When Performance Testing Is Not Feasible: A Methodological Perspective on Digital Skills Assessment in Higher Education

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Abstract
Digital skills are essential for participation in digital, data-driven, and AI-enabled societies. While performance-based assessments remain the gold standard, their financial, technological, and organizational demands often exceed the capacity of resource-constrained higher education institutions. This paper proposes a practical framework for digital skills assessment that combines validated self-report measures with second-generation structural equation modeling (SEM). Drawing on evidence from a research project conducted at an Albanian university, it shows how Exploratory Structural Equation Modeling (ESEM), Hierarchical Exploratory Structural Equation Modeling (H-ESEM), and bifactor-based SEM approaches can improve construct representation, reduce measurement bias, and strengthen the assessment of digital competence. Findings indicate that digital skills are multidimensional, hierarchical, and composed of interconnected functional and critical dimensions. Furthermore, digital skills profiling informed by latent profile analysis of bifactor-ESEM–derived factor scores facilitates evidence-based, targeted, and personalized curriculum development. The proposed framework offers a feasible alternative to performance testing while supporting evidence-based decision-making in under-resourced higher education institutions.

Keywords: Digital skills assessment, Digital competence, Second-generation structural equation modeling, Resource-constrained higher education, Digital skills profiling.

1. Introduction

The rapid expansion of digital technologies, artificial intelligence (AI), big data, automation, and intelligent systems is fundamentally reshaping education, employment, and social participation. In this evolving context, digital skills are no longer viewed as supplementary competencies but as essential prerequisites for effective participation in contemporary society. Governments, educational institutions, and international organizations increasingly acknowledge that individuals require not only the ability to operate digital technologies but also the capacity to critically evaluate information, communicate effectively in digital environments, and create digital content responsibly and ethically. These capabilities are reflected in contemporary digital competence frameworks, which conceptualize digital competence as a multidimensional construct encompassing information and data literacy, communication and collaboration, digital content creation, safety, and problem solving (Ferrari, 2013; Vuorikari et al., 2022).

Higher education institutions play a particularly important role in preparing students for participation in increasingly digital and AI-enabled societies. Universities are expected to equip graduates with competencies that extend beyond disciplinary knowledge and include a broad range of digital capabilities necessary for lifelong learning, employability, innovation, and civic engagement. In response to these demands, the development and assessment of digital skills have become strategic priorities for educational systems worldwide (European Commission, 2024; UNESCO, 2023). However, effective curriculum development and evidence-based educational policies require reliable information about students' actual levels of digital skills. Without accurate assessment, institutions face difficulties in identifying strengths, addressing weaknesses, monitoring progress, and evaluating the effectiveness of educational interventions (European Commission, 2024; UNESCO, 2023).

Despite growing interest in digital competence assessment, important methodological challenges remain. One of the most fundamental concerns relates to the distinction between digital competence and digital skills. While digital competence is typically conceptualized as a broader construct encompassing knowledge, skills, attitudes, and values associated with technology use, digital skills refer more specifically to the operational, informational, communicative, creative, and critical abilities that enable individuals to achieve meaningful outcomes in digital environments (van Dijk & van Deursen, 2014). Furthermore, accumulating evidence suggests that digital skills are multidimensional rather than unidimensional. Contemporary frameworks identify multiple interrelated domains, including technical and operational skills, information navigation and processing skills, communication and interaction skills, and content creation and production skills, each incorporating both functional and critical dimensions of digital engagement (Helsper et al., 2020). Recent research further highlights the importance of considering functional and critical dimensions jointly, as these dimensions shape individuals' ability to engage effectively and strategically in digital environments (Polizzi, 2025).

The assessment of such complex constructs presents substantial challenges. Performance-based assessments are generally regarded as the gold standard because they evaluate actual behavior through authentic tasks situated in digital environments. Large-scale initiatives such as PIAAC and

ICILS have demonstrated the value of performance testing for obtaining valid estimates of digital skills. However, performance-based assessments often require significant financial resources, specialized infrastructure, intensive administration procedures, and extensive technical expertise, limiting their feasibility in many higher education settings, particularly those operating under resource constraints (Darling-Hammond & Adamson, 2010; van Dijk & van Deursen, 2014).

