample standard deviation of differences (equivalently $t/\sqrt{35}$). Two-sided 95% confidence intervals for mean changes used

the t distribution with 34 degrees of freedom. Five comparisons (overall and four domains) were assessed using a Bonferroni familywise threshold of $\alpha = .01$ alongside unadjusted two-sided p-values. The 95% confidence intervals for Cohen's d_z were obtained by inverting the noncentral t distribution for the observed paired t statistic (df = 34), then dividing the noncentrality limits by $\sqrt{35}$. These intervals quantify uncertainty in standardized within-person changes, separately from confidence intervals for mean gains.

Statistical reporting distinguishes descriptive means from paired inferential estimates: standard deviations of pre-test and post-test scores characterize scores at each occasion, whereas the standard deviation of within-person differences is the denominator for the paired t statistic and Cohen's d_z. The reported 95% confidence intervals for mean gains and standardized changes describe sampling uncertainty in the within-person contrasts; they are not confidence intervals for a controlled treatment effect. The five outcomes are correlated because the overall score includes the four domains. The Bonferroni threshold is therefore a conservative familywise decision rule, not a claim that the tests are independent. Given the exploratory sample and self-report measurement, statistical significance should be interpreted alongside precision, measurement limitations, and the absence of a comparison group.

5. Results

Results are presented in the order of instrument reliability, descriptive outcomes, paired comparisons, and qualitative integration. All quantitative changes refer to participants' self-reported competence, rather than independently observed classroom performance.

5.1 Pilot reliability

The pilot provided an initial estimate of the internal consistency of the study-specific DICS before the main cohort was assessed. Table 4 summarizes the reported pilot reliability information.

Table 4. Pilot internal consistency of the DICS

Scale	Cronbach alpha	Pilot n
42-item pilot draft	.89	15

5.2 Descriptive statistics

The following table summarizes the relevant evidence and reporting details for this part of the study.

Table 5. Descriptive DICS scores before and after the program

DICS measure	Pre M	Pre SD	Post M	Post SD	Gain
Overall DICS	2.81	0.49	3.92	0.44	1.11
D - Data-driven Pedagogy	2.65	0.62	3.88	0.55	1.23
I - Industry 4.0 Tool Integration	2.70	0.71	4.05	0.48	1.35
S - Simulated and Augmented Learning Environments	2.55	0.68	3.75	0.60	1.20
C - Continuous and Customized Upskilling	3.34	0.53	4.01	0.42	0.67

Note. N = 35 paired observations. DICS item responses range from 1 (lowest) to 5 (highest); reported values are mean item scores on the same 1–5 scale. M = mean; SD = standard deviation; Gain = post-test mean minus pre-test mean (positive values indicate higher post-test self-reported scores).

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5.3 Paired changes

Paired comparisons quantify within-instructor differences between the two assessment occasions. Table 6 reports the mean changes, uncertainty intervals, test statistics, and standardized paired differences.

Table 6. Paired changes in overall and domain-specific DICS scores

DICS measure	Mean gain	SD gain	t(34)	p	Cohen's d_z	95% CI gain	95% CI d_z
Overall DICS	1.11	0.53	12.47	< .001	2.11	[0.93, 1.29]	[1.50, 2.70]
D - Data-driven Pedagogy	1.23	0.74	9.85	< .001	1.66	[0.98, 1.48]	[1.15, 2.18]
I - Industry 4.0 Tool Integration	1.35	0.73	10.90	< .001	1.84	[1.10, 1.60]	[1.29, 2.39]
S - Simulated and Augmented Learning Environments	1.20	0.81	8.73	< .001	1.48	[0.92, 1.48]	[0.99, 1.95]
C - Continuous and Customized Upskilling	0.67	0.64	6.20	< .001	1.05	[0.45, 0.89]	[0.63, 1.46]

Note. N = 35 paired observations. Gain = post-test minus pre-test. Cohen's d_z = mean paired difference / SD of paired differences = t / √35. Confidence intervals are two-sided 95% intervals: paired-t intervals for mean gains and noncentral-t intervals for d_z. All p values are two-sided and remain below the Bonferroni-adjusted threshold of .01 for five comparisons (overall score and four domains). Scores are self-reported on a 1–5 scale; the intervals describe paired score changes.

