Development and Preliminary Validation of the Future Readiness Competencies Assessment Instrument (FRCAI) for Higher Education

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Abstract

Higher education institutions need credible ways to examine how students and young professionals perceive their preparedness for technological, economic and societal uncertainty. Existing competency frameworks are valuable but rarely integrated into a single multidimensional instrument. This study presents the development and preliminary validation of the 22-item Future Readiness Competencies Assessment Instrument (FRCAI), covering five proposed domains. Development involved literature review, comparative framework analysis, expert review and pilot testing. The instrument was administered to 270 respondents recruited through partner higher education institutions in Slovenia, Austria and North Macedonia. Overall internal consistency was high (Cronbach's α = .892), while domain coefficients ranged from .598 to .805. Parallel analysis favoured three factors; a theory-constrained five-factor exploratory solution showed substantial cross-domain overlap. Confirmatory factor analysis of the prespecified five-factor model produced mixed fit (CFI = .859, TLI = .837, RMSEA = .071, SRMR = .063). Perceived preparedness was highest in Digital, Data and Media Competence and lowest in Financial and Economic Resilience. The results demonstrate the feasibility of the FRCAI and provide a transparent basis for item refinement, independent validation and curriculum-oriented diagnostic use, rather than definitive confirmation of a stable five-factor model.

Keywords: future readiness; competence assessment; higher education; self-assessment; curriculum evaluation

1. Introduction

Higher education is being reshaped by technological, economic, environmental and geopolitical change. Artificial intelligence, automation, demographic shifts and climate instability are altering labour markets and the capabilities graduates need in uncertain professional environments (European Commission, 2020; OECD, 2023; UNESCO, 2021; World Economic Forum, 2023). These conditions echo accounts of risk and continuous social change (Beck, 1992; Bauman, 2000) and increase the need for higher education to assess not only disciplinary knowledge but also students' perceived preparedness to anticipate, adapt and act responsibly under uncertainty.

International organisations have responded with competency frameworks including DigComp, EntreComp, GreenComp, the EU/OECD-INFE Financial Competence Framework for Adults, the OECD Learning Compass 2030 and UNESCO's Futures Literacy initiative. Although developed for different priorities, these frameworks converge around capabilities for adaptation, collaboration, responsible decision-making and future-oriented action (Bacigalupo et al., 2016; Bianchi et al., 2022; Carretero et al., 2017; European Union and OECD, 2022; OECD, 2019; UNESCO, 2021; Wiek et al., 2011).

These frameworks and their associated measures remain largely domain specific. A university may draw on several of them at once and still lack a single way to examine students' broader perceived preparedness. Existing assessment approaches likewise tend to isolate individual competence areas rather than treat future readiness as a multidimensional construct (Le Deist and Winterton, 2005; Mulder, 2014; Rychen and Salganik, 2003).

This fragmentation sits within a broader competence tradition that conceptualises effective performance as an integration of knowledge, skills, attitudes and values rather than a single ability (McClelland, 1973; Boyatzis, 1982; Spencer and Spencer, 1993; Weinert, 2001). Contemporary higher education extends this view to adaptability, ethical judgement, digital capability and anticipatory thinking, but integrated assessment instruments remain limited.

The Future Readiness Competencies Assessment Instrument (FRCAI) was developed to address this gap. It does not propose another competency framework; instead, it translates convergent dimensions from established frameworks into a single self-assessment architecture intended for competence diagnosis, curriculum evaluation and longitudinal research.

This study introduces the FRCAI and reports its preliminary empirical evaluation in a cross-national higher education project context. Three questions guide the inquiry. First, how can future readiness competencies be operationalised as an integrated, multidimensional construct? Second, how can contemporary international frameworks be translated into a unified assessment design? Third, what does the baseline application reveal about respondents' self-assessed preparedness for complex and uncertain futures?

The article brings previously separate competence traditions into one assessment design, documents the instrument-development process and evaluates the reliability and preliminary structural evidence of the resulting measure in a sample recruited through three higher education institutions.

2. Literature Review

2.1. Competence-Based Education and Future Readiness

Competence-based education has shifted attention from knowledge transmission towards capabilities for effective action, lifelong learning and adaptation (McClelland, 1973; Boyatzis, 1982; Spencer and Spencer, 1993; Weinert, 2001). In higher education, this includes preparing graduates for professional and societal challenges that may not yet be fully defined (Aoun, 2017).

The graduate capability approach similarly emphasises broad intellectual and personal capacities for dealing with ambiguity and change, extending competence beyond narrow employability or occupation-specific skills (Barnett, 1994; Stephenson, 1998).

Competence-focused higher education therefore aligns learning outcomes with critical inquiry, ethical judgement, problem solving and adaptability (Biggs and Tang, 2011; Knight and Yorke, 2003). Against accelerating technological and societal change, future readiness can be understood as an integrative perspective combining knowledge, skills and dispositions needed to anticipate and respond to emerging conditions.

While the concept of "future readiness" appears frequently in policy reports, it lacks a consensus operational definition. Research frequently treats individual skills in isolation, leaving a gap in integrated measurement models suitable for university-wide assessment.

2.2. International Competency Frameworks

Over the past two decades, several international organisations have developed competency frameworks addressing different dimensions of preparedness for future societal and professional challenges. Although each framework emerged from a distinct policy context, together they provide a comprehensive foundation for understanding Future Readiness Competencies.

DigComp conceptualises digital competence through information literacy, communication, content creation, safety and problem solving, including critical and responsible digital participation (Carretero et al., 2017; Vuorikari et al., 2022). EntreComp frames entrepreneurship as a transferable capacity involving creativity, opportunity recognition, value creation, initiative and action rather than business creation alone (Bacigalupo et al., 2016). GreenComp links sustainability competence with systems thinking, futures thinking, critical reflection and collective action (Bianchi et al., 2022). The OECD Learning Compass 2030 emphasises learner agency, transformative competencies and responsible action, including the capacity to create value and manage tensions under uncertainty (OECD, 2019). The EU/OECD-INFE Financial Competence Framework for Adults identifies knowledge, behaviours and attitudes required for sound personal financial decisions, including planning, risk management, digital finance and financial well-being (European Union and OECD, 2022). It provides the direct international reference point for the FRCAI domain of Financial and Economic Resilience. UNESCO's Futures Literacy initiative treats anticipation as a learnable capability through which alternative futures can inform present decisions and expose assumptions about change (Miller, 2018; UNESCO, 2021).