As a result, self-report instruments remain among the most frequently used approaches for measuring digital skills. Nevertheless, traditional self-assessment measures have been criticized for their susceptibility to response biases, including social desirability effects and inaccurate self-evaluations, which may compromise the validity of reported skill levels (van Dijk & van Deursen, 2014). These limitations have generated skepticism regarding the accuracy of self-reported digital skills and have motivated the development of more sophisticated measurement frameworks and psychometrically robust instruments. One notable example is the Youth Digital Skills Indicator (yDSI), which was specifically designed to assess functional and critical digital skills while addressing several common limitations of earlier self-report measures through rigorous conceptualization, validation, and item development procedures (Helsper et al., 2020).

However, the quality of assessment depends not only on the measurement instrument but also on the analytical framework used to evaluate its latent structure. Traditional approaches, particularly conventional confirmatory factor analysis (CFA), often impose restrictive assumptions such as fixed zero cross-loadings that may oversimplify the multidimensional and interconnected nature of digital skills. Recent methodological developments in structural equation modeling, including exploratory structural equation modeling (ESEM) and bifactor exploratory structural equation modeling (B-ESEM), provide more flexible alternatives capable of representing cross-domain relationships, hierarchical structures, and overlapping dimensions more realistically. These approaches have been shown to improve model fit, reduce parameter bias, and provide a more accurate representation of complex multidimensional constructs than conventional CFA models (Asparouhov & Muthén, 2009; Marsh et al., 2014; Morin et al., 2016).

Against this background, the present paper argues that validated self-report instruments, when combined with advanced structural equation modeling approaches, provide a scientifically rigorous and practically feasible alternative for assessing digital skills in higher education. Using data collected at Fan S. Noli University and the internationally validated Youth Digital Skills Indicator (yDSI), the study illustrates how ESEM and bifactor-ESEM frameworks can improve construct representation, address measurement challenges, and generate more nuanced insights into students' digital skills profiles. More broadly, the findings underscore the importance of aligning assessment practices with the growing complexity of the digital competencies required for participation in increasingly AI-driven societies.

2. The Multidimensional Nature of Digital Skills

Contemporary research increasingly suggests that digital skills should not be conceptualized as a simple collection of independent abilities. Instead, they represent a multidimensional construct comprising multiple interrelated domains that jointly enable effective participation in digital environments. Frameworks such as DigComp conceptualize digital competence as encompassing five broad areas: information and data literacy, communication and collaboration, digital content creation, safety, and problem solving (Ferrari, 2013; Vuorikari et al., 2022). These domains rarely operate in isolation; successful engagement with digital technologies typically requires the integration of competencies from multiple domains when individuals search for information, communicate online, create digital content, solve technology-related problems, or interact with emerging AI-enabled systems.

As digital technologies become increasingly sophisticated, attention has shifted from basic operational abilities toward higher-order cognitive processes. Contemporary scholarship emphasizes that effective engagement with technology requires not only technical proficiency but also strategic thinking, ethical awareness, reflective judgment, and the capacity to critically evaluate digital information (Helsper et al., 2020; Polizzi, 2025). Individuals are expected to assess information credibility, recognize algorithmic influences, manage online risks, and make informed decisions in technology-mediated contexts. Accordingly, digital skills are now understood as a multifaceted construct encompassing behavioral, cognitive, social, and evaluative dimensions.

A particularly influential contribution to this perspective is the distinction between functional and critical digital skills introduced within the ySKILLS framework (Helsper et al., 2020). Functional skills refer to the practical abilities needed to access, navigate, communicate, and create using digital technologies, whereas critical skills involve evaluating information, understanding digital systems, and exercising informed judgment. This distinction is especially relevant in AI-driven societies, where the ability to interpret, question, and assess digital content may be as important as the ability to access, produce, or share it.