Assumption and sensitivity checks. Shapiro–Wilk tests indicated non-normal paired differences for the overall score ($p = .0331$) and simulation domain ($p = .0329$), but not for the other three domains (all $p \geq .407$). No absolute standardized gain exceeded 3 in the reported screening (largest observed across outcomes = 2.07). Two-sided Wilcoxon signed-rank sensitivity tests remained below .01 for all five outcomes (reported p values from 5.82×10^{-11} to 1.24×10^{-5}). This agreement supports the direction of the observed paired changes across analytic approaches; it does not remove the limitations of an uncontrolled design. Because Wilcoxon signed-rank inference has its own distributional assumptions, these tests are treated as sensitivity analyses rather than definitive assumption-free confirmation.

Interpretation of domain differences. Industry 4.0 Tool Integration had the largest observed mean gain (+1.35), whereas Continuous and Customized Upskilling had the smallest (+0.67). These are descriptive comparisons across domains; no formal paired contrasts between domain gains or multiplicity-adjusted tests of domain-to-domain differences were reported. Accordingly, the observed ranking should not be interpreted as evidence that one pillar was statistically more effective than another. Baseline differences (for example, C pre-test M = 3.34 versus S pre-test M = 2.55) also affect the available room for change on a bounded 1–5 scale.

The paired analyses identified higher DICS self-ratings at post-test than at pre-test following the 12-session program among the 35 instructors with matched assessments. The overall DICS mean increased from 2.81 to 3.92 (mean paired change 1.11, 95% CI [0.93, 1.29]; $t(34) = 12.47$, $p < .001$; Cohen's $d_z = 2.11$, 95% CI [1.50, 2.70]). Positive changes were also observed in each of

the four domains, and all five comparisons met the Bonferroni-adjusted threshold of .01. These findings are preliminary within-group changes in perceived competence following participation.

5.4 Qualitative findings and mixed-methods integration

Evidence and source limitations. The focus-group dataset comprises 320 transcript turns, the journal dataset comprises 140 entries, and the lesson-plan dataset comprises 35 pre/post pairs. These are counts of records, not counts of independent participants endorsing a theme. The same participant may contribute across sources, and repeated or similar phrasing cannot be treated as independent triangulation. Excerpts are labeled by participant and focus group. The three themes are illustrated with focus-group excerpts, reflective journals, and paired lesson plans. The sources show how instructors described their experiences and how they planned instruction.

5.4.1 Assumption and sensitivity checks

Table 7 summarizes the distribution and sensitivity checks for the paired comparisons reported in Table 6.

Table 7. Supplementary paired analyses and sensitivity checks

DICS outcome	Shapiro–Wilk p	Wilcoxon p	Maximum absolute z
Overall	.0331	5.82×10^{-11}	1.83
D	.605	5.20×10^{-7}	2.07
I	.407	2.46×10^{-7}	1.98
S	.0329	3.97×10^{-7}	1.72
C	.606	1.24×10^{-5}	1.99

Shapiro–Wilk tests indicated departures from normality for the overall and simulation gain scores. No standardized paired difference exceeded the absolute screening threshold of 3. Wilcoxon signed-rank tests supported the direction of the paired changes across all five outcomes (Table 7).

5.4.2 Program schedule and participation

Table 8 outlines the twelve weekly program sessions from 10 February through 28 April 2025 and the additional post-test and focus-group session on 5 May 2025. The assessment meeting is distinguished from the instructional program. The program ran from 10 February to 28 April 2025 across twelve scheduled weekly sessions. A thirteenth meeting on 5 May 2025 was dedicated to the post-test and five focus-group discussions. Table 8 presents the twelve-session program schedule and the separate assessment meeting.