Across these frameworks, recurring themes include anticipation, responsibility, collaboration, digital competence, financial decision-making and adaptive learning. Sustainability competence research adds systems, normative, strategic and interpersonal dimensions (Wiek et al., 2011). This convergence informed the proposed five-domain architecture of the FRCAI. Table 1 summarises the principal frameworks and their contribution to each domain.

Table 1. International Competency Frameworks and their conceptual contributions to the development of the FRCAI

Framework	Primary focus	Competence contribution to FRCAI	Related FRCAI domain
DigComp 2.2	Digital competence, data literacy, safety, communication and problem-solving	Supports operationalisation of digital participation, data-informed decision-making, cybersecurity and responsible use of digital technologies	Digital, Data and Media Competence
OECD Learning Compass 2030	Transformative competencies, responsibility, agency, value creation	Supports the integrative understanding of adaptive learning, responsible action and future-oriented competence	Future and Anticipatory Competence; Leadership, Communication and Collaborative Competence
GreenComp	Sustainability competence, systems thinking, futures thinking, collective action	Supports inclusion of long-term thinking, sustainability awareness and system-oriented reflection	Future and Anticipatory Competence
EntreComp	Creativity, opportunity recognition, value creation, entrepreneurial action	Supports operationalisation of innovation, entrepreneurship and implementation of ideas	Innovation and Entrepreneurial Competence
UNESCO Futures Literacy	Anticipation, alternative futures, use of the future for present decisions	Supports operationalisation of futures thinking, anticipation and reflection under uncertainty	Future and Anticipatory Competence
EU/OECD-INFE Financial Competence Framework for Adults	Personal finance, planning, risk, digital finance and financial well-being	Supports operationalisation of financial decision-making, resilience under economic uncertainty and understanding of digital finance	Financial and Economic Resilience

2.3. Fragmentation of Competence Assessment

Despite substantial progress in competence research, assessment practices remain considerably more fragmented than the theoretical frameworks upon which they are based. Most existing instruments have been developed to evaluate individual competence domains, such as digital competence, entrepreneurial capability or sustainability literacy, reflecting the specialised objectives of the frameworks from which they originate (Le Deist and Winterton, 2005; Mulder, 2014).

While domain-specific measures offer valuable diagnostic depth, they often constrain institutional capacity to evaluate graduates' broader, cross-disciplinary readiness. Taken together, these limitations mean that existing frameworks provide only limited insight into graduates' overall preparedness for complex and uncertain professional environments. Universities increasingly implement multiple competency frameworks simultaneously, yet rel-

atively few assessment instruments provide an integrated perspective capable of capturing the interaction between complementary competence domains.

The resulting fragmentation presents both conceptual and methodological challenges. Conceptually, it obscures the interdependence of competencies that are increasingly required in professional practice. Methodologically, it complicates curriculum evaluation by requiring institutions to administer multiple independent assessment instruments rather than a coherent multidimensional measure.

These limitations suggest the need for assessment approaches capable of integrating competencies derived from established international frameworks while preserving their theoretical distinctiveness.

2.4. Research Gap

The review of competence theory and international competency frameworks reveals a clear gap within contemporary higher education research. Considerable attention has been devoted to conceptualizing individual competence domains, yet comparatively little research has focused on integrating these perspectives into multidimensional assessment instruments applicable across disciplinary contexts.

Existing studies therefore provide important theoretical foundations but offer limited guidance regarding how complementary competency frameworks may be synthesised into a coherent assessment architecture suitable for educational evaluation and curriculum development. This gap is particularly important because higher education institutions require valid and reliable assessment instruments capable of evaluating multidimensional competence development beyond individual competency frameworks.

The FRCAI addresses this gap by operationalising competencies repeatedly identified across established international frameworks within a coherent multidimensional self-assessment model. The aim is methodological integration rather than the introduction of a new competency framework.

3. Development of the Future Readiness Competencies Assessment Instrument

3.1. Instrument Development Process

The FRCAI was developed through a transparent multi-stage process intended to support theoretical coherence and practical applicability in higher education, following established recommendations for scale development (Boateng et al., 2018; DeVellis and Thorpe, 2021). Rather than adapting one existing questionnaire, the instrument was constructed to integrate competence areas that are usually assessed separately.

The development process comprised four sequential phases (Figure 1). First, a comprehensive review of competence theory and recent literature identified the principal competence domains associated with preparedness for future societal and professional challenges. Second, internationally recognised competency frameworks—including DigComp, EntreComp, GreenComp, the OECD Learning Compass 2030 and UNESCO's Futures Literacy initiative—were comparatively analysed to identify recurring competence dimensions across different theoretical traditions.

