

Exploring Industry 4.0 Competencies in Career Guidance: Development and Preliminary Evaluation of the Careers 4.0 Skill Assessment Tool

Fotini Vlachaki, Maria Tountopoulou

PROGRESSUS Research & Counselling, Athens, Greece
Email: progressus.projects@gmail.com

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Abstract

The structural changes associated with the Fourth Industrial Revolution (Industry 4.0) have increased the need for vocational education and training (VET) approaches that support the development and recognition of transversal and future-oriented competencies. The present study describes the development and preliminary psychometric evaluation of the Careers 4.0 Skill Assessment Tool, an ICT-based self-report instrument designed to assess 18 competencies related to employability, adaptability, and career development within contemporary labor market conditions. The study also explores a conceptual connection between these competencies, Holland's RIASEC model, and selected ESCO classifications in order to support more competency-oriented career guidance approaches. The instrument underwent a back-translation and cultural adaptation process into four European languages and was administered to a cross-national convenience sample of 303 young participants from five European countries. Exploratory construct evaluation was conducted using Principal Component Analysis (PCA) with Varimax rotation. The retained items demonstrated factor loadings ranging from 0.42 to 0.74, while Cronbach's alpha coefficients ranged from 0.69 to 0.85 across the competency scales. Additional analyses indicated differences in competency scores across gender and country groups. Overall, the findings provide preliminary support for the internal consistency and exploratory construct structure of the instrument and suggest that the Careers 4.0 Skill Assessment Tool may offer a useful resource for career guidance and VET contexts within rapidly changing labor market environments.

Keywords

Industry 4.0, Careers 4.0, Skill Assessment, Psychometric Validation, RIASEC Model, Vocational Education, Soft Skills

1. Introduction

The accelerating digitization and automation of work, commonly referred to as the Fourth Industrial Revolution (Industry 4.0), is transforming the global economy and the nature of work (World Economic Forum, 2016; McKinsey Global Institute, 2018; Vlachaki, 2018). Driven by the integration of physical, digital, and biological technologies, together with broader developments such as green growth, these changes are affecting labor markets and creating new demands for vocational education and training (VET) systems (World Economic Forum, 2016; Vlachaki, 2018). As a result, traditional job roles are evolving, while new forms of work, including teleworking and platform-based employment, continue to expand (World Economic Forum, 2016; McKinsey Global Institute, 2018). Although automation is expected to replace some routine tasks, occupations requiring social interaction, communication, and complex problem-solving are considered less vulnerable to automation (Gray, 2016; Dondi et al., 2021).

These technological changes have also contributed to increasing skills mismatches in labor markets. Despite relatively high unemployment rates, particularly among young people in Europe, many employers report difficulties in finding workers with the required skills (Cedefop, 2018; World Economic Forum, 2014). At the same time, labor market forecasts suggest that many existing skills will change significantly in the coming years, with growing demand for digital, cognitive, and socio-emotional competencies (McKinsey Global Institute, 2018; Dondi et al., 2021). In this context, transversal skills such as adaptability, resilience, communication, and emotional regulation are increasingly recognized as important for employability and career development (Andrews & Higson, 2008; Schulz, 2008). Previous research highlights that these competencies support individuals in responding more effectively to changing working environments and career transitions (Andrews & Higson, 2008; The Adecco Group, 2017).

Despite the growing emphasis on transversal and future-oriented skills, there is still limited agreement regarding how these competencies should be systematically assessed across different European contexts (Cedefop, 2018). To contribute to this discussion, the present study introduces the Careers 4.0 Competencies Framework. Drawing on international frameworks such as ESCO (European Commission, 2019) and the OECD Programme for the International Assessment of Adult Competencies (PIAAC) (OECD, 2016), the framework aims to provide a structured approach for understanding competencies associated with the contemporary labor market. The framework was initially explored through participatory research involving 26 employers, human resource managers, career counselors, and

VET stakeholders across Greece, Italy, Cyprus, and Romania (Dewson et al., 2000; Gibb, 2014). Based on expert feedback regarding labor market relevance, the framework was refined to include 18 competencies grouped into four broad domains: Cognitive and Problem-Solving Skills (e.g., numeracy, creativity), Interpersonal and Leadership Skills (e.g., communication, intercultural competence), Self-Management Skills (e.g., resilience, organisation), and Future-Oriented Technical Skills (e.g., digital skills, environmental awareness, ethical competence) (Council of Europe, 2016; Bacigalupo et al., 2016). These competencies are conceptualized as transferable and potentially developable through lifelong learning processes (Savickas & Porfeli, 2012; Covacevich et al., 2021).