Table 8. Program schedule: Twelve weekly sessions and one assessment meeting

Week	Date	Module	Session type
1	10 Feb 2025	Program orientation and baseline assessment	Program session
2	17 Feb 2025	Data-driven Pedagogy	Program session
3	24 Feb 2025	Data-driven Pedagogy	Program session
4	03 Mar 2025	Data-driven Pedagogy	Program session
5	10 Mar 2025	Industry 4.0 Tool Integration	Program session
6	17 Mar 2025	Industry 4.0 Tool Integration	Program session

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Week	Date	Module	Session type
7	24 Mar 2025	Industry 4.0 Tool Integration	Program session
8	31 Mar 2025	Simulated and Augmented Learning Environments	Program session
9	07 Apr 2025	Simulated and Augmented Learning Environments	Program session
10	14 Apr 2025	Simulated and Augmented Learning Environments	Program session
11	21 Apr 2025	Continuous and Customized Upskilling	Program session
12	28 Apr 2025	Continuous and Customized Upskilling	Program session
13	05 May 2025	Post-test and focus groups	Post-test and focus groups

5.5 Qualitative findings: Thematic evidence and source coverage

The qualitative material is organized around three descriptive themes, followed by a joint display that places those accounts alongside the quantitative domains.

5.5.1 Pedagogical mindset shift

Focus-group accounts illustrate a reported move from lecturer-led delivery toward feedback, guided practice, and simulation debriefing (e.g., P01/FG1 on LMS feedback and P09/FG2 on VR coaching). Reflective journals and paired lesson-plan records also contain references to data-informed feedback and simulation activities. These are descriptions of reported intentions and documented plans.

P01 illustrated how learning-management-system data informed decisions about what to revisit in the next lesson.

> "Before, I assumed I knew who was struggling. Now, the LMS dashboard shows me the exact activity where half the class disengaged. I redesign my next lesson on the spot" (P01, FG1; Pillar D).

P09 described using performance data from a welding simulator to give feedback during guided practice.

> "In a VR welding simulator, I am not at the front lecturing. I watch their digital metrics and give immediate feedback. I have become a coach" (P09, FG2; Pillar S).

5.5.2 Navigating barriers

Focus-group excerpts identify practical constraints: P33/FG5 describes approval requirements for lab access, while P27/FG4 describes assessment rules emphasizing theory. The coding summary also associates barriers with reflective journals. Such accounts qualify favorable self-ratings; they do not establish how many instructors encountered each specific obstacle or explain individual DICS changes.

P33 contrasted enthusiasm for an ERP simulator workshop with the approval process for booking the laboratory.

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> "The ERP simulator workshop was brilliant, but booking the lab takes three approvals. The enthusiasm from the training crashes against the bureaucracy" (P33, FG5; Barriers).

P27 described a different barrier: assessment rules that emphasized theory over digital competence.

> "I want to continue learning, but assessment rules still emphasize theory more than digital competence" (P27, FG4; Pillar C).

5.5.3 Empowerment and increased self-efficacy

Focus-group excerpts describe confidence with CNC simulation (P17/FG3) and motivation from micro-credentials (P25/FG4). Reflective journals provide an additional self-report source for confidence and continued learning. These accounts are consistent with perceived development but cannot establish objectively measured competence.

P17 linked being able to operate the CNC simulator independently with greater confidence in answering students' questions.

> "When I could run the CNC simulation software myself, a huge anxiety lifted. I no longer fear that a student will ask a question I cannot answer" (P17, FG3; Pillar I).

P25 described the micro-credential as both a concrete professional-learning goal and a form of recognition.

> "The micro-credential badge changed my perspective. It is a specific, achievable goal, and it gave me a recognition system I never had before" (P25, FG4; Pillar C).

The paired lesson-plan dataset includes 35 pre-intervention and 35 post-intervention records linked by participant ID. Its "evidence of change" field is coded "Yes" for each post-intervention record and "No" for each pre-intervention record. Illustrative records describe movement from lecture/demonstration toward guided practice, dashboard-based feedback, simulator use, and professional-learning goals (e.g., P01). These fields constitute a descriptive comparison of recorded planning elements, not an independently rated rubric, blinded assessment, or demonstrated improvement in classroom practice. Table 9 compares domain-level changes in self-ratings with participant accounts and lesson-plan examples, highlighting where the findings align and where implementation barriers qualify them.