Emerging evidence further indicates that digital skills are organized through both broad and domain-specific capabilities. While some aspects reflect general digital proficiency, others capture more specialized competencies that contribute unique aspects of performance. At the same time, substantial overlap among skill domains suggests that digital activities typically draw upon multiple competencies simultaneously rather than discrete, independent abilities (Helsper et al., 2020; Polizzi, 2025). This perspective highlights digital skills as a coherent network of mutually reinforcing competencies that support effective participation in contemporary digital environments.

These conceptualizations carry important implications for assessment. Measurement models must be capable of capturing general capabilities alongside domain-specific skills while accommodating the overlap that naturally exists among them. Approaches that impose overly restrictive structures risk obscuring meaningful patterns of variation and providing incomplete representations of learners' digital profiles. Consequently, advances in digital skills theory reinforce the need for flexible psychometric frameworks that can adequately represent the layered and interconnected nature of digital capabilities in contemporary and AI-enabled societies.

3. Why Advanced Structural Equation Modeling Matters for Digital Skills Assessment

The complex nature of digital skills poses important methodological challenges for measurement and validation. Because digital skills encompass multiple related domains that may overlap conceptually and empirically, assessment models must be capable of representing multidimensionality while accommodating relationships among dimensions. Traditionally, researchers have relied on latent variable approaches such as Independent Clusters Model Confirmatory Factor Analysis (ICM-CFA) to evaluate the factorial validity of educational and psychological instruments. However, ICM-CFA assumes that each indicator loads exclusively on a single latent factor and that all cross-loadings are fixed to zero. Although this specification facilitates model interpretation, it often provides an overly restrictive representation of complex constructs, particularly when indicators are theoretically or empirically associated with more than one dimension (Asparouhov & Muthén, 2009; Marsh et al., 2014).

These limitations are especially relevant in the assessment of digital skills. Competencies such as information navigation, online communication, problem solving, and digital content creation frequently share common cognitive, behavioral, and technological foundations. As a result, indicators designed to measure one domain may also reflect aspects of related domains. Under these conditions, constraining all cross-loadings to zero can distort parameter estimates, inflate factor correlations, and obscure the true structure of the construct (Asparouhov & Muthén, 2009; Marsh et al., 2014).

To address these limitations, recent methodological developments have introduced more flexible modeling frameworks, most notably Exploratory Structural Equation Modeling (ESEM). ESEM integrates the exploratory flexibility of exploratory factor analysis with the confirmatory advantages of structural equation modeling, allowing indicators to load on non-target factors while simultaneously estimating structural relationships and overall model fit. By incorporating cross-loadings directly into the model, ESEM often provides a more realistic representation of complex multidimensional constructs and reduces biases associated with overly restrictive CFA specifications (Asparouhov & Muthén, 2009; Marsh et al., 2014).

In educational and psychological research, where constructs are frequently multidimensional and characterized by conceptually related domains, Exploratory Structural Equation Modeling (ESEM) has emerged as an important alternative to traditional confirmatory factor analytic approaches. By allowing the estimation of theoretically meaningful cross-loadings, ESEM provides a more flexible representation of latent structures and can reduce distortions associated with overly restrictive measurement models (Marsh et al., 2014).

A second major methodological development in structural equation modeling concerns the representation of hierarchical constructs. Although ESEM addresses construct multidimensionality and cross-domain associations, many educational and psychological constructs are also characterized by broader sources of common variance that coexist with more specific dimensions. Digital skills provide a clear example. Individuals may differ in competencies related to information management, communication, content creation, and technical operations while simultaneously exhibiting an overarching level of digital proficiency. Accurately representing both shared and domain-specific variance therefore requires modeling frameworks that extend beyond traditional first-order factor structures.

Important advances in this area emerged from the work of Reise (2012), Reise et al. (2012), and Rodriguez et al. (2016), who renewed interest in bifactor modeling as a powerful framework for investigating construct dimensionality. In bifactor models, each indicator loads simultaneously on a general factor representing variance common to all indicators and on a specific factor representing variance unique to a particular domain. This approach enables researchers to distinguish between broad underlying proficiency and more narrowly defined competencies, providing a more nuanced understanding of complex constructs.