The framework also draws conceptually on Holland's theory of vocational interests (Holland, 1997). Holland's RIASEC model proposes that vocational satisfaction is influenced by the degree of congruence between personality characteristics and work environments (Sidiropoulou et al., 2008). In the context of Industry 4.0, however, career development increasingly involves continuous transitions and changing skill demands. For this reason, the Careers 4.0 framework attempts to connect traditional vocational interest approaches with broader employability and transversal competencies relevant to contemporary labor markets (Savickas & Porfeli, 2012; Sidiropoulou-Dimakakou, 2000). More specifically, the framework theoretically associates the 18 competencies with Holland's typologies and selected ESCO classifications (EC, 2019), with the aim of supporting more flexible and skills-oriented career guidance approaches.

To support the practical application of the framework, the Careers 4.0 Skill Assessment Tool was developed as an ICT-based self-report instrument designed to assess these competencies in career guidance and VET contexts (Chamorro-Premuzic et al., 2017). The development process aimed to balance broad competency coverage with relatively concise measurement in order to reduce respondent burden (Booth & Hughes, 2014). The present study reports the initial development, linguistic adaptation, and preliminary psychometric evaluation of the instrument across a cross-national European youth sample. The broader objective is to contribute to the development of evidence-informed approaches for career guidance and skills profiling within the changing conditions of the Industry 4.0 labor market.

The Present Study

The primary aim of this study is to explore the applicability of the Careers 4.0 Competencies Framework within the context of contemporary labor market changes. More specifically, the study examines the development and initial evaluation of the Careers 4.0 Skill Assessment Tool, an ICT-based instrument designed to assess future-oriented and transversal competencies relevant to Industry 4.0 working environments. The framework also draws conceptually on Holland's RIASEC model by attempting to connect vocational interests with broader employability competencies associated with changing labor market conditions.

To support the practical use of the framework in vocational education and

training (VET) and career guidance contexts, the present study describes the development process, linguistic adaptation, and preliminary psychometric evaluation of the instrument. The broader objective is to contribute to career support practices by providing an exploratory competency profiling tool intended to support career adaptability, self-awareness, and career decision-making in rapidly changing employment environments.

2. Methodology

2.1. Study Design

To explore and refine the theoretical constructs of the Careers 4.0 Competencies Framework, an initial participatory research approach was adopted. Focus groups involving 26 stakeholders—including human resource managers (26%), career counselors (17%), entrepreneurs (13%), and other VET-related professionals—were conducted across Greece, Italy, Cyprus, and Romania (Dewson et al., 2000; Gibb, 2014). Participants evaluated the preliminary framework in terms of perceived labor market relevance and practical applicability. Their qualitative and quantitative feedback informed the refinement of the competency framework.

2.2. Instrument Development and Linguistic Adaptation

The Careers 4.0 Skill Assessment Tool was developed as a closed-ended self-report questionnaire using a 3-point Likert response format. During the initial development stage, an item pool of 123 statements was generated across the 18 competency domains in order to allow item selection and refinement during subsequent psychometric analyses. The relatively large initial pool was intended to ensure adequate coverage of each competency while allowing for the removal of weaker items during the validation process (Dewson et al., 2000; Gibb, 2014; Council of Europe, 2016).

The instrument was originally developed in English and subsequently translated into Greek, Romanian, Italian, and Spanish using a back-translation procedure (Beaton et al., 2000; Brislin, 1970). The adaptation process aimed to support conceptual and linguistic equivalence across participating countries for the target group of young people aged 16 - 29 (Dewson et al., 2000). In each country, the procedure involved three stages: initial translation by a bilingual expert, independent back-translation into English by a second expert, and final review and synthesis by a third expert. Discrepancies were discussed collectively until consensus was achieved (Gibb, 2014; Booth & Hughes, 2014).