Table 9. Joint display of quantitative changes and qualitative evidence

Quantitative finding	Qualitative theme and illustrative evidence	Integration: support, qualification, or divergence
Overall: +1.11; dz = 2.11	Mindset Shift and Empowerment describe perceived growth; Navigating Barriers describes practical constraints.	Broad thematic convergence with improved self-ratings; constraints qualify implementation. No independent performance outcome.
D: +1.23; dz = 1.66	Mindset Shift: P01/FG1 describes LMS dashboard use and targeted feedback; related	Supports a perceived change toward data-informed pedagogy; plans and

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Quantitative finding	Qualitative theme and illustrative evidence	Integration: support, qualification, or divergence
	plans mention formative feedback.	accounts do not demonstrate enacted teaching.
I: +1.35; dz = 1.84	Empowerment: P17/FG3 describes greater confidence with CNC simulation; P33/FG5 reports ERP lab-access approvals.	Confidence accounts align with the largest gain, while access barriers qualify implementation; no participant-level gain–theme association tested.
S: +1.20; dz = 1.48	Mindset Shift: P09/FG2 describes VR simulation coaching and immediate feedback.	Supports perceived movement toward simulation-based practice; no direct observation or student outcome.
C: +0.67; dz = 1.05	Empowerment: P25/FG4 describes micro-credential motivation; Barriers: P27/FG4 describes assessment rules.	Positive but smallest gain; barriers provide context, not an established reason for the smaller gain. No linked individual-level analysis.

Mixed-methods integration was conducted at the level of DISC domains and descriptive qualitative themes, rather than by statistically linking individual interview statements to DICS change scores. The quantitative strand documents higher post-test self-ratings for the overall scale and all four domains. The qualitative strand offers illustrative accounts of pedagogical reorientation (data-informed feedback and simulation, principally D and S), confidence with occupational technologies (I), and motivation for continued learning (C). Accounts of laboratory access restrictions and theory-oriented assessment rules qualify these favourable experiences across domains. Thus, the strands show broad thematic compatibility alongside meaningful contextual tension, rather than independent confirmation of actual teaching improvement. The smallest descriptive mean gain occurred in C (+0.67), but the qualitative barrier accounts cannot be used to explain this difference without participant-linked analysis or a tested mechanism. Neither qualitative theme frequency nor agreement with an individual score trajectory can be established from the reported aggregate evidence.

Additional vocational-education evidence further contextualizes these findings: studies examined the association between vocational teachers' digital-competence beliefs and technology acceptance (Antonietti et al., 2022), assessed preservice TVET teachers' digital competence (Bitemirova et al., 2023), investigated ICT integration and TPACK among vocational teachers (Istiningsih, 2022), and examined attitudes and digital competencies in a vocational-school sample (Gui et al., 2026). These studies address related constructs in different populations and designs and do not establish causal efficacy for the DISC intervention.

6. Discussion

The observed increases in self-reported scores should be interpreted in relation to established educator-competence frameworks rather than as evidence that the DISC model is psychometrically or causally superior to them. The DigCompEdu framework treats digital competence as encompassing assessment, learning resources, teaching, and learners' engagement (Redecker, 2017). The DICS changes in data-driven pedagogy and simulated learning are consistent with the relevance of these areas, but this study used a newly constructed self-report instrument and cannot establish equivalence with DigCompEdu measures. In contrast to general educator-competence

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frameworks, DISC deliberately combines pedagogical data use with occupation-specific technology, simulation, and continuing upskilling within one TVET professional-development sequence.

The industry 4.0 integration domain showed the largest observed mean pre–post difference (1.35 points). This pattern is compatible with the vocational emphasis on keeping instruction aligned with changing work processes and tools (Cedefop, 2017; UNESCO, 2021). Those sources establish a policy and sectoral rationale, however, rather than a directly comparable effect estimate from a controlled teacher-training trial. Participants reported greater confidence using occupational software and described barriers to accessing the tools.

The simulation domain also showed a higher post-test self-report mean (mean gain 1.20). Prior educational research has examined how animation and visual cueing support the learning of processes and concepts (Lin & Atkinson, 2011), and research on scientific visualization highlights the importance of interpreting representations rather than treating their presence as sufficient for learning (Franconeri et al., 2021). These studies concern learning and visual communication in different populations and settings, so they provide a conceptual comparison, not direct replication of a TVET-instructor intervention. The present data capture instructors' self-assessed readiness to use simulations, not students' performance in simulated or authentic vocational tasks.

