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Validating a critical thinking scale: an essential skill for vocational education students in the era of artificial intelligence

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ABSTRACT

Critical thinking is a fundamental competence in education and professional training, particularly in a technology-driven era increasingly shaped by generative artificial intelligence (GenAI). To address the need for contextually relevant assessment tools, this study aimed to evaluate the reliability and validity of the critical thinking disposition scale (CTDS) among vocational training (VT) students. A descriptive, exploratory, and cross-sectional design was applied using quantitative methods. Data was collected from 879 students enrolled in VT programs. Exploratory and confirmatory factor analyses were conducted to examine the scale's factorial structure, reliability, and construct validity. Results supported an 11-item structure comprising two dimensions—executive function and reflective thinking—with satisfactory psychometric properties (KMO=0.817; CFI=0.883; TLI=0.851; RMSEA=0.0672; SRMR=0.0428). The findings confirm that the CTDS is a reliable and valid instrument for assessing critical thinking dispositions in vocational education. This tool provides educators and researchers with a robust means to evaluate critical thinking, a key competence for learning, personal development, and professional preparedness in the age of GenAI. This is the first validation of the CTDS with VT students in Spain.

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1. INTRODUCTION

We currently find ourselves living in the era of generative artificial intelligence (GenAI), where vast quantities of content can be produced and personalized almost instantaneously. The ability to critically analyze information has taken on a new level of importance. GenAI tools, capable of creating text, images, audio, and even deepfakes that closely mimic human output, blur the lines between authentic and synthetic information. This poses unique challenges for individuals seeking to discern truth and assess credibility in an information-saturated world, where critical thinking is essential to navigate AI-generated content that may seem authoritative but often lacks depth, accuracy, and ethical grounding [1].

In this new era, hybrid learning methods take on special relevance, making the development of critical thinking skills essential in the current educational landscape. Accordingly, scholarship highlights the need for vocational training (VT) students to strengthen these skills in hybrid environments and offers guidance for both educators and policymakers [2]. So then, "students need frequent and repeated exposure to critical thinking practices, whose training must begin at an early age" [3]. Given this, the training of

individuals' critical thinking capacity must be prioritized as this is an essential skill for citizens to be able to fully participate in a democratic society in a critical and conscious way [4]. Critical thinking influences not only students' academic performance and learning outcomes [3], but also their competence in lifelong learning, problem-solving, and leadership in both professional settings and everyday life [5]. For this reason, fostering this competence is particularly important in VT, an educational stage that prepares learners both for entry into the labor market and for independent participation in twenty-first-century society, which demands essential competences such as critical thinking [6].

Given this, practical training is necessary in VT to promote student reflection, providing them with resources for the development of critical thinking both inside and outside of the school context [7]. In this regard, correlations have been found between a series of abilities such as critical thinking, effective communication and collaboration skills, problem solving, management and leadership, flexibility and adaptability, ongoing self-directed learning, and self-engagement. All of these skills should be considered at the time of promoting practical educational exercises in order to improve student critical thinking [8].

In addition, it is important to note that information and communication technologies (ICT) play an essential role. The use of smart technologies has been shown to foster the development of students' critical thinking, particularly in professional training contexts [9]. Similarly, collaborative technologies contribute to higher-order thinking and self-sufficient learning, especially among adult learners [10]. Furthermore, ICT tools are valuable in forming professional competences in teacher education [11]. The use of discussion forums, wiki links, and social networks (LinkedIn, Facebook) also provides important opportunities in this regard. At the same time, GenAI tools such as ChatGPT are rapidly transforming education, offering new possibilities for personalized learning, assessment, and intelligent tutoring systems [12], [13]. However, their integration also presents challenges, including ethical considerations and the necessity of exercising critical thinking skills [14]. Student use of GenAI tools may lead to over-reliance on these systems [15], making it more essential than ever to apply critical thinking in evaluating AI-generated outputs.

Before promoting or implementing pedagogical interventions to improve critical thinking in VT, it is necessary to conduct a diagnosis and/or assessment to understand students' needs in this regard. In the literature, we find a series of studies that design and validate scales to measure students' critical thinking in specific subjects or disciplines. Along these lines, studies have been conducted to design and validate the critical thinking in academic reading scale for English language teaching students (CTARS-ELT) across undergraduate, master's, and doctoral programs [16].