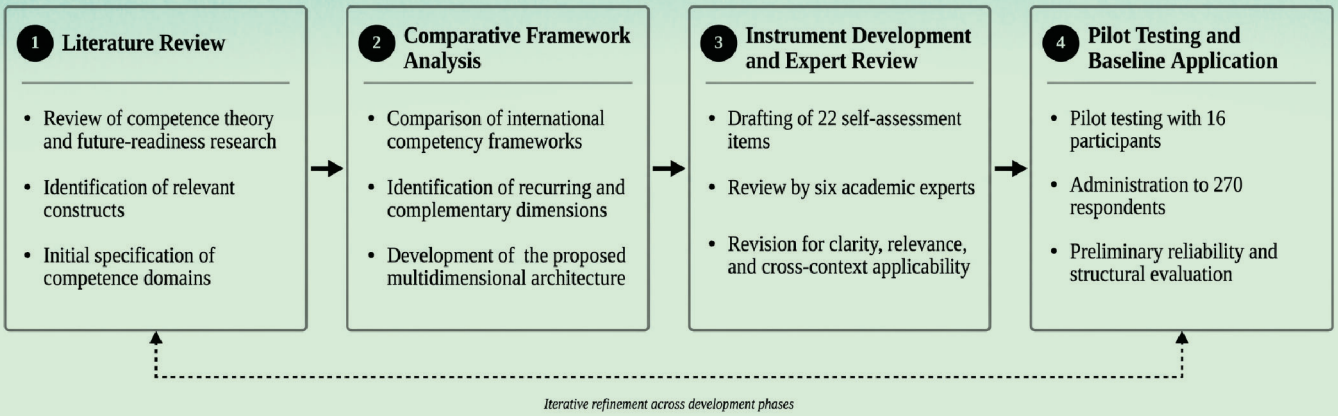


Figure 1. Four-phase development process of the Future Readiness Competencies Assessment Instrument

Third, questionnaire items were generated by operationalizing the identified constructs into measurable indicators suitable for self-assessment in higher education. The preliminary instrument was subsequently reviewed by academic experts from three participating higher education institutions in Slovenia, Austria and North Macedonia. Their feedback resulted in revisions concerning item wording, conceptual clarity and content coverage.

Finally, the revised questionnaire was pilot tested with 16 students representing the participating institutions to evaluate comprehensibility, response consistency and administration procedures before the baseline study.

3.2. Identification of Competence Domains

The literature review and comparative framework analysis demonstrated substantial conceptual convergence across international competency frameworks despite their different educational origins. Rather than reproducing the structure of any single framework, the instrument was organized around competence domains that consistently appeared across multiple sources.

Five domains were identified as representing complementary dimensions of Future Readiness Competencies:

- Future and Anticipatory Competence;
- Digital, Data and Media Competence;
- Financial and Economic Resilience;
- Innovation and Entrepreneurial Competence;
- Leadership, Communication and Collaborative Competence.

Taken as a set, the five domains cover technological, economic and societal aspects of preparedness while retaining the multidimensional view of competence found in contemporary higher education research.

3.3. Operationalisation of Competence Domains

Each competence domain was operationalised through multiple questionnaire items derived from theoretical constructs identified during the literature review and comparative analysis of international competency frameworks.

The final structure of the instrument and allocation of questionnaire items to domains are summarised in Table 2.

Table 2. Structure of the Future Readiness Competencies Assessment Instrument

FRCAI domain	Variables	Number of items	Main construct measured
Future and Anticipatory Competence	Q2a–Q2d	4	Futures thinking, anticipation, strategic foresight and reflection on long-term change
Digital, Data and Media Competence	Q3a–Q3e	5	Digital competence, media literacy, AI ethics, cybersecurity and data-informed decision-making
Financial and Economic Resilience	Q4a–Q4d	4	Financial capability, economic decision-making and resilience under uncertainty
Innovation and Entrepreneurial Competence	Q5a, Q5c, Q5d	3	Creativity, innovation processes, entrepreneurial implementation and interdisciplinary problem-solving
Leadership, Communication and Collaborative Competence	Q5b, Q6a–Q6e	6	International teamwork, critical media evaluation, strategic digital communication, professional digital identity and collaboration

Note. Q5b appeared in questionnaire section Q5 but was assigned to Leadership, Communication and Collaborative Competence on the basis of expert-panel content review. Q3e and Q6e were identically worded in the baseline survey and were administered in separate sections; Q3a and Q6a also covered closely related media-evaluation content. These overlaps were retained to preserve the instrument as administered and are treated as priorities for revision.

The final version of the instrument contains five competence domains represented by twenty-two self-assessment items. All items employ a common Likert-type response format, enabling comparison across domains while maintaining conceptual consistency throughout the questionnaire.

3.4. Expert Review and Pilot Testing

Content validation formed an integral part of the instrument development process. The preliminary questionnaire was independently reviewed by a panel of six academic experts from the three participating institutions with relevant expertise in higher education, curriculum development and fields represented in the instrument. Using a structured expert-review procedure, the panel assessed item relevance, clarity, international applicability and alignment between the proposed constructs, international frameworks and questionnaire items.

Based on expert feedback, several items were refined to improve clarity and reduce conceptual overlap. Particular attention was devoted to ensuring that the instrument could be applied across different higher education systems without relying on country-specific terminology.

The revised instrument was subsequently pilot tested with 16 students representing the participating higher education institutions. Based on participant feedback and expert review, several wording modifications were introduced to improve clarity before the baseline survey. The pilot study confirmed the comprehensibility of the questionnaire, identified only minor linguistic adjustments and demonstrated that the administration procedure was suitable for larger-scale implementation.

3.5. Conceptual Architecture of the Instrument

The FRCAI is conceptualised as an integrative self-assessment instrument in which five theoretically proposed domains jointly describe a profile of perceived future readiness (Figure 2). The diagram is a conceptual map; it does not represent causal ordering or establish that the domains are empirically independent.

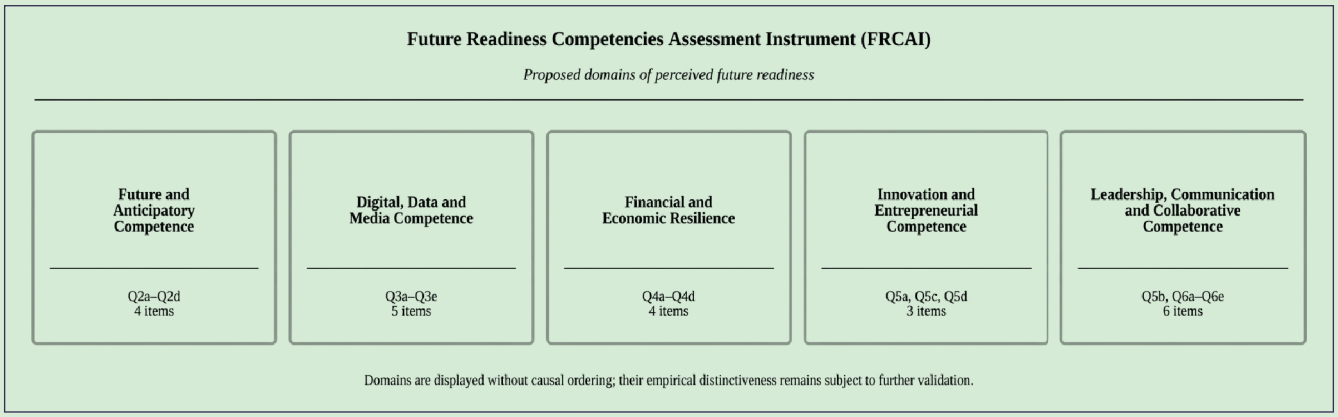


Figure 2. Proposed five-domain conceptual architecture of the Future Readiness Competencies Assessment Instrument (FRCAI)