The smaller gain in continuous and customized upskilling (0.67 points) is noteworthy alongside its higher pre-test mean (3.34). Participants described recognition and professional-learning opportunities but also institutional constraints. This is compatible with broader concerns about the conditions under which educational technologies are adopted (Selwyn, 2023); nevertheless, neither institutional support nor individual opportunity was measured as an explanatory predictor. Baseline differences, ceiling effects, and differences in implementation exposure are alternative explanations that cannot be distinguished here.

Taken together, the quantitative phase establishes the relative size and uncertainty of the self-report changes, whereas the qualitative phase illustrates possible enabling and constraining experiences. The interpretation that institutional barriers limited Pillar C improvement remains a hypothesis, not a finding of an explanatory association: no participant-level linkage of C change scores to coded qualitative accounts, baseline professional-learning orientation, institutional support, or item-level ceiling analyses was conducted. Future studies should examine item distributions and response shift, assess test–retest and domain measurement properties, and prospectively link individual change scores with independently coded accounts and institutional indicators.

The Pillar C accounts describe both a reason to pursue further learning (recognition through a micro-credential) and a constraint on putting that learning into practice (assessment rules that emphasize theory). These contrasting experiences contextualize the quantitative pattern without explaining why the Pillar C mean gain was smaller. The difference in Pillar C should first be described descriptively rather than attributed to one mechanism. Its pre-test mean (3.34) exceeded the baselines for D (2.65), I (2.70), and S (2.55), leaving less upward room on the five-point response scale; its mean change (+0.67) was also smaller than those for D (+1.23), I (+1.35), and S (+1.20). A higher starting score is consistent with a possible ceiling or restricted-range explanation, but the domain mean alone cannot establish item-level ceiling effects. The Pillar C post-test reliability estimate (Cronbach's alpha = .679) also warrants caution when interpreting differences across domains; the domains were not equated for measurement precision or sensitivity to change.

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Across the four domains, the convergence of positive self-report changes with focus-group and journal accounts resembles the favorable engagement often discussed in technology-supported professional development, but the present design does not permit direct effect-size comparison with randomized or controlled interventions. Its distinctive contribution is an explicitly integrated, TVET-oriented instructional arrangement evaluated with linked quantitative and qualitative sources. Future research should test the model against established professional-development approaches, use independently rated teaching artifacts and student outcomes, and assess whether institutional conditions moderate longer-term changes.

Comparable empirical studies in vocational education strengthen the interpretation of these findings. A school-based professional-development program for TVET teachers in China was evaluated using pre- and post-training assessments and participant feedback (Diao & Qu, 2024). The findings provide a closer intervention-level parallel than general educational-technology literature, although differences in outcomes, instruments, and sampling prevent direct comparison of effect sizes. A survey of 1,692 Swiss vocational teachers identified personal and contextual factors, including workload, as relevant to digital competence (Cattaneo et al., 2022). Similarly, a study of 2,514 Chinese TVET teachers used a context-specific competence framework and identified variation associated with teacher characteristics and other factors (Xin et al., 2024). These observational studies support attention to vocational context and institutional conditions, but neither tests the DISC intervention.

More recent evidence provides an important methodological contrast. A 10-week industry-integrated TPACK professional-development intervention was evaluated using matched comparison groups of vocational teachers (Cui et al., 2026). Unlike that controlled comparison, the present study has only a single pre–post cohort, so its observed changes cannot be attributed uniquely to DISC Taken together, the studies indicate that context-specific competence frameworks and structured professional learning are active areas of empirical TVET research. The present contribution is the exploratory combination of four DISC domains with self-report and qualitative implementation evidence; claims of uniqueness or superiority over existing TVET models are not warranted.