On the other hand, there are other studies in that design and validate general scales to assess critical thinking skills and/or dispositions. Some of these are: the critical thinking evaluation scale (CTES), which is composed of a series of items related to argumentative abilities (includes motivational dispositions and cognitive skills) and analytical abilities (mainly related to cognitive skills) of critical thinking. It was designed and validated in a sample of adults of Colombian nationality with diverse educational backgrounds, including: high school, undergraduate, master's and doctoral degrees [17]. The critical thinking disposition scale (CTDS) for college students, which was designed and validated in a sample of university students from Portugal and which presents a series of items divided into seven dimensions: search for truth-seeking, open-mindedness, analyticity, systematicity, CT self-confidence, inquisitiveness and maturity of judgment [18]. The student-educator negotiated critical thinking dispositions scale (SENCTDS) was designed and validated in a sample of university students and adults over 18 with fluent English proficiency. It is composed of a series of items that measure six critical thinking dispositions: reflection, attentiveness, open-mindedness, organization, perseverance and intrinsic goal motivation [19]. Also, the CTDS designed and validated in a sample of university students in the area of education and composed of eleven items divided into two dimensions: critical openness and reflective skepticism [20].

Beyond the development and validation of new critical-thinking scales, whether general or subject-specific, researchers have also devoted attention to adapting and revalidating existing instruments for use in other contexts. Thus, the Three-Dimensional Critical Thinking Scale (individual critical thinking skills, criticality, and critical pedagogy) in reading English as a foreign language [21] has been adapted and validated in a sample of Iranian undergraduate students of English as a foreign language [22]. The critical thinking self-assessment scale (CTSAS) [23] has been abbreviated, adapted, and validated in a sample of university students from different countries (Greece, Portugal, Romania, Lithuania, and Germany) and from different disciplines (business informatics, business and economics, teacher education, English as a foreign language, and veterinary medicine). It is composed of a series of items divided into six sub-scales referring to interpretation, analysis, evaluation, inference, explanation and self-regulation [18]. Finally, the clinical critical thinking skills scale (CCTS) has been adapted and validated in a sample of Korean university nursing student [24]. As can be seen, many studies related to the validation of scales for measuring various aspects of critical thinking have been developed in higher education, while this aspect has received little attention in VT. In this regard, this study offers a novel contribution by having as its main objectives: adapting the CTDS for use

with Spanish VT students and testing its reliability, validity, and multifactorial structure when measuring a complex construct such as critical thinking.

2. METHOD

This study presents the process of determining construct validity of the CTDS in the specific context of VT education in the region of Andalusia (Spain). Particular attention is given to the examination of the instrument's internal structure and its consistency with the conceptual framework of critical thinking dispositions. The findings are intended to inform future applications of the scale in similar educational contexts.

2.1. Participants

A multi-stage sampling strategy was employed. First, stratified sampling was used to select VT centers across Andalusia (Spain), including both public and private institutions. From these centers, volunteer students were recruited, yielding a final sample of 879 VT students aged between 15 and 58 years, with 82.7% aged 16–24. The sample comprised 44.1% male and 55.9% female participants. Data were collected from six VT centers in the province of Granada. Among the respondents, 47.1% were enrolled in intermediate-level VT, 47.1% in higher-level VT, and 5.8% in basic VT, as shown in Table 1.

Table 1. Sample distribution by gender and educational stage

		Higher level VT	Intermediate VT	Basic VT	Total
Gender	Male	161 (18.3%)	191 (21.7%)	36 (4.1%)	388 (44.1%)
	Female	253 (28.9%)	223 (25.4%)	15 (1.7%)	491 (55.9%)
Total		414 (47.1%)	414 (47.1%)	51 (5.8%)	879

2.2. Instrument

The original instrument used in the study was the CTDS developed by Sosu [20]. This was specifically designed to remedy the long-noted shortage of sound instruments that capture the dispositional side of critical thinking, a dimension often ignored by skill-oriented tests such as the California critical thinking skills tests (CCTST), the Cambridge thinking skills assessment (TSA), the Watson-Glaser critical thinking appraisal (WGCTA), the Cornell critical thinking test (CCTT), and the Halpern critical thinking assessment [25]. The original instrument submitted to validation, as seen in Table 2, is composed by a total of 11 items with a Likert type response scale from totally disagree=1 to completely agree=5. The original author of the CTDS proposed two latent dimensions, denominated "critical openness" (CT1, CT2, CT3, CT4, CT5, CT6 and CT7) and "reflective skepticism" (CT8, CT9, CT10 and CT11), and carried out the initial validation process with graduate and post-graduate university students [20].