3.6. Positioning of the FRCAI

The FRCAI does not replace existing competency frameworks. It provides an assessment architecture through which convergent dimensions from those frameworks can be examined within a common analytical structure.

Whereas frameworks such as DigComp, EntreComp and GreenComp primarily define educational objectives, the FRCAI operationalises selected convergent dimensions for empirical research, curriculum evaluation and longitudinal monitoring in higher education.

Its novelty therefore lies less in proposing new competence domains than in showing how established perspectives can be translated into one coherent approach to multidimensional assessment.

4. Methodology

4.1. Research Design

The instrument was developed through a systematic four-phase process involving literature review, comparative framework analysis, expert review and pilot testing. In doing so, we followed standard guidelines for scale development (Boateng et al., 2018). The research formed part of the Erasmus+ project [details withheld for anonymous review], which seeks to strengthen future-oriented competencies among university students through interdisciplinary educational innovation.

The four development phases are described in detail above and summarised in Figure 1.

The primary objective of the present study was not comprehensive psychometric validation, but rather to demonstrate the instrument's conceptual applicability, examine its practical implementation and establish an empirical baseline for future validation studies. This baseline analysis represents an initial step in the continuing development of the FRCAI and provides a foundation for more extensive psychometric validation in future research.

4.2. Participants

The questionnaire was distributed through three partner higher education institutions in North Macedonia, Slovenia and Austria to the project's target population of students and young professionals.

Data collection produced 270 submitted questionnaires. Complete responses across all 22 FRCAI items were available for 241 participants, while domain-specific analytical samples ranged from 241 to 248. Current-status and permanent-residence data were available for 223 respondents: 153 (68.6%) identified as students, 56 (25.1%) as employed, 4 (1.8%) as self-employed professionals, 5 (2.2%) as job seekers and 5 (2.2%) selected other; 117 (52.5%) reported residence in Slovenia, 63 (28.3%) in North Macedonia, 12 (5.4%) in Austria and 31 (13.9%) in other countries. Across all 270 questionnaires, business and management accounted for 43%, economics 16%, communication and media 9%, finance 7%, information technology 4%, leadership 1%, data science 1% and other fields 18%.

The sample included several disciplinary and employment backgrounds, but business, economics and finance together accounted for 66% of respondents. No claim of national or disciplinary representativeness is made; subsequent validation requires more balanced samples.

4.3. Instrument

The FRCAI comprises 22 Likert-type self-assessment items organised into five proposed domains. The broader survey contained 17 questionnaire sections and 37 variables, including contextual, demographic and open-ended questions; only Q2a–Q6e entered the psychometric analyses.

The domains include:

- Future and Anticipatory Competence;
- Digital, Data and Media Competence;
- Financial and Economic Resilience;

- Innovation and Entrepreneurial Competence;
- Leadership, Communication and Collaborative Competence.

All FRCAI items used the same five-point response scale, facilitating comparison between domains. The instrument assesses respondents' perceived preparedness; it is not an objective test of demonstrated competence.

Q3e and Q6e were identically worded and administered in separate sections, while Q3a and Q6a addressed closely related aspects of media evaluation. Both duplicated or overlapping item pairs were retained to preserve the instrument as administered, but they are treated as limitations and priorities for revision.

4.4. Data Collection

The questionnaire was administered online through the 1KA survey platform from 6 November 2025 to 6 February 2026. The survey interface used the project's operational title, withheld here to preserve anonymous review.

Participation was voluntary and anonymous. Respondents were informed that the baseline survey would be used to inform curriculum development within the project and that their responses would be treated anonymously.

All submitted questionnaires were screened prior to analysis. Questionnaires containing item-level missing responses were retained for descriptive analyses where appropriate, whereas analyses involving the complete instrument were conducted using complete cases only.

4.5. Data Analysis

The empirical analysis focused on describing respondents' perceived Future Readiness Competencies across the five competence domains.

Descriptive statistics—frequencies, means, standard deviations and score ranges—were calculated for each item. Domain scores were computed as arithmetic means. Means, standard deviations and Cronbach's alpha coefficients were calculated among respondents with complete data for all items in the relevant domain (domain-wise complete-case analysis), producing analytical samples of n = 241–248.

Before analysis, the 1KA export code −99, which represented response category 5 ("strongly agree"), was recoded to 5; −3 represented an interrupted or skipped response and was treated as missing. Analyses involving all 22 items—including the descriptive overall coefficient, exploratory factor analysis and confirmatory factor analysis—used complete cases (n = 241).

Domain-level findings are presented in Table 3 and Figure 3. Full factor-retention results, exploratory pattern coefficients, confirmatory loadings and latent-factor correlations are provided in Supplementary Material S1.

4.6. Ethical Considerations

Participation was fully voluntary and anonymous. Before completing the questionnaire, participants received information about the purpose of the study and the confidentiality of the collected data. No personally identifiable information was collected, and respondents were free to discontinue participation at any stage without consequence.

The present article reports a secondary scientific analysis of the anonymised baseline dataset. Under the applicable regulations of the participating institutions, formal ethics committee review was not required. The analysis complied with institutional requirements concerning confidentiality, voluntary participation and responsible research data management.