Conceptual levels and measured outcomes. The macro–meso–micro mapping in DISC is a framework for identifying potential implementation contexts, not an empirical finding that gaps at all three levels have been bridged. At the micro level, the study measured immediate changes in 35 instructors' self-reported digital competence and documented their perceptions, reflections, and lesson-plan materials. These observations may inform hypotheses about instructional decision-making, but the study did not observe classroom delivery or assess learners' performance. At the meso level, alignment between vocational curricula and workplace skill demands remains a proposed application of the framework: the study did not collect employer evaluations, graduate-proficiency measures, independent curriculum-alignment ratings, or evidence of organizational adoption. At the macro level, policy relevance follows from the context of digital transformation and TVET priorities, but no policy implementation, institutional reform, or system-wide outcome was measured.

Accordingly, claims about narrowing industry–education gaps or improving workforce readiness should be read as future research propositions rather than outcomes of this evaluation. Testing these propositions would require multi-institutional designs, documented curriculum changes, external industry assessments, direct observation of teaching, and longitudinal graduate or learner outcomes. The present contribution is narrower: it offers a TVET-oriented professional-

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development structure accompanied by preliminary within-participant self-report changes and contextual qualitative accounts.

Theoretical contribution and scope of novelty. DISC does not replace or claim to improve on DigCompEdu as a validated general educator-competence framework (Redecker, 2017). Rather, its proposed contribution is a TVET-specific synthesis of four instructional priorities—data-driven pedagogy, Industry 4.0 tool integration, simulated learning, and continuous and customized upskilling—within one professional-development sequence. Its macro–meso–micro mapping specifies hypothesized sites of application, not demonstrated cross-level effects. The 12-session intervention operationalizes this synthesis, while the one-group pre–post assessment and qualitative records provide an initial implementation appraisal rather than an independent test of theoretical novelty or comparative superiority. Research on vocational teachers' digital competence and professional learning shows that occupation-specific competence and structured training are not unique to DISC; the distinctive proposal here is their particular four-domain organization and integration (Cattaneo et al., 2022; Cui et al., 2026; Diao & Qu, 2024; Xin et al., 2024).

Theoretical implications versus practical application. The theoretical proposition is that these four domains can be organized as a coherent, context-sensitive lens for TVET instructor development; whether they represent separable, generalizable constructs requires additional psychometric and comparative testing. Practically, the framework may help TVET program coordinators, instructor educators, curriculum teams, and institutional leaders plan professional learning, identify equipment and simulation needs, and arrange continuing-learning opportunities. Implementation would require access to relevant occupational technologies, instructor time, pedagogical support, institutional recognition, and adaptation to local curricula and resources. The present study offers a preliminary example for adaptation and further testing, not a validated or universally replicable blueprint. Multi-site comparison studies, independent teaching assessments, and longer-term learner and institutional outcomes are needed before making efficacy or system-level claims.

Implementation implications and boundaries. For practice, the four domains may serve as a planning checklist rather than a validated diagnostic standard: instructors and coordinators can identify an occupationally relevant data-use task, select industry tools appropriate to local curricula, determine where simulation offers safe rehearsal, and schedule follow-up learning opportunities. Any adaptation should document available equipment, accessibility, staff support, assessment requirements, and instructor workload. The current evaluation does not determine which component is necessary, how much training is sufficient, or whether the approach is cost-effective. These questions require comparative and implementation-focused research. Additional directly relevant studies sharpen the comparative context. Prior work synthesized vocational teachers' professional digital-competence frameworks (Lahn & Berntsen, 2023), investigated multidisciplinary digital competence in pre-service vocational teachers (M. J. J. Roll & Ifenthaler, 2021), and examined competence development in technical vocational schools through Learning Factories 4.0 (M. Roll & Ifenthaler, 2021). Another study analyzed vocational teachers' technology use across teaching profiles (Cattaneo et al., 2025). These studies highlight the importance of vocational context and of distinguishing self-perceived competence from technology use or demonstrated performance.