Beyond advancing the conceptual interpretation of multidimensional measures, this framework also introduced rigorous tools for evaluating dimensionality. Rodriguez et al. (2016) proposed a set of complementary bifactor indices, including Omega Hierarchical (ωH), Explained Common Variance (ECV), and Percentage of Uncontaminated Correlations (PUC) that allow researchers to assess the relative contribution of general and specific factors to scale variance. These indices have become important criteria for evaluating whether constructs are best represented as essentially unidimensional, multidimensional, or characterized by a combination of general and domain-specific components.

A further methodological advancement was the integration of bifactor modeling with ESEM. Morin et al. (2016) proposed the bifactor-ESEM framework, arguing that complex constructs are often not adequately represented by either traditional bifactor-CFA models or conventional ESEM models alone. By combining the flexibility of ESEM with the hierarchical representation provided by bifactor models, bifactor-ESEM simultaneously accommodates construct-relevant multidimensionality, cross-loadings, and the existence of both general and specific sources of variance. This framework enables researchers to model broad underlying dimensions while retaining information about domain-specific constructs, thereby providing a more comprehensive representation of complex latent structures.

Subsequent methodological work has further expanded the application and evaluation of bifactor-ESEM models within educational and psychological research. Recent recommendations emphasize the importance of selecting measurement models that adequately reflect both multidimensionality and hierarchical organization, particularly when constructs contain overlapping domains and substantial shared variance (Gegenfurtner, 2022; Morin et al., 2020).

From a methodological perspective, these advances are particularly relevant for digital skills assessment because they align measurement models more closely with contemporary theoretical conceptualizations of digital competence. As digital skills are increasingly understood as multidimensional, overlapping, and organized across both general and specific domains, advanced SEM approaches offer a more appropriate framework for evaluating their latent structure. Consequently, the adoption of ESEM and bifactor-ESEM methodologies can enhance construct validity, improve parameter estimation, and provide a stronger empirical basis for educational research and evidence-based decision-making.

An important development within the ESEM framework is Hierarchical Exploratory Structural Equation Modeling (H-ESEM), which integrates the flexibility of ESEM with the representation of higher-order latent structures (Marsh et al., 2014; Morin et al., 2016). H-ESEM allows researchers to model broad higher-order constructs that emerge from multiple correlated first-order dimensions while retaining the capacity to estimate cross-loadings among indicators. By relaxing the restrictive assumptions typically imposed in higher-order CFA models, H-ESEM provides a more flexible representation of hierarchical multidimensional constructs and allows for a more accurate evaluation of relationships among latent dimensions. Moreover, H-ESEM offers a useful framework for examining whether covariance among first-order factors can be explained by broader latent factors, thereby providing an important conceptual and methodological link between multidimensional ESEM models and bifactor-based approaches (Marsh et al., 2014; Morin et al., 2016).

More recent developments within the ESEM tradition have expanded the range of models available for representing complex multidimensional constructs. Among these are set-ESEM and set bifactor-ESEM approaches, which allow indicators to be organized into theoretically meaningful sets while retaining the flexibility to model cross-loadings and hierarchical structures (Marsh & Alamer, 2024; Morin et al., 2016). These approaches are particularly useful when constructs comprise conceptually distinct but related domains that may exhibit different patterns of multidimensionality.

This perspective is especially relevant for digital skills assessment, where contemporary frameworks increasingly distinguish between functional and critical digital skills (Helsper et al., 2020). Functional digital skills refer to the practical abilities required to access, navigate, communicate, and create using digital technologies, whereas critical digital skills involve evaluating information, exercising judgment, understanding digital systems, and making informed and responsible decisions in digital contexts. Although these dimensions represent distinct aspects of digital capability, they are also expected to share substantial common variance because both contribute to effective participation in digital environments (Helsper et al., 2020; Polizzi, 2025).