The final instrument was designed to retain four items per competency domain in order to achieve adequate construct coverage while maintaining a concise format suitable for career guidance and VET settings.

2.3. Participants

The preliminary psychometric evaluation of the instrument was conducted using a cross-national convenience sample of 303 young participants from five Euro-

pean countries. Eligibility criteria included being between 16 and 29 years of age and providing informed consent to participate in the study. The sample comprised 137 males (45%) and 166 females (56%).

Participants were recruited from educational settings and included high school students, vocational education and training (VET) students, and university students. Country representation included Romania ($n = 75$), Italy ($n = 75$), Greece ($n = 60$), Spain ($n = 53$), and Cyprus ($n = 40$). The age range of participants was 16 - 29 years.

Given the exploratory nature of the study, a convenience sampling approach was adopted to obtain an initial cross-national sample suitable for the preliminary evaluation of the Careers 4.0 Skill Assessment Tool.

2.4. Psychometric Validation Procedures

2.4.1. Content Validity Assessment

Content validity was initially examined using expert evaluation procedures. A panel of 15 subject-matter experts (three from each participating country) reviewed the preliminary items in terms of relevance, clarity, and potential bias using a 3-point Likert scale (Lynn, 1986). Item-Level Content Validity Index (I-CVI) values were calculated, and items with values below 0.79 were considered for revision or removal (Polit & Beck, 2006).

2.4.2. Procedures for Item Analysis and Construct Evaluation

Initial item analysis was planned to evaluate the discriminative power of the statements, with the intent to eliminate items exhibiting poor construct validity or deleterious effects on scale reliability (Fabrigar et al., 1999; Costello & Osborne, 2005).

Exploratory construct evaluation was subsequently conducted using Principal Component Analysis (PCA) with Varimax rotation. Because the instrument was developed around 18 theoretically defined competency domains, PCA was conducted separately for each competency scale in order to examine the internal coherence of the individual constructs. Although PCA primarily represents a data reduction approach rather than a latent variable model, it was considered appropriate for this preliminary exploratory phase of instrument development. Sampling adequacy was assessed using the Kaiser-Meyer-Olkin (KMO) index (Kaiser, 1974) and Bartlett's Test of Sphericity. Factor retention was guided by the examination of eigenvalues and the interpretability of the resulting factor solution. Varimax rotation was selected to facilitate a simpler and more interpretable factor structure. Items with factor loadings below 0.40, low communalities, or substantial cross-loadings (>0.30) were considered for exclusion (Fabrigar et al., 1999; Costello & Osborne, 2005).

2.4.3. Internal Consistency Reliability Assessment

The internal consistency of the retained scales was evaluated utilizing Cronbach's alpha (McNeish, 2018).

2.5. Data Analysis and Scoring

For practical interpretation within career counseling contexts, raw participant scores were rank-ordered and converted into deciles (0 - 10) for automated profiling. Further inferential statistical analyses, specifically independent samples t-tests and Analysis of Variance (ANOVA), were conducted to explore demographic variances based on gender and country of origin.

3. Results

3.1. Framework Refinement

Based on the qualitative and quantitative feedback obtained from the expert focus groups, several theoretical constructs within the preliminary framework were revised. For example, organisational skills and work efficiency were merged into a broader “Organisation” competence, while “Green competence-environmental awareness” was added as a separate competency area. These revisions resulted in a final framework consisting of 18 competencies (Dewson et al., 2000; Gibb, 2014).

3.2. Results of the Content Validity Analysis

The initial item pool consisted of 123 items distributed across the 18 competency domains. Following expert panel evaluation, five items did not meet the pre-defined I-CVI threshold ($I-CVI < 0.79$) and were removed. The resulting 118-item version demonstrated satisfactory content validity, with Scale-Level Content Validity Index (S-CVI) values ranging from 0.95 to 0.99 and Item-Level Content Validity Index (I-CVI) values ranging from 0.80 to 1.00.