Recent vocational-education research also addresses contextual and methodological considerations. Recent studies examined digital competencies in agricultural vocational teaching (Khademi-Vidra & Bakos, 2025), synthesized vocational-teacher digital-competence research (Purnama et al., 2026), and reported diagnostic work with future vocational educators (Kuznietsov & Dobroskok, 2026). A broader systematic review examined digital competencies in teacher professional

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development (Fernández-Batanero et al., 2022). These studies are relevant comparisons, not direct replications of the DISC intervention. Related research addressed AI-supported creative thinking in English learning (Roozafzai, 2024a), digitally enhanced language-learning environments (Roozafzai, 2024b), flipped-classroom learning outcomes (Roozafzai, 2024c), and animation and inclusive discourse in earth-science learning (Roozafzai & Zaeri, 2025). These studies provide examples of digital pedagogical applications in other educational contexts, but they do not independently validate the DISC framework in TVET.

7. Limitations

The study used an uncontrolled one-group pre-test/post-test design with no random assignment or comparison condition. The modest sample (35 matched participants) was drawn from a single institutional setting through voluntary participation, creating potential self-selection and limiting transferability to other TVET institutions, occupational areas, and national contexts. The post-test one week after the final instructional session provides no evidence of maintenance or longer-term transfer. The principal quantitative outcome was self-reported competence on the study-specific DICS; although internal-consistency estimates were examined, additional evidence is needed for content and construct validity, measurement stability, responsiveness, and comparability across the four domains, particularly given the lower post-test reliability for Pillar C.

8. Conclusion

The DISC framework organizes TVET instructors' digital professional development across four domains: data-driven pedagogy, industry-aligned technology integration, simulation-based learning, and continuous and customized upskilling. In this exploratory one-group study, 35 instructors completed matched assessments before the program and one week after the final instructional session. Their mean self-reported DICS score increased from 2.81 to 3.92 (mean paired change 1.11, 95% CI [0.93, 1.29]), with increases in each domain. Focus-group discussions and reflective journals described changes in perceived confidence and barriers to implementation. The paired lesson plans documented changes in planned instruction, including dashboard-based feedback and simulator-supported guided practice. Four priorities follow for future research. First, larger, multi-institutional evaluations with an appropriate comparison group should assess whether changes can be attributed to the program. Second, further psychometric testing of the DICS should be combined with independent observation or assessment of teaching practice rather than relying only on instructor self-report. Third, studies should assess student learning, occupational skill development, and employer-relevant outcomes before making claims about graduate employability or industry alignment. Fourth, longitudinal follow-up should establish whether perceived gains persist and transfer to routine instruction. These are proposed evaluations, not outcomes demonstrated by the present study. The framework's wider educational and economic benefits remain propositions for future evaluation rather than outcomes established by this study. The immediate contribution is therefore a clearly specified framework and a preliminary account of perceived change among participating instructors. The results should inform further refinement and rigorous evaluation rather than recommendations for universal adoption.

Author's declaration

Author contribution

The sole author conceptualized the DISC framework and designed the mixed-methods study, collected and analyzed the quantitative and qualitative data, and interpreted the findings. The author drafted and revised the manuscript and approved the final version for submission.

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Conflict of interest

The author, I, declares no competing interests.

Data availability

The participant-level questionnaire responses, focus-group transcripts, reflective journals, and lesson plans are not publicly deposited because the qualitative records may contain potentially identifying information. Requests for appropriately de-identified materials may be directed to the corresponding author and will be considered subject to participant consent, institutional permissions, and applicable confidentiality requirements. This statement does not imply that all underlying data can be released.

Ethical clearance

The Research Ethics Office / Office of the Chancellor, One of the Centres of Isfahan – University of Applied Science and Technology, Tehran, Iran, issued a determination of exemption from full ethical committee review on 10 December 2024 for the study "The DISC Model: A Structured Framework for Digital Intelligence in TVET." The determination preceded the start of study activities on 10 February 2025. The reported exemption conditions required voluntary participation, written informed consent, and the right to withdraw without penalty. Pre- and post-test responses were linked using participant study codes rather than names; therefore, the linked research records are described as coded or de-identified, not as anonymous at collection. Focus-group recordings, reflective journals, and lesson plans were reported using participant codes, and identifying information was excluded from manuscript excerpts. Consent documentation was kept separate from the analytical records, and access to research records was restricted as described in the study documentation. The institutional correspondence identifies the exemption by study title and determination date.

AI statement

AI tools were used to support language editing, readability, and manuscript organization. The author is responsible for verifying all research claims, analyses, references, and the final submitted text.

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