From a measurement perspective, set bifactor-ESEM provides a potentially valuable framework for representing this dual structure. By allowing indicators to be grouped into theoretically defined sets while simultaneously modeling general and domain-specific sources of variance, the approach offers a flexible means of examining how functional and critical dimensions contribute to broader digital proficiency. Such a representation is consistent with contemporary conceptualizations of digital skills and may provide a more nuanced understanding of digital competence in increasingly complex and AI-enabled societies (Helsper et al., 2020; Polizzi, 2025).

4. Overview of the UNIKO Digital Skills Research Project

To illustrate the practical application of the conceptual and methodological issues discussed in this paper, we draw on evidence generated through a research project conducted at Fan S. Noli University (UNIKO), Albania. The project aimed to assess university students' digital skills using a theoretically grounded and internationally validated measurement framework while evaluating the potential of advanced structural equation modeling approaches for representing complex competence structures.

The study employed the Youth Digital Skills Indicator (yDSI) developed within the European ySKILLS initiative (Helsper et al., 2020), a measurement instrument specifically designed to assess both functional and critical digital skills while reducing common sources of self-report bias. Data were collected from 603 undergraduate students who voluntarily completed an anonymous online questionnaire following institutional ethical approval procedures. The project incorporated a comprehensive sequence of psychometric analyses conducted in Mplus 8.11, including ESEM, H-ESEM, bifactor-ESEM, and set bifactor-ESEM models, as well as measurement invariance testing, criterion-related validity analyses, latent profile analysis (LPA), and Monte Carlo simulations designed to identify optimal sample size requirements for future studies.

The analytical strategy was guided by the assumption that digital skills constitute a multidimensional construct characterized by hierarchical organization and substantial overlap among domains. Consequently, emphasis was placed on comparing alternative latent structures and identifying models capable of providing the most conceptually meaningful and empirically robust representation of students' digital skills. Findings from various stages of the project have been disseminated through peer-reviewed journal articles, international scientific conferences, and methodological presentations focusing on digital skills measurement, psychometric validation, bifactor modeling, exploratory structural equation modeling, latent profile analysis, and Monte Carlo simulation methodologies.

Rather than presenting detailed empirical findings, the present paper uses the UNIKO project as an illustrative case demonstrating how validated self-report instruments can be integrated with contemporary SEM frameworks to strengthen digital skills assessment in higher education. More broadly, the project exemplifies how institutions operating under resource constraints can generate robust evidence to support curriculum development, educational planning, and digital transformation initiatives.

5. Summary of Key Findings in Light of Existing Literature

The UNIKO digital skills research project provided empirical evidence supporting the use of advanced structural equation modeling approaches for the assessment of complex competence constructs. Across a series of complementary studies, the results consistently indicated that students' digital capabilities are not adequately represented by simplistic or strictly unidimensional measurement models. Instead, the findings supported a multidimensional and hierarchical representation encompassing both functional and critical dimensions of digital proficiency (Frashëri & Teneqexhi, 2025; Frashëri, 2026a). Similar conclusions have emerged from the DigComp framework (Vuorikari et al., 2022), the ySKILLS initiative (Helsper et al., 2020), and recent scholarship emphasizing the multidimensional nature of digital competence and the distinction between functional and critical dimensions of digital engagement (Polizzi, 2025).

A first major finding concerned the advantages of ESEM- and bifactor-based frameworks over conventional confirmatory approaches. Compared with traditional CFA models, these methodologies provided a more accurate representation of latent structures, improved discriminant validity, and reduced the inflation of factor correlations associated with overly restrictive measurement specifications (Frashëri & Teneqexhi, 2025, 2026). These findings are consistent with the methodological literature demonstrating that models permitting cross-loadings and the simultaneous estimation of general and specific factors often provide a more realistic representation of construct-relevant multidimensionality in educational and psychological research (Asparouhov & Muthén, 2009; Gegenfurtner, 2022; Marsh et al., 2014; Morin et al., 2016).