Table 2. CTDS original wording

Item	Description
CT1	I usually try to think about the bigger picture during a discussion.
CT2	I often use new ideas to shape (modify) the way I do things.
CT3	I use more than one source to find out information for myself.
CT4	I am often on the lookout for new ideas.
CT5	I sometimes find a good argument that challenges some of my firmly held beliefs.
CT6	It is important to understand other people's viewpoint on an issue.
CT7	It is important to justify the choices I make.
CT8	I often re-evaluate my experiences so that I can learn from them.
CT9	I usually check the credibility of the source of information before making judgements.
CT10	I usually think about the wider implications of a decision before taking action.
CT11	I often think about my actions to see whether I could improve them.

2.3. Design and procedure

The present study adhered to a descriptive, exploratory, and cross-sectional design. It was used to measure dispositions towards critical thinking at a different educational context (VT in Andalusia, Spain), and in this way, validate the CTDS to determine the latent variables underlying this construct when the scale is administered to a sample from this specific context. To do so, the procedure followed was: firstly, in order to perform this analysis, the CTDS was translated into Spanish, as seen in Table 3.

Table 3. Translation of the CTDS into Spanish

Item	Description
CT1	*Durante una discusión pienso en lo que lo ha provocado.*
CT2	*A menudo pienso nuevas ideas para mejorar como hago las cosas.*
CT3	*Utilizo más de una fuente o documento (Internet, libros,...) para encontrar información por mí mismo.*
CT4	*A menudo busco nuevas ideas.*
CT5	*A veces encuentro ideas que contradicen mi opinión.*
CT6	*Es importante comprender el punto de vista que tienen otras personas sobre un problema*
CT7	*Considero que es importante justificar las elecciones que yo hago.*
CT8	*A menudo pienso sobre mis experiencias para poder aprender de ellas.*
CT9	*Suelo comprobar que sea verdad la información antes de opinar sobre ella.*
CT10	*Normalmente pienso en las consecuencias que tiene una decisión antes de actuar.*
CT11	*Con frecuencia pienso sobre mis actos/acciones para ver si puedo mejorarlos/as.*

Once the CTDS had been translated, a number of educational centers were contacted, via telephone, to request their participation in the study. Further, complete information about the research and its objectives was sent to the centers, alongside a copy of the instrument to be administered to students. Following receipt of authorization from center directors, the instrument was administered individually to each participant making up the sample.

Gathered data was imported into the statistical software Jamovi version 2.3.28 [26], following preliminary descriptive examination of study data and assessment of its compliance with the assumptions of normality by constructing P-P plots for each item [27]. Next, exploratory factor analysis (EFA) was applied to determine the latent factor structure underlying the initial set of scale items and the extent to which these were related with each factor. For this, the principal component extraction method was used with Varimax rotation. Reliability of the overall CTDS and the factors was calculated with the application of Cronbach's alpha and McDonald w coefficients, with the reliability index being set at 95%.

Following this, with the aim of confirming validity of the obtained structure, confirmatory factor analysis (CFA) was carried out. To interpret the results obtained, the criteria proposed by Sathyanarayana and Mohanasundaram [28] were used. To examine model fit, Chi-squared indices were calculated and considered alongside the comparative fit index (CFI), root mean square error of approximation (RMSEA), standardized root mean square residual (SRMR), and Tucker Lewis index. So as to make up the model structure, prediction error terms with the endogenous variables were associated and calculated parameters estimation using the maximum likelihood method. This method was chosen as it is consistent, (asymptotically) unbiased and scale-invariant, and generally recommended when the sample size is at least around 200 cases [29].