4.7. Reliability and Validation Strategy

Validation was treated as an accumulation of evidence supporting the intended interpretation and use of scores, rather than as a single statistical event (Messick, 1995). The present study therefore examines content development, internal consistency and preliminary structural evidence while avoiding claims of comprehensive psychometric validation.

Content evidence was developed through literature review, comparative analysis of international competency frameworks, review by six academic experts and pilot testing with 16 participants. These stages followed established guidance for scale construction and early validation (Boateng et al., 2018; DeVellis and Thorpe, 2021).

Cronbach's alpha coefficients were calculated for each proposed domain and across all 22 items (Table 3). The coefficient across all items is reported descriptively and is not interpreted as evidence that FRCAI is unidimensional or that a single total score is warranted.

Table 3. Internal consistency reliability and domain mean scores of the Future Readiness Competencies Assessment Instrument (FRCAI)

Competence domain	Items	n	Mean (M)	SD	Cronbach's α
Future and Anticipatory Competence	4	248	3.54	0.64	.598
Digital, Data and Media Competence	5	245	3.77	0.63	.750
Financial and Economic Resilience	4	244	3.41	0.75	.752
Innovation and Entrepreneurial Competence	3	242	3.49	0.74	.669
Leadership, Communication and Collaborative Competence	6	241	3.71	0.66	.805
All 22 items (descriptive only)	22	241	3.61	0.52	.892

Note. Domain means, standard deviations and Cronbach's alpha coefficients were calculated using respondents with complete data on every item in the respective domain (domain-wise complete-case analysis). Before analysis, −99 was recoded to response category 5 and −3 was treated as missing. The coefficient across all 22 items and all factor analyses used complete cases across the full item set (n = 241). The overall coefficient is descriptive and does not establish one-dimensionality.

Across all 22 items, Cronbach's α was .892. Domain coefficients were .805 for Leadership, Communication and Collaborative Competence, .752 for Financial and Economic Resilience, .750 for Digital, Data and Media Competence, .669 for Innovation and Entrepreneurial Competence and .598 for Future and Anticipatory Competence. The two lower coefficients warrant caution and further item development, particularly because those domains contain only three and four items. The identical wording of Q3e and Q6e and the conceptual overlap between Q3a and Q6a may also increase cross-domain covariance and weaken domain distinctiveness.

Future revisions should expand and sharpen the anticipatory and innovation domains, remove or differentiate duplicated and overlapping items, and test theoretically aligned

content from established futures and sustainability competence measures (Ahvenharju et al., 2021; Redman and Wiek, 2021).

Independent samples are needed to reassess the structure, convergent and discriminant validity, measurement invariance, score responsiveness and predictive validity across educational, disciplinary and cultural settings.

4.8. Exploratory and Confirmatory Factor Analysis

Factor analyses used the 241 complete cases. Because this was a preliminary evaluation, the five-point items were treated as approximately continuous and analysed using Pearson correlations. Exploratory factor analysis used principal-axis factoring with oblimin rotation (Fabrigar et al., 1999). Horn's parallel analysis used 2,000 random normal datasets and the 95th-percentile criterion to determine the empirically supported number of factors (Horn, 1965). Sampling adequacy was high (KMO = .881), and Bartlett's test of sphericity was significant, $\chi^2(231) = 1851.93$, $p < .001$.

Parallel analysis retained three factors: the first three observed eigenvalues (7.015, 1.653 and 1.561) exceeded the corresponding 95th-percentile random eigenvalues (1.684, 1.556 and 1.467), whereas the fourth and fifth did not. Because the conceptual model specified five domains, a theory-constrained five-factor principal-axis solution was also examined. Its extracted communalities corresponded to 45.0% of total item variance, but the pattern did not reproduce the five domains cleanly. Financial items formed the clearest cluster; innovation items grouped with Q5b, digital and communication items divided across several factors, and the future-oriented items did not form a strong separate factor (Supplementary Tables S1–S2).

The prespecified five-factor model was then evaluated by maximum likelihood using the sample covariance matrix, with five correlated factors and one marker loading fixed per factor. Fit was mixed: $\chi^2(199) = 436.45$, $p < .001$; CFI = .859; TLI = .837; RMSEA = .071; SRMR = .063. Standardised loadings ranged from .350 to .786, while latent-factor correlations ranged from .546 to .833 (Supplementary Tables S3–S4). The model therefore received only partial support. Because EFA and CFA were conducted on the same dataset, the CFA is a preliminary model evaluation rather than independent confirmation. Treating ordinal items as continuous is an additional limitation; future work should use polychoric correlations and robust ordinal estimators (Brown, 2015).

5. Results

5.1. Sample Characteristics

The baseline dataset contained 270 submitted questionnaires. Complete responses on all 22 FRCAI items were available for 241 respondents; status information was available for 223. The sample was predominantly student-based but also included employed and other young professionals.

Business and management represented 43% of the sample, followed by economics (16%), communication and media (9%), finance (7%), information technology (4%), leadership (1%), data science (1%) and other fields (18%). Business, economics and finance together accounted for 66%, limiting generalisability beyond related disciplinary settings.

The data are therefore suitable for a preliminary application of FRCAI across several backgrounds, but not for nationally representative or discipline-balanced conclusions.

Effective sample sizes varied across domains because domain-wise complete cases were used (Table 3).

5.2. Descriptive Results by Competence Domain

The domain labels retain the terminology of the international frameworks, but the scores reported below represent self-assessed perceived preparedness rather than demonstrated competence.

Future and Anticipatory Competence. Respondents reported a moderate level of perceived preparedness in the Future and Anticipatory Competence domain, with an average score of 3.54. The highest scores were observed for the ability to imagine multiple possible futures and anticipate technological disruption, whereas familiarity with formal foresight methods such as scenario planning or backcasting received comparatively lower evaluations. These findings suggest that respondents are relatively confident in future-oriented thinking but possess less experience with structured futures methodologies.