A second key finding emerged from the investigation of functional and critical digital skills, indicating that these domains represent distinct but interrelated dimensions of digital competence. Set bifactor-ESEM models were particularly effective in capturing both the common variance shared across these dimensions and the unique variance associated with each domain, thereby providing a flexible framework for representing their simultaneous distinctiveness and interdependence (Frashëri, 2026a). This interpretation is consistent with recent theoretical work emphasizing the complementary contribution of functional and critical digital skills to meaningful digital participation (Polizzi, 2025).

The project also confirmed the strong psychometric performance of the Youth Digital Skills Indicator (yDSI), demonstrating satisfactory reliability, construct validity, and full measurement invariance across gender groups (Frashëri & Teneqexhi, 2025, 2026). These results are consistent with and further strengthen the validation evidence presented in the original ySKILLS research (Helsper et al., 2020).

Another important contribution emerged from the integration of variable-centered and person-centered analytical perspectives. Latent profile analyses based on factor scores derived from bifactor-ESEM models produced more informative student classifications than approaches relying solely on observed scores or first-order dimensions. The resulting profiles revealed meaningful heterogeneity in students' digital capabilities and identified distinct configurations of strengths and weaknesses across competence domains. By incorporating information from both general and domain-specific dimensions, these profiles provided a richer basis for understanding individual differences in digital proficiency (Frashëri & Vangjeli, 2026; Frashëri, 2026b).

From an educational perspective, the findings illustrated the potential of profile-based assessment to support targeted and personalized curriculum development. Rather than assuming a uniform level of competence across learners, this approach recognizes that students may require different learning pathways depending on their specific patterns of strengths and developmental needs. Such evidence can assist higher education institutions in aligning digital skills interventions with the characteristics of different student groups.

The project further contributed methodological evidence regarding sample size requirements for advanced latent variable modeling. Using Monte Carlo simulation procedures based on the framework proposed by Muthén, L. & Muthén, B. (2002), the study identified sample size conditions associated with stable parameter recovery, accurate standard errors, and acceptable model performance. These results offer practical guidance for future applications of ESEM and bifactor-based models in digital skills research (Frashëri, 2025).

Collectively, the findings demonstrate that validated self-report instruments, when combined with contemporary structural equation modeling methodologies, can provide a scientifically rigorous and practically feasible alternative for assessing digital skills in higher education settings where large-scale performance testing may be difficult to implement. Moreover, the project illustrates how advanced psychometric approaches can generate actionable evidence to support curriculum innovation, institutional planning, and digital transformation initiatives.

6. Conclusion

The rapid digital transformation of society, accelerated by artificial intelligence and data-driven technologies, has heightened the need for accurate and theoretically informed assessment of digital skills in higher education. Although performance-based assessment remains an important benchmark for measuring actual behavior, its implementation is often constrained by financial, logistical, and technological demands. Consequently, there is a growing need for assessment strategies that balance methodological rigor with practical feasibility.

The central argument advanced in this paper is that the quality of digital skills assessment depends not only on the measurement instrument itself but also on the analytical framework used to represent the underlying construct. Drawing on evidence from the UNIKO digital skills research project, the paper demonstrates that validated self-report instruments, such as the Youth Digital Skills Indicator (yDSI), can provide meaningful and reliable assessments when combined with advanced structural equation modeling methodologies. The findings support the view that digital skills are best represented as multidimensional constructs characterized by overlapping domains, hierarchical organization, and the coexistence of functional and critical dimensions.

From a methodological perspective, the project illustrates the value of moving beyond restrictive measurement models toward more flexible frameworks capable of accommodating construct-relevant complexity. Approaches such as ESEM, H-ESEM, bifactor-ESEM, set bifactor-ESEM, and bifactor-informed latent profile analysis allow researchers to simultaneously model multidimensionality, cross-loadings, general and specific sources of variance, and individual heterogeneity. As a result, these approaches provide a more comprehensive representation of digital skills than traditional factor analytic models and generate richer evidence for both research and educational practice.