3. RESULTS

3.1. Examination of normality

Table 4 summarizes the univariate descriptive indices for the 11 items of the CTDS instrument. For each item, we report the sample mean, the 95% confidence interval (CI) around that mean, the variance, and the coefficients of skewness and kurtosis. With the present sample (N=879), item means range from 3.51 (CT10) to 4.48 (CT6), indicating moderate-to-strong endorsement and the absence of ceiling or floor effects. The widths of the CIs (0.13–0.16) show adequate measurement precision. Item variances span 0.705 to 1.412, providing sufficient dispersion for differentiating respondents. Moreover, skewness values (ranging from –1.781 to –0.855) and kurtosis values (ranging from–0.697 to 2.794) fall within the ±3.29 threshold recommended by Field [27].

Table 4. Descriptive statistics of scale items

Item	Mean	95% CI	Variance	Skewness	Kurtosis
CT1	3.72	[3.64-3.79]	1.318	-0.583	-0.388
CT2	3.92	[3.85-3.98]	0.901	-0.619	-0.079
CT3	3.72	[3.65-3.80]	1.325	-0.602	-0.478
CT4	3.53	[3.46-3.60]	1.097	-0.405	-0.360
CT5	3.55	[3.47-3.62]	1.273	-0.389	-0.544
CT6	4.48	[4.42-4.54]	0.705	-1.706	2.794
CT7	3.95	[3.88-4.02]	1.073	-0.855	0.250
CT8	4.17	[4.10-4.23]	0.923	-1.081	0.753
CT9	3.91	[3.85-3.98]	1.021	-0.744	0.089
CT10	3.51	[3.43-3.59]	1.412	-0.397	-0.697
CT11	3.90	[3.84-3.97]	0.963	-0.818	0.477

In addition to evaluating numerical indices shown in Table 4, P–P plots were constructed as an additional means of examining the data distribution. No meaningful deviations were observed, enabling the assumption of normality to be confirmed for all items, as presented in Figure 1. Given the outcomes obtained following examination of data distribution, it was decided to include all items as they had been administered to participants, in the subsequent EFA.