3.3. Results of the Item Analysis and Construct Evaluation

Subsequent item analysis and exploratory factor evaluation resulted in the removal of 46 additional items from the 118-item version. Items were excluded because of weak discrimination indices, low factor loadings, low communalities, or substantial cross-loadings. The retained items demonstrated discrimination indices ranging between 0.20 and 0.80 (Fabrigar et al., 1999; Costello & Osborne, 2005). Following this process, the final version of the Careers 4.0 Skill Assessment Tool consisted of 72 items distributed across the 18 competency scales. Each competency scale retained four items, resulting in a balanced structure across the 18 domains and a total of 72 items in the final instrument.

For the exploratory factor analysis procedures, Kaiser-Meyer-Olkin (KMO) values indicated acceptable sampling adequacy across the examined scales (range: 0.69 - 0.79), while Bartlett’s Test of Sphericity was statistically significant in all cases ($p < 0.001$), supporting the suitability of the data for exploratory factor analysis (Fabrigar et al., 1999; Costello & Osborne, 2005).

Based on the predefined item retention criteria, several items were removed due to low factor loadings, low communalities, or substantial cross-loadings. For example, items 33 and 82 were removed from the Communication scale because they demonstrated cross-loading patterns with Emotional Competence. The re-

tained items demonstrated factor loadings ranging from 0.42 to 0.74. Overall, the exploratory analyses provided preliminary support for the internal structure of the individual competency scales (Fabrigar et al., 1999). Across the competency scales, the retained factor solutions were consistent with the expected unidimensional structure of the corresponding competency domains.

3.4. Internal Consistency Results

The instrument demonstrated acceptable to strong internal consistency. Cronbach's alpha coefficients ranged from 0.71 to 0.85 across 17 of the competency scales, with a marginal but acceptable alpha of 0.69 recorded for the Ethical Competence scale (McNeish, 2018). Detailed psychometric information for all 18 competency scales, including factor loading ranges, removed items, and internal consistency coefficients, is presented in Table 1.

3.5. Demographic Variances

Exploratory inferential analyses indicated several demographic differences across competency scores. Male participants reported higher scores in digital skills ($p = 0.009$, Cohen's $d = 0.31$), whereas female participants reported higher scores in emotional competence ($p = 0.034$, Cohen's $d = 0.26$), organisation ($p = 0.029$, Cohen's $d = 0.27$), and literacy ($p = 0.005$, Cohen's $d = 0.35$). According to conventional benchmarks, these effect sizes were small.

In addition, Analysis of Variance (ANOVA) indicated statistically significant differences across participating countries for adaptability ($\eta^2 = 0.08$), communication ($\eta^2 = 0.07$), and environmental awareness ($\eta^2 = 0.10$). Tukey HSD post-hoc comparisons revealed significant differences between several country pairs, with the most consistent differences involving Italy and other participating countries. Given the exploratory nature of the study and the use of a convenience sample, these findings should be interpreted cautiously and may warrant further investigation using larger and more representative samples.

Table 1. Psychometric properties of the careers 4.0 skill assessment tool: construct validity and internal consistency.

Skill Scale	Loading Range	Items Removed	Reason for Removal	Cronbach's α
Adaptability	0.45 - 0.72	3, 32	Low factor loading (<0.40)	0.73
Communication	0.46 - 0.74	33, 82	Low loading & Cross-loading (Emotional)	0.78
Digital Skills	0.43 - 0.71	129, 131	Low factor loading (<0.40)	0.74
Emotional Competence	0.44 - 0.70	51, 80, 96	Low factor loading (<0.40)	0.75
Entrepreneurial Skills	0.46 - 0.73	92, 125	Cross-loading with Innovation	0.71
Environmental Awareness	0.45 - 0.70	None	N/A	0.79
Ethical Competence	0.44 - 0.71	27, 45	Low factor loading (<0.40)	0.69
Innovation	0.48 - 0.74	106	Low factor loading (<0.40)	0.77
Intercultural Competence	0.44 - 0.72	37, 84	Low factor loading (<0.40)	0.71
Literacy	0.42 - 0.71	None	N/A	0.84