The findings also highlight the advantages of integrating variable-centered and person-centered methodologies. While advanced latent variable models improve the representation of construct structure, latent profile analysis extends this perspective by identifying meaningful patterns of individual differences. Such integration offers a stronger empirical basis for targeted and personalized curriculum development, enabling educational interventions to be aligned with distinct learner profiles rather than relying solely on population averages.

More broadly, the implications of this work extend beyond the assessment of digital skills. As educational, psychological, and behavioral constructs are increasingly recognized as multidimensional and hierarchically organized, researchers face growing challenges in selecting models that adequately reflect their complexity. In this context, contemporary structural equation modeling frameworks provide valuable methodological tools for improving construct representation, strengthening validity evidence, and enhancing the quality of inferences drawn from educational data.

Ultimately, the contribution of this paper lies in demonstrating that rigorous assessment is not solely a function of instrument quality but also of methodological choice. When theoretically grounded measurement instruments are combined with advanced latent variable modeling approaches, researchers and institutions can obtain more accurate, interpretable, and actionable evidence to support educational research, curriculum innovation, and data-informed decision-making in increasingly complex and AI-enabled learning environments.

Limitations

Despite the valuable methodological and empirical contributions of the UNIKO Digital Skills Research Project, several limitations should be acknowledged when interpreting the findings.

First, the project relied on a cross-sectional research design, with data collected at a single point in time. As a result, the analyses do not permit conclusions regarding causal relationships or the developmental progression of digital skills. Although advanced latent variable models provide valuable insights into the structure of digital competence, longitudinal studies are needed to examine how digital skills evolve over time and how educational interventions influence their development.

Second, the study was conducted within a single higher education institution, namely Fan S. Noli University of Korça (UNIKO). While the sample was sufficiently large for the statistical analyses undertaken and provided robust evidence regarding the psychometric properties of the measurement models, the findings should not be interpreted as representative of all university students in Albania or other educational contexts. Future research should therefore seek to replicate the findings across multiple universities, regions, and national contexts.

Third, although the Youth Digital Skills Indicator (yDSI) incorporates several design features intended to reduce common limitations of self-report measures, the study remains dependent on self-reported data. Consequently, responses may still be influenced by factors such as self-perception biases, social desirability effects, or differences in respondents' interpretations of questionnaire items. Future studies could strengthen validity evidence through the integration of self-report, performance-based, and observational assessment approaches.

Taken together, these limitations suggest that the findings should be viewed as an important contribution to the methodological literature on digital skills assessment rather than as definitive evidence regarding the digital skills profile of the broader student population. Future multi-institutional and longitudinal investigations will be essential for extending and validating the conclusions reported in this project.

References:

Asparouhov, T., & Muthén, B. (2009). Exploratory structural equation modeling. *Structural Equation Modeling: A Multidisciplinary Journal, 16*(3), 397–438. https://doi.org/10.1080/10705510903008204

Darling-Hammond, L., & Adamson, F. (2010). *Beyond basic skills: The role of performance assessment in achieving 21st century standards of learning*. Stanford Center for Opportunity Policy in Education, Stanford University. https://edpolicy.stanford.edu/library/publications/686

European Commission. (2024). *Report on the state of the Digital Decade 2024*. Publications Office of the European Union. https://digital-strategy.ec.europa.eu/en/library/report-state-digital-decade-2024 [digital-st....europa.eu]

Ferrari, A. (2013). *DIGCOMP: A framework for developing and understanding digital competence in Europe* (EUR 26035 EN). Publications Office of the European Union. https://doi.org/10.2788/52966

Frashëri E., Teneqexhi M. (2025). Validating a Psychometric Instrument for Assessing Students' Digital Skills: A Latent Variable Approach for Policy-Oriented Educational Research. A preprint version of this manuscript has been posted on Springer Nature's Research Square (DOI: https://doi.org/10.21203/rs.3.rs-7289357/v1).