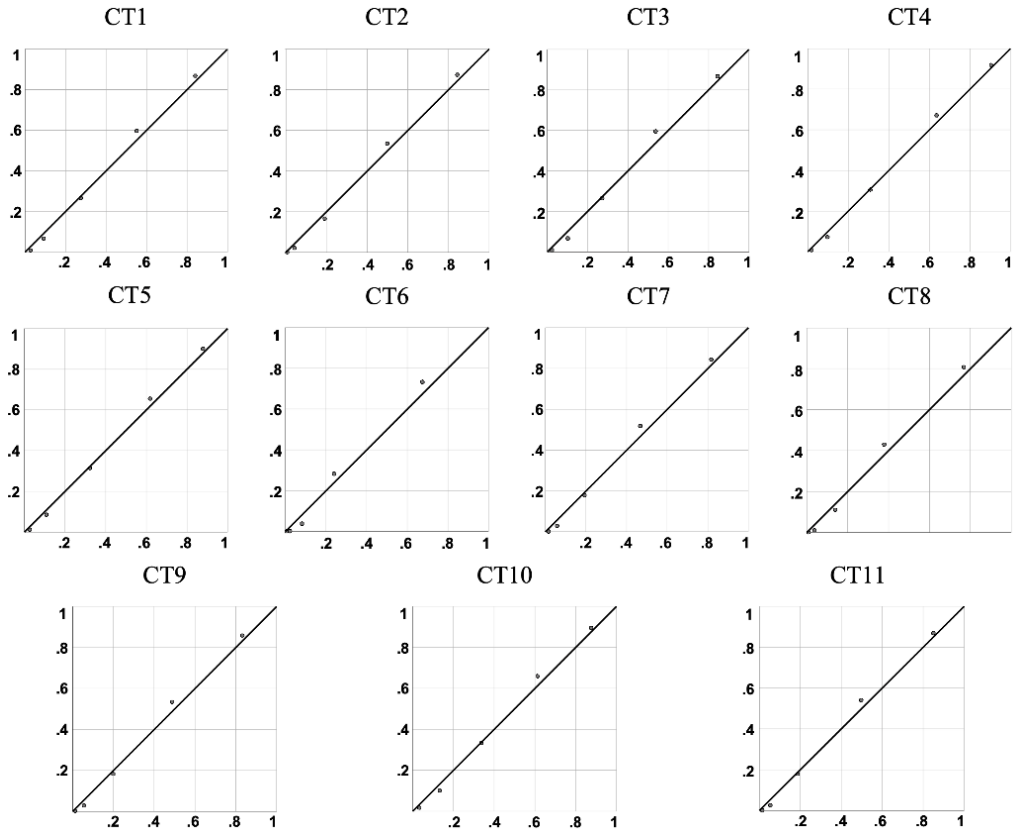

Figure 1. P-P plots for visual examination of data distribution in each item

3.2. Exploratory factor analysis (EFA)

In the EFA, principal component extraction and Varimax rotation were used, producing acceptable fit as demonstrated by Bartlett sphericity test outcomes [1508.017; df=55; p<.001]. The Kaiser-Meyer-Olkin (KMO) measure also produced an acceptable value [KMO=0.817], as did the measure of sampling adequacy (MSA) for each of the different variables [MSA.CT1=0.872; MSA.CT2=0.809; MSA.CT3=0.798; MSA.CT4=0.771; MSA.CT5=0.773; MSA.CT6=0.864; MSA.CT7=0.825; MSA.CT8=0.825; MSA.CT9=0.850; MSA.CT10=0.762; MSA.CT11=0.826].

In consideration of the factor structure of the original scale and given that other factor solutions have led to groupings which are difficult to interpret in the context of the present research, the CTDS structure was set to comprise two components. The two-factor solution enabled interpretations to be made which aligned with the theory on which the model was based and produced an overall explained variance of 39.7%. Table 5 presents the pattern coefficients obtained showing a clean simple structure, with every loading ≥ 0.487 on its primary component with these being considered to be acceptable in the case of all items [30]. Next, we examined the scale's internal consistency and obtained reliability indices that exceed the commonly accepted .70 threshold for research instruments, confirming that the items function coherently as a set. Cronbach's alpha was 0.745, indicating satisfactory inter-item homogeneity without suggesting redundancy. McDonald's omega, which relaxes the tau-equivalence assumption and therefore offers a more robust estimate of composite reliability, was 0.756, closely mirroring the alpha result. Together, these coefficients demonstrate that the CTDS yields dependable scores appropriate for group comparisons and for inclusion in subsequent structural analyses.

Table 5. Factor loadings matrix

Item	F. Loading Factor 1	F. Loading Factor 2
CT4. I am often on the lookout for new ideas.	0.809	
CT3. I use more than one source to find out information for myself.	0.619	
CT2. I often use new ideas to shape (modify) the way I do things.	0.548	
CT5. I sometimes find a good argument that challenges some of my firmly held beliefs.	0.522	
CT8. I often re-evaluate my experiences so that I can learn from them.		0.673
CT6. It is important to understand other people's viewpoint on an issue.		0.602
CT9. I usually check the credibility of the source of information before making judgements.		0.588
CT1. I usually try to think about the bigger picture during a discussion.		0.580
CT11. I often think about my actions to see whether I could improve them.		0.541
CT7. It is important to justify the choices I make.		0.487
CT10. I usually think about the wider implications of a decision before taking action.		0.495

Following this initial factor analysis, the dimensions could be identified to emerge from the CTDS when applied in the context of VT:

- Factor 1=executive critical thinking (ECT) [items CT2, CT3, CT4, and CT5]
- Factor 2=reflective critical thinking (RCT) [items CT1, CT6, CT7, CT8, CT9, CT10, and CT11]

3.3. Confirmatory factor analysis (CFA)

With the aim of examining reliability of the factor structure, CFA was conducted through structural equation modelling (SEM). This grouped each of the obtained factors according to exogenous unobserved variables and grouped the factors' different associated items as empirical observed variables. Following execution of this analysis, a significant Chi-squared value was obtained [χ^2=214; df=43; p<.001]. However, given that the chi-squared value is highly sensitive to sample size, other fit indices were employed with the aim of providing a comparison. In this regard, both comparative fit (CFI) and Tucker-Lewis (TLI) indices were acceptable, being very close to 0.9 (CFI=0.883; TLI=0.851). Further, the RMSEA value was 0.0672 and the standardized root mean squared value (SRMR) was 0.0428. All of these parameters are within the limits established for acceptable fit of proposed models [28]. Table 6 presents the standardized regression weights as a measure of the relative contribution of the variables to the factors detected in the previous analysis as an indicator of the proposed model structure. As can be seen, all examined associations were significant and positive.