Digital, Data and Media Competence. The Digital, Data and Media Competence domain obtained the highest mean score (M = 3.77), indicating comparatively high perceived preparedness regarding digital technologies, information evaluation and the responsible use of artificial intelligence. Respondents reported particularly high confidence in evaluating online information, understanding the ethical implications of artificial intelligence and using digital collaboration tools. Comparatively lower scores were observed for cybersecurity practices and data-driven decision making, indicating potential areas for further curricular development.

Financial and Economic Resilience. Respondents reported the lowest level of perceived preparedness in the Financial and Economic Resilience domain (M = 3.41). Respondents were more confident in basic financial decision-making than in items concerning fintech and cryptocurrencies. The pattern identifies financial and economic resilience as a potential area for curricular attention, but the self-report design does not establish the extent to which these results reflect actual curriculum provision or objective financial competence.

Innovation and Entrepreneurial Competence. The Innovation and Entrepreneurial Competence domain achieved a mean score of M = 3.49, indicating a moderate level of perceived preparedness. Respondents expressed relatively strong confidence in interdisciplinary problem-solving and in translating ideas into practical initiatives, while familiarity with structured innovation methods was rated less positively. This contrast suggests a potential distinction between general confidence in innovative action and familiarity with formal innovation methodologies.

Leadership, Communication and Collaborative Competence. The Leadership, Communication and Collaborative Competence domain achieved the second-highest mean score (M = 3.71), indicating a high level of perceived preparedness in strategic communication, digital identity management and international collaboration. Respondents reported strong confidence in strategic digital communication, managing their professional digital identity and collaborating in international environments. Leadership in multicultural teams received comparatively lower evaluations, suggesting opportunities for strengthening intercultural leadership capabilities through higher education curricula.

5.3. Comparative Analysis Across Competence Domains

To facilitate comparison across competence domains, average scores were calculated for each of the five dimensions of the FRCAI (Table 3). Table 3 summarises the descriptive statistics and internal consistency coefficients for each competence domain and serves as the basis for the comparative analysis presented below. Digital, Data and Media Competence achieved the highest overall mean score (M = 3.77), followed by Leadership, Communication and Collaborative Competence (M = 3.71). Future and Anticipatory Competence occupied an

intermediate position (M = 3.54), followed by Innovation and Entrepreneurial Competence (M = 3.49), whereas Financial and Economic Resilience received the lowest evaluation (M = 3.41).

Although differences between domains were modest, respondents reported uneven levels of perceived future readiness. Digital participation, communication and collaboration were rated more strongly than financial resilience and structured innovation or foresight methodologies. Figure 3 presents this comparative profile.

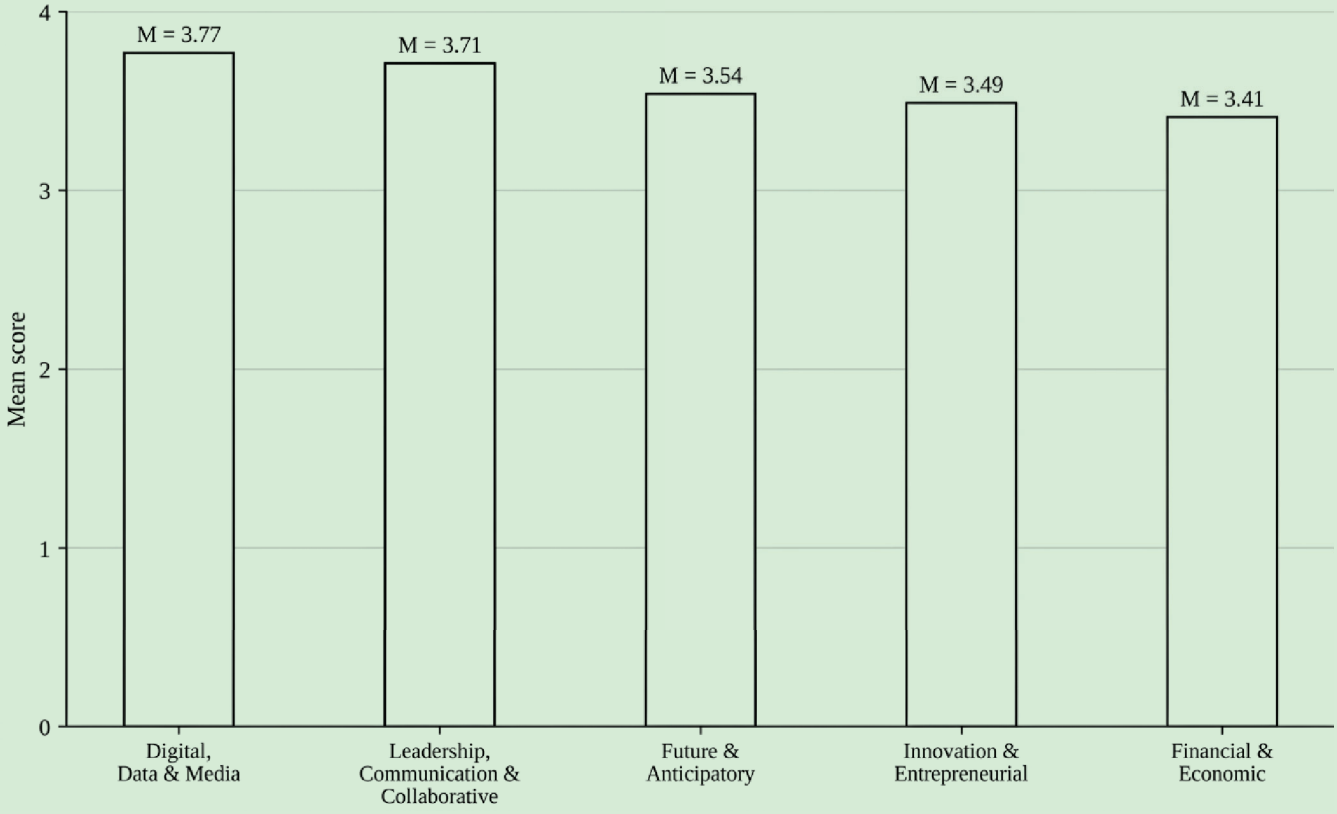


Figure 3. Mean scores across the five proposed FRCAI domains

Note. Items were rated from 1 to 5. The y-axis is displayed from 0 to 4 because all observed domain means were below 4; exact means are printed above the bars.