Frashëri, E. (2025). *Determining the minimum optimal sample size for exploratory structural equation modeling: A Monte Carlo simulation study*. In *Regional Development in Times of Change: Integrating Challenges and Opportunities for a Sustainable Future: Book of Proceedings of the International Scientific Conference* (November 21–22, 2025, Korçë, Albania).

Frashëri, E. (2026a). Are functional and critical digital skills distinct? Evidence from set bifactor ESEM using the yDSI among students. In Proceedings of the 16th Edition of the Future of Education International Conference. Filodiritto Editore. https://doi.org/10.82075/FOE_2026_16_PAG.186

Frashëri, E. (2026b). Shaping future learning through digital skills profiling. In Proceedings of the 16th Edition of the Future of Education International Conference. Filodiritto Editore. https://doi.org/10.82075/FOE_2026_16_PAG.195

Frashëri, E., & Teneqexhi, M. (2026). Modeling digital competence in education: A bifactor-ESEM approach to general and domain-specific skills. *International Journal of Assessment Tools in Education, 13*(2), 557–586. https://doi.org/10.21449/ijate.1791291

Frashëri, E., & Vangjeli, E. (2026). *A hierarchical and multidimensional approach to profiling students' digital skills in educational technology. Journal of Educational Technology Development and Exchange, 19*(2), 185–214. https://doi.org/10.18785/jetde.1902.09

Frashëri, E., Vangjeli, E., & Teneqexhi, M. (2026). *Digital competence assessment in higher education: A methodological contribution with policy implications*. Paper presented at the 11th International Scientific-Business Conference: Leadership, Innovation, Management, and Economics (LIMEN), Zurich, Switzerland

Gegenfurtner, A. (2022). *Bifactor exploratory structural equation modeling: A meta-analytic review of model fit. Frontiers in Psychology, 13*, Article 1037111. https://doi.org/10.3389/fpsyg.2022.1037111

Helsper, E. J., Schneider, L. S., van Deursen, A. J. A. M., & van Laar, E. (2020). *The youth Digital Skills Indicator: Report on the conceptualisation and development of the ySKILLS digital skills measure*. ySKILLS. https://doi.org/10.5281/zenodo.4608010

Marsh, H., & Alamer, A. (2024). When and how to use set-exploratory structural equation modelling to test structural models: A tutorial using the R package *lavaan*. *British Journal of Mathematical and Statistical Psychology, 77*(3), 459–476. https://doi.org/10.1111/bmsp.12336

Marsh, H. W., Morin, A. J. S., Parker, P. D., & Kaur, G. (2014). Exploratory structural equation modeling: An integration of the best features of exploratory and confirmatory factor analysis. *Annual Review of Clinical Psychology, 10*, 85–110. https://doi.org/10.1146/annurev-clinpsy-032813-153700

Morin, A. J. S., Arens, A. K., & Marsh, H. W. (2016). A bifactor exploratory structural equation modeling framework for the identification of distinct sources of construct-relevant psychometric multidimensionality. *Structural Equation Modeling: A Multidisciplinary Journal, 23*(1), 116–139. https://doi.org/10.1080/10705511.2014.961800

Morin, A. J. S., Marsh, H. W., & Nagengast, B. (2020). Exploratory structural equation modeling. In G. R. Hancock, L. M. Stapleton, & R. O. Mueller (Eds.), *The reviewer's guide to quantitative methods in the social sciences* (2nd ed., pp. 395–436). Routledge.

Muthén, L. K., & Muthén, B. O. (2002). *How to use a Monte Carlo study to decide on sample size and determine power*. Structural Equation Modeling, 9(4), 599–620. https://doi.org/10.1207/S15328007SEM0904_8

Polizzi, G. (2025). Digital literacy and strategic (dis)engagement: Examining how functional and critical digital literacy shapes participation. *Information, Communication & Society, 28*(14), 2483–2502. https://doi.org/10.1080/1369118X.2025.2452282

Reise, S. P. (2012). The rediscovery of bifactor measurement models. *Multivariate