Table 6. Standardized regression weights for the proposed scale

Factor	Item	Std. Estimate	Std. Error	Z	*p*
ECT	CT4	0.633	0.0418	15.85	< .001
	CT2	0.615	0.0366	15.93	< .001
	CT3	0.452	0.0456	11.40	< .001
	CT5	0.321	0.0447	8.10	< .001
RCT	CT11	0.630	0.0351	17.63	< .001
	CT8	0.577	0.0346	16.03	< .001
	CT9	0.524	0.0369	14.31	< .001
	CT6	0.505	0.0308	13.76	< .001
	CT10	0.447	0.0443	11.97	< .001
	CT1	0.423	0.0427	11.35	< .001
	CT7	0.370	0.0390	9.82	< .001
ECT	RCT	0.756	0.0350	20.3	< .001

CFA results confirmed the structural model derived from the EFA, though standardized weights revealed some differences in the relative importance of certain indicators compared with the factor loadings obtained for one factor in the EFA. In relation to the dimension describing executive function in critical thinking (ECT), all four items load significantly and positively on the executive factor. Standardized estimates range from 0.633 for CT4 (I am often on the lookout for new ideas) to 0.321 for CT5 (I sometimes find a good argument that challenges some of my firmly held beliefs). The two highest coefficients in items CT4 and CT2 surpass the 0.50 benchmark for strong item–factor linkage, highlighting active idea-seeking and practical updating of behavior as the core of ECT. CT3 contributes moderately (0.452), while CT5, though lower, still meets the accepted 0.30 cut-off and adds the crucial element of openness to counterarguments. Small standard errors (≤0.045) and large Z values (8.10–15.85) attest to the precision of these estimates.

The factor grouping the reflective aspects of critical thinking (RCT) comprises seven items, all with significant positive loadings between 0.630 and 0.370. The strongest contributors are CT11 (self-reflection on actions), CT8 (re-evaluating experiences) and CT9 (checking source credibility), underscoring self-monitoring and evidence appraisal as the backbone of RCT. Supporting facets, perspective-taking (CT6), anticipating consequences (CT10), maintaining a big-picture view (CT1) and justifying choices (CT7), flesh out its metacognitive character. Standard errors remain low (≤0.044) and Z values high (11.35–17.63), confirming statistical robustness. On the other hand, the latent correlation between ECT and RCT is 0.756, indicating a strong yet non-redundant relationship: the two dimensions share a common critical-thinking foundation while retaining sufficient distinctiveness to warrant separate interpretation within the proposed two-factor model, as shown in Figure 2.