Continued

Leadership	0.45 - 0.73	38, 85, 120	Low factor loading (<0.40)	0.76
Numeracy	0.44 - 0.70	None	N/A	0.81
Organisation	0.43 - 0.71	40, 86	Low loading & Low Communalities	0.74
Physical-Manual Skills	0.44 - 0.69	None	N/A	0.85
Problem Solving	0.46 - 0.72	87, 105, 121	Low loading & Cross-loading (Organisation)	0.73
Stress Tolerance	0.45 - 0.71	59	Cross-loading with Emotional Competence	0.77
Teamwork	0.46 - 0.73	83	Low factor loading (<0.40)	0.76
Willingness to Learn	0.47 - 0.74	73	Cross-loading with Teamwork	0.72

4. Discussion

The primary aim of this study was to explore the development and initial evaluation of the Careers 4.0 Skill Assessment Tool within the context of changing labor market demands associated with Industry 4.0 ([International Labour Organization, 2018](#)). The findings provide preliminary support for the applicability of the Careers 4.0 Competencies Framework and suggest that the instrument may offer a useful approach for assessing a range of future-oriented and transversal competencies relevant to vocational education, employability, and career guidance contexts. Overall, the results demonstrated acceptable psychometric characteristics in terms of item performance, exploratory construct evaluation, and internal consistency ([Chamorro-Premuzic et al., 2017](#); [Booth & Hughes, 2014](#)).

One of the main conceptual contributions of the study is the attempt to connect traditional vocational interest approaches with broader employability and transversal competencies relevant to contemporary labor markets. Holland's RIASEC model was originally developed within relatively stable occupational environments ([Sidiropoulou-Dimakakou et al., 2012](#)). However, current labor market conditions are increasingly shaped by digitalization, occupational transitions, and changing skill requirements. In response to these developments, the Careers 4.0 framework attempts to conceptually connect Holland's vocational typologies with 18 future-oriented competencies and selected classifications from the European Skills, Competences, Qualifications and Occupations (ESCO) framework ([EC, 2019](#)). In this way, the framework proposes a more flexible and competency-oriented perspective for career guidance within Industry 4.0 contexts. Although the present study did not empirically examine the structural alignment between the competencies and the RIASEC model, the proposed framework may provide a useful basis for future research exploring the relationship between vocational interests, employability competencies, and emerging occupational demands ([EC, 2019](#); [Sidiropoulou-Dimakakou et al., 2008](#)).

The findings also indicated several demographic differences across competency scores. Male participants reported higher scores in areas such as digital skills and

physical-manual competencies, whereas female participants reported higher scores in emotional competence, organisation, and literacy. Although these findings should be interpreted cautiously due to the exploratory nature of the study and the use of a convenience sample, they appear generally consistent with previous labor market research suggesting gender-related differences in educational pathways, occupational experiences, and skill development opportunities. Previous labor market forecasts have also suggested that socio-emotional and interpersonal competencies are expected to increase in importance in the coming years due to their lower susceptibility to automation processes (Dondi et al., 2021).

The analyses also revealed differences across participating countries, particularly in areas such as adaptability, communication, and environmental awareness. These variations may reflect broader cultural, educational, and labor market differences across European contexts (OECD, 2016; ILO, 2018). Consequently, the findings support the importance of considering local contexts and labor market conditions when designing career guidance and competency development interventions.

From a practical perspective, the Careers 4.0 Skill Assessment Tool may contribute to current efforts aimed at supporting the recognition and discussion of transversal competencies within European career guidance and VET contexts (Cedefop, 2018). The instrument was designed as a career support and self-reflection tool rather than a diagnostic psychological assessment. By providing competency profiles based on self-reported responses, the tool may support career counselors and young people in identifying strengths, development areas, and potential training needs related to contemporary labor market transitions (Savickas & Porfeli, 2012; Covacevich et al., 2021). In this sense, the framework may encourage a broader shift from static job-matching approaches toward more flexible and competency-oriented career development perspectives.