The five proposed domain means are relatively close, and none indicates critically low perceived preparedness. These descriptive differences are not evidence of teaching effectiveness or causal effects of curriculum. They identify financial resilience and structured innovation or foresight methods as areas for closer curricular investigation.

6. Discussion

6.1. Future Readiness as an Integrative Educational Construct

The results support the broad proposition that perceived future readiness is multidimensional, but they do not establish the proposed five-domain model as a stable measurement structure. Parallel analysis favoured three factors, the theory-constrained five-factor EFA showed substantial overlap and CFA fit was mixed. Domain means must therefore be interpreted as provisional profiles based on the prespecified content architecture, not as scores from five fully validated independent scales.

The empirical overlap is substantively understandable: digital participation, communication, collaboration and innovation often co-occur in educational and professional practice. It is also partly attributable to item design. Q3e and Q6e were identically worded, Q3a and Q6a were closely related, and the Leadership, Communication and Collaborative domain combined several distinct types of content. The next instrument version should resolve these overlaps before stronger claims of discriminant validity are made.

FRCAI nevertheless offers a transparent way to examine several competence traditions within one assessment design. The present study supports the feasibility of that integrative approach while showing that the proposed domain boundaries require conceptual and psychometric refinement.

6.2. Implications for Curriculum Design and Higher Education Policy

For curriculum design, the profile is best treated as a diagnostic prompt rather than evidence of objective mastery or institutional effectiveness. Lower ratings for financial resilience and specific foresight or innovation-method items can guide further needs assessment and targeted learning design. Repeated administration could support evaluation over time only after score stability, responsiveness and measurement invariance have been established (Aoun, 2017; Barnett, 2018).

A refined multidimensional self-assessment could complement course-level learning outcomes by adding a broader account of how learners perceive their preparedness across several future-oriented areas.

Potential curricular responses include practice-oriented financial literacy activities, foresight workshops and interdisciplinary innovation challenges. The present cross-sectional self-report data do not show that these interventions would be effective; their effects would need to be evaluated through longitudinal and performance-based designs.

6.3. Methodological Contribution, Limitations and Future Research

Methodologically, the study makes the route from framework synthesis to item development, expert review, pilot testing and preliminary structural evaluation explicit. It also reports evidence that challenges, rather than merely confirms, the proposed architecture, allowing the instrument to be revised transparently.

The study has several important limitations. EFA and CFA were conducted on the same sample; five-point items were treated as continuous; the sample was concentrated in business-related fields; and two items were duplicated verbatim across domains while two others overlapped closely. These features constrain claims about factor retention, discriminant validity and generalisability.

Future research should revise the overlapping items, broaden the anticipatory and leadership content, and test the resulting instrument in larger independent samples using polychoric correlations and robust ordinal CFA. It should also examine convergent and discriminant validity, measurement invariance, test–retest reliability, responsiveness to educational interventions and predictive validity.

FRCAI captures perceived preparedness rather than demonstrated competence. Future studies should therefore pair self-reports with authentic tasks, portfolios, simulations or external performance assessments and investigate how perceived and demonstrated competence relate.

7. Conclusion

Higher education is being asked to prepare graduates for technological, economic and societal conditions that are changing quickly and unevenly. International competency frameworks offer useful guidance, but assessment practices remain fragmented and seldom provide an integrated picture of students' preparedness for uncertain futures.

FRCAI was developed to address that gap by bringing five proposed areas of perceived future readiness into one self-assessment design. Its purpose is methodological integration, not the introduction of another competency framework or a claim that a stable five-factor model has already been established.

The development process combined literature review, comparative framework analysis, expert review across three partner institutions and pilot testing. The baseline application demonstrates feasibility, but parallel analysis, cross-loadings and mixed CFA fit show that several item and domain boundaries require revision.

Respondents generally rated their preparedness positively, with digital participation highest and financial resilience lowest. These differences describe perceptions and may inform further curricular inquiry; they do not demonstrate objective competence or causal effects of higher education provision.

The main contribution is methodological and diagnostic. FRCAI offers a traceable starting point for integrating several future-oriented competence traditions, while the reported psychometric evidence identifies where that design succeeds and where it needs refinement. Stronger use of the instrument depends on revised items, independent replication and longitudinal validation.

For higher education, multidimensional self-assessment profiles may complement other forms of assessment and inform curriculum development, provided they are not mistaken for direct measures of performance. Future studies should use more heterogeneous samples and combine FRCAI with objective evidence before making claims about educational outcomes or predictive validity.

Supplementary Material

Supplementary Material S1 (appended below the references) reports Horn's parallel analysis, the theory-constrained EFA pattern matrix, standardised CFA loadings and latent-factor correlations.

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Disclosure Statement

The authors declare that they have no competing interests.

Data Availability Statement

The anonymised dataset and detailed analysis documentation are available from the corresponding author on reasonable request, subject to project data-governance requirements.

Ethical Approval

Under the applicable regulations of the participating institutions, formal approval from an institutional ethics committee was not required for this secondary analysis of anonymous, voluntarily provided baseline-survey data.

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Supplementary Material S1: Supplementary Factor Analysis

Analytical Specification

Analyses used the 241 respondents with complete data on all 22 FRCAI items. In the 1KA export, −99 represented response category 5 (strongly agree) and was recoded to 5; −3 represented an interrupted or skipped response and was treated as missing. Five-point items were treated as approximately continuous. Exploratory factor analysis used Pearson correlations, principal-axis factoring and oblimin rotation in Python 3.13 with NumPy 2.3.5 and statsmodels 0.14.6. Horn's parallel analysis used 2,000 random normal datasets and the 95th-percentile eigenvalue criterion (random seed 42). Confirmatory factor analysis used maximum-likelihood estimation of the sample covariance matrix with five correlated latent factors, one marker loading fixed per factor and numerical optimisation in SciPy 1.17.0. Because EFA and CFA used the same dataset, CFA results are preliminary rather than an independent confirmation.