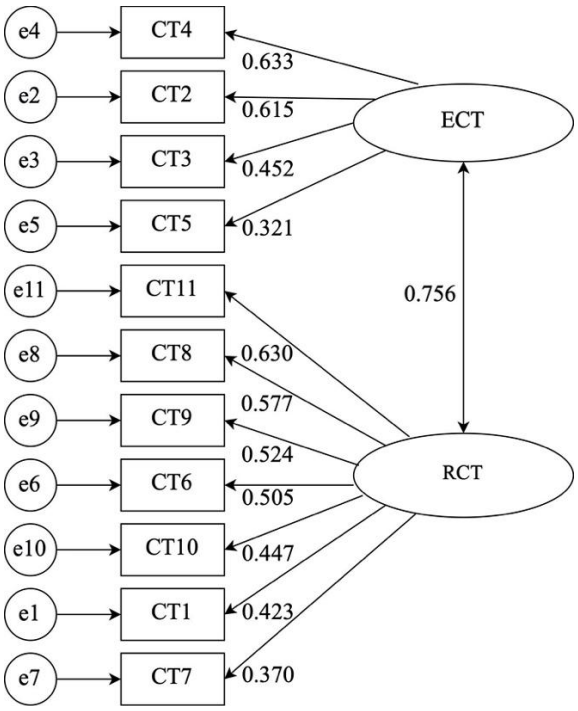

Figure 2. Proposed structural model following CFA

4. DISCUSSION

This paper examined the psychometric properties of the CTDS when applied to VT students in Andalusia, Spain, through exploratory and CFA. Analysis was based on a previous study about a scale designed to measure dispositions towards critical thinking [20]. CFA, via structural equation modelling, confirmed the grouping of 11 scale items (observable variables) into two factors as endogenous variables (RCT and ECT). It is important to highlight that the eleven items from the original CTDS are retained. However, there is no exact correspondence between the items within each factor. In the original study, critical openness comprised seven items (CT1–CT7), and reflective skepticism included four (CT8–CT11). However, in the Spanish validation for the VT educational stage carried out in this study, the ECT factor was composed of four items (CT2, CT3, CT4, and CT5) and the RCT factor by seven items (CT1, CT6, CT7, CT8, CT9, CT10, and CT11). Despite this, the study objective was met, as the CTDS was adapted and validated for use in the Spanish VT context.

In any case, the distinction between these two dimensions sheds light on the multifaceted nature of critical thinking. ECT captures cognitive regulation and self-discipline, which are vital for systematic and logical reasoning. RCT emphasizes introspection and the evaluation of personal experiences, which foster deeper understanding and empathy. Together, these dimensions underscore the complexity of critical thinking as a construct that intertwines both analytical and reflective processes. This dual perspective aligns with contemporary theories of critical thinking, emphasizing the integration of metacognition and self-regulation with evaluative and judgmental skills [5]. This demonstrates the complexity of measuring critical thinking and confirms that a multifactorial CTDS provides a reliable and valid measure of critical thinking dispositions among Spanish VT students, fully addressing the study's objectives.

Along these lines, several studies have demonstrated the multidimensional nature of the CTDS by validating it in various contexts. A cross-cultural adaptation was carried out and evaluated, and the CTDS was validated in Persian-speaking environments with a sample of Iranian undergraduate nursing students. The CTDS was composed of 11 items divided into two factors: critical openness and reflective skepticism [31]. In addition, the Vietnamese version of the scale (CTDS-V) was developed through a cross-cultural adaptation of the scale that was applied and validated in a sample of university students in their final year of the nursing degree, obtaining a scale composed of 11 items and divided into two dimensions corresponding to the original CTDS [32]. It is important to highlight that in both studies, the items of each factor correspond to those proposed in the original scale [20], in contrast to the results of the present study for the VT context.

In addition to these two scales, the good fit of the CTDS divided into two factors was also demonstrated in a sample of university students from the southern United States. However, in this case, there is no exact match between the number of items that make up the scale or each factor since in the original study the critical openness factor is composed of seven items (CT1–CT7) and the reflective skepticism factor by four items (CT8–CT11), and in this study the critical openness factor is composed of three items (CT2, CT4, and CT5) and the reflective skepticism factor by six items (CT6–CT11). In this study, two items corresponding to the critical openness dimension (CT1 and CT3) were eliminated because they loaded simultaneously on both factors. The elimination of these items meant that the fit indices of the proposed model better fit the observed data [33].

On the other hand, in contrast to the results of this research, there are also studies in the literature that show that the unidimensional model of the CTDS better fits the populations analyzed. This is the case of the adaptation of the CTDS to the Spanish version validated in a sample of students from the high school and university stages of education in Spain [34]; of the CTDS validated in the Peruvian context with a sample of adolescent students, most of whom were in their third year of secondary school [35], based on the Spanish version of the CTDS referred [34]; and the CTDS translated, cross-culturally adapted and validated into Brazilian Portuguese in a sample of university nursing students [36].

There are studies that, like the one developed, agree on the multidimensional nature of the CTDS as an appropriate model for assessing students' critical thinking dispositions. However, not all agree on which items correspond to each dimension of critical thinking (ECT or RCT). Furthermore, other studies disagree on whether the most appropriate CTDS model is this one, highlighting that the unifactorial model is more suitable. Also, in recent years the most significant adaptations and validations of the CTDS have been carried out in a few countries and primarily at higher education levels such as universities. All of this highlights the need to continue advancing the validation of techniques that allow for assessing the disposition of a skill as complex as critical thinking in students, especially at underexplored educational levels such as VT.