Limitations and Future Research

Several limitations of the present study should be acknowledged. The exploratory construct evaluation relied on Principal Component Analysis (PCA), which primarily represents a data reduction approach rather than a latent variable modeling technique. Although PCA is commonly used during initial stages of instrument development and item reduction, future studies could further examine the internal structure of the instrument using approaches such as Principal Axis Factoring (PAF) or Confirmatory Factor Analysis (CFA). In addition, the study utilized a cross-national convenience sample of 303 participants. While the sample was considered adequate for this preliminary exploratory phase, larger and more representative samples would strengthen the generalizability and stability of the findings (Costello & Osborne 2005). Internal consistency was also examined exclusively through Cronbach's alpha coefficients, and future research may benefit from the inclusion of additional reliability indicators such as McDonald's Omega (ω) (McNeish, 2018).

An additional limitation concerns the cross-national nature of the study. Although the instrument underwent a structured translation and back-translation procedure, measurement invariance across the different language versions was not formally tested. Consequently, cross-country comparisons should be interpreted as exploratory, as observed differences may reflect both substantive variation and potential differences in the interpretation of translated items. Future research should examine measurement invariance across language versions using larger cross-national samples.

Another limitation concerns the conceptual integration of the Careers 4.0 competencies with Holland's RIASEC framework. Although the competencies were theoretically associated with the RIASEC typologies and ESCO classifications, the present study did not empirically examine the circumplex structure of the RIASEC model or the positioning of the competencies within this structure. Furthermore, the decile-based profile indicators generated by the tool should be interpreted as preliminary reference scores intended to support career exploration and guidance rather than formal diagnostic norms. Since the scoring system was developed using a convenience sample, future research should aim to establish broader normative data using more representative sampling procedures. Additional longitudinal studies may also help examine the relationship between competency profiles, career adaptability, and future educational or employment outcomes.

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Further information regarding the project outcomes and the digital version of the Careers 4.0 Skill Assessment Tool can be found at <https://www.progressus-rc.gr/eu-projects/careers-4-0/>.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix: Mapping of Careers 4.0 Competencies to RIASEC and ESCO

<i>Competency</i>	<i>Associated RIASEC Type(s)</i>	<i>ESCO Occupational Categories</i>
Adaptability	R, I, A, S, E, C	Cross-cutting competency across occupational sectors
Communication	S, E	Teaching Professionals; Health Professionals; Customer Service Workers; Sales and Services Workers
Digital Skills	R, I, A, S, E, C	ICT Professionals; Information and Communications Technicians; Science and Engineering Professionals
Emotional Competence	S	Health Professionals; Social and Cultural Professionals; Personal Care Workers
Entrepreneurial Skills	E	Administrative and Commercial Managers; Business Professionals; Sales and Services Workers
Environmental Awareness	R, I	Agricultural, Forestry and Fishery Workers; Environmental Protection Professionals; Science and Engineering Professionals
Ethical Competence	S, E, C	Health Professionals; Legal and Social Professionals; Administrative Managers
Innovation	I, A	Science and Engineering Professionals; ICT Professionals; Creative Occupations
Intercultural Competence	A, S	Teaching Professionals; Social and Cultural Professionals; Customer Service Occupations
Literacy	A, S, E	Teaching Professionals; Social and Cultural Professionals; Business and Administration Occupations
Leadership	E	Senior Officials; Managers; Business and Administration Professionals
Numeracy	E, C	Business Professionals; Financial Analysts; Administrative Occupations
Organisation	R, I, E, C	Administrative Occupations; Managers; ICT and Technical Occupations
Physical-Manual Skills	R	Engineering Technicians; Skilled Trades; Manufacturing Occupations
Problem Solving	I, C	Science and Engineering Professionals; ICT Professionals; Business Professionals
Stress Tolerance	S, E	Health Professionals; Customer Service Workers; Managers
Teamwork	A, S, E, C	Cross-sector occupational competency
Willingness to Learn	R, I, A, S, E	Cross-sector occupational competency