Table S1. Horn's parallel analysis

Factor	Observed eigenvalue	95th-percentile random eigenvalue	Retain?
1	7.015	1.684	Yes
2	1.653	1.556	Yes
3	1.561	1.467	Yes
4	1.196	1.391	No
5	1.091	1.329	No
6	1.017	1.270	No
7	0.841	1.216	No
8	0.814	1.166	No
9	0.726	1.120	No
10	0.693	1.074	No

Note. Parallel analysis retained three factors. The five-factor solution reported in Table S2 was therefore estimated as a theory-constrained exploratory solution.

Table S2. Theory-constrained five-factor principal-axis solution with oblimin rotation

Item	Abbreviated content	F1	F2	F3	F4	F5	Uniqueness
Q2a	Multiple possible futures	**0.325**	-0.008	0.222	-0.040	0.211	0.698
Q2b	Anticipate AI/automation disruptions	0.167	-0.051	0.195	0.140	0.282	0.704
Q2c	Strategic foresight methods	**0.512**	-0.010	0.081	-0.053	0.132	0.663
Q2d	Long-term changes and career	0.131	-0.045	0.184	0.030	0.089	0.907
Q3a	Evaluate media/ disinformation	-0.044	**0.687**	0.024	0.018	0.143	0.428
Q3b	Cybersecurity measures	-0.102	0.110	0.186	0.023	**0.456**	0.677
Q3c	AI ethics and risks	0.088	**0.342**	0.088	-0.151	**0.381**	0.611
Q3d	Data-driven decisions	0.260	**0.343**	0.036	-0.020	0.291	0.533
Q3e	Digital tools for international collaboration	0.123	0.054	-0.014	0.174	**0.616**	0.395
Q4a	Financial decisions	0.050	**0.314**	**0.544**	-0.000	-0.203	0.547
Q4b	FinTech and cryptocurrencies	-0.133	-0.055	**0.637**	0.052	0.155	0.570
Q4c	Financial challenges under instability	0.091	0.048	**0.688**	-0.035	-0.044	0.486
Q4d	Digitalisation in financial markets	0.071	-0.090	**0.621**	0.124	0.085	0.500
Q5a	Turn ideas into projects	**0.746**	-0.019	-0.028	0.037	-0.034	0.456
Q5b	Lead international teams	**0.492**	0.077	-0.041	0.253	0.065	0.513
Q5c	Business innovation tools	**0.465**	-0.132	0.272	0.121	-0.041	0.605
Q5d	Interdisciplinary problem-solving	**0.478**	0.198	0.063	-0.036	0.124	0.583
Q6a	Evaluate media/ disinformation/ propaganda	0.014	**0.857**	-0.003	0.083	-0.042	0.224
Q6b	Strategic digital communication	-0.065	0.017	0.051	**0.748**	0.009	0.441
Q6c	Professional digital content	0.179	0.078	-0.017	**0.580**	-0.021	0.505
Q6d	Digital footprint	0.011	0.244	0.129	0.273	0.183	0.632
Q6e	Digital tools for international collaboration (duplicate of Q3e)	0.159	0.177	0.041	**0.458**	0.186	0.418

Notes. Pattern coefficients with absolute values of .30 or greater are bolded. The sign of F3 was reversed for interpretability. The five-factor solution had an average extracted communality equivalent to 45.0% of total item variance. Factors are deliberately left unlabelled because the observed pattern did not reproduce the five prespecified domains cleanly.

Table S3. Standardised loadings from the prespecified five-factor CFA

Item	Abbreviated content	Assigned factor	Standardised loading
Q2a	Multiple possible futures	FA	0.624
Q2b	Anticipate AI/automation disruptions	FA	0.575
Q2c	Strategic foresight methods	FA	0.571
Q2d	Long-term changes and career	FA	0.350
Q3a	Evaluate media/disinformation	DDM	0.609
Q3b	Cybersecurity measures	DDM	0.497
Q3c	AI ethics and risks	DDM	0.582
Q3d	Data-driven decisions	DDM	0.694
Q3e	Digital tools for international collaboration	DDM	0.709
Q4a	Financial decisions	FER	0.594
Q4b	FinTech and cryptocurrencies	FER	0.609
Q4c	Financial challenges under instability	FER	0.721
Q4d	Digitalisation in financial markets	FER	0.707
Q5a	Turn ideas into projects	IEC	0.637
Q5b	Lead international teams	LCC	0.641
Q5c	Business innovation tools	IEC	0.608
Q5d	Interdisciplinary problem-solving	IEC	0.662
Q6a	Evaluate media/disinformation/propaganda	LCC	0.612
Q6b	Strategic digital communication	LCC	0.578
Q6c	Professional digital content	LCC	0.621
Q6d	Digital footprint	LCC	0.624
Q6e	Digital tools for international collaboration (duplicate of Q3e)	LCC	0.786

Note. FA = Future and Anticipatory Competence; DDM = Digital, Data and Media Competence; FER = Financial and Economic Resilience; IEC = Innovation and Entrepreneurial Competence; LCC = Leadership, Communication and Collaborative Competence. Model fit: $\chi^2(199) = 436.45$, $p < .001$; CFI = .859; TLI = .837; RMSEA = .071; SRMR = .063.

Table S4. Latent-factor correlations in the prespecified CFA

Factor	FA	DDM	FER	IEC	LCC
FA	1.000				
DDM	0.712	1.000			
FER	0.625	0.546	1.000		
IEC	0.801	0.654	0.572	1.000	
LCC	0.669	0.833	0.565	0.760	1.000

Interpretive caution. The high latent correlations, same-sample EFA/CFA, use of Pearson correlations and maximum likelihood for ordinal items, duplicated wording of Q3e/Q6e, and overlap between Q3a/Q6a all limit claims of discriminant validity. Independent validation with revised items, polychoric correlations and robust ordinal estimation is required.

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