Along these lines, this study extends the validation of the CTDS to vocational education, demonstrating a stable two-factor structure (executive vs. reflective CT). The ramifications of these findings extend across all VT professional families, encompassing the 26 distinct specialties currently recognized within the Spanish educational system, highlighting the versatility and applicability of the CTDS in assessing critical thinking dispositions across diverse contexts. The validated CTDS offers a framework for embedding critical thinking into curricula across various educational levels and disciplines. By operationalizing critical thinking into measurable constructs, educators can better align their teaching strategies with broader educational goals, such as fostering lifelong learning and preparing students for an AI-driven workforce. Additionally, policymakers could utilize these insights to design competency-based educational standards that prioritize critical thinking as a core skill.

At this point, the complexity of the construct of critical thinking can be appreciated, with regards to which a number of inter-related variables emerge to exert a meaningful influence. Alongside this fact, the scarcity of scientific production in relation to this concept should also be considered in the VT setting. As a result, the development and adaptation of instruments to measure critical thinking becomes even more complex, with this being one of the main limitations of the present study. Despite this, the present study can be considered as a positive step forward given that the viability CTDS items [20] was supported for evaluating students' dispositions towards critical thinking, revealing the dimensions to be consistent with definitions and components previously described in the literature. In addition to this limitation, the specific nature of the sample should be considered as it was exclusively comprised of VT students studying in the province of Granada (Spain), although students came from different academic centers.

5. CONCLUSION

The main results of the study include: first, the adaptation of a critical thinking scale, namely, the CTDS, for use with VT students. The evaluation of dispositions toward critical thinking is particularly significant given the growing integration of GenAI tools in educational settings. In this evolving landscape,

students must constantly filter, weigh, and question the outputs provided by such technologies, highlighting the need for validated instruments to assess and foster critical thinking within VT contexts. Second, the reliability, validity, and multifactorial structure of the scale allow for the analysis of VT students' dispositions toward a construct as complex as critical thinking. The examination of validity supported the retention of the 11 original scale items, grouping them according to two dimensions. These dimensions enable two aspects of critical thinking to emerge, with these pertaining to reflective and executive components. These components are consistent and supported at a theoretical level via the definitions, models and empirical studies previously produced by the scientific community.

Despite this, these findings have significant implications for educators and researchers. For educators, the validated CTDS provides a reliable tool to assess students' critical thinking dispositions, enabling targeted interventions to enhance their cognitive and metacognitive skills. This is particularly crucial in VT, where critical thinking directly influences students' professional competencies and adaptability in a rapidly evolving technological environment. For researchers, the study establishes a foundation for exploring the relationship between critical thinking dispositions and other variables, such as academic performance, problem-solving skills, and engagement with GenAI tools. These insights can inform the design of interdisciplinary educational programs that integrate critical thinking as a core component.

As a future line of research, it would be important to analyze the psychometric properties and behavior of the scale at a national level and with a more diverse sample of VT students. This would be useful to corroborate obtained outcomes and could, perhaps, even include a multi-group analysis of outcomes gathered from other countries. Longitudinal studies are recommended to assess the development of critical thinking dispositions over time and to examine the impact of specific educational interventions. Moreover, integrating the CTDS with technological tools, such as learning analytics platforms, could provide dynamic feedback to educators and students, further supporting personalized learning experiences. Further, it would be interesting to continue working on the development of complementary instruments capable of measuring more aspects of these dispositions towards critical thinking. As shown by the present study, it is a highly complex concept influenced by a multitude of factors. These factors, subsequently, influence learning-teaching processes, which in turn impact the capacity to engage in lifelong learning and lead to the full inclusion of individuals in society. Nevertheless, the study has shown that the CTDS is a robust tool for measuring CT dispositions in VT, a critical competence in the age of AI.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review &**E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The present study received approval from the Human Research Ethics Committee at the University of Granada–Spain (reference code: 1858/CEIH/2020).

DATA AVAILABILITY

The data supporting the findings of this study are available upon reasonable request from the corresponding author [JJR-DG], who will seek the required authorization from the funding institution. Due to institutional restrictions, these data cannot be made directly available in a public repository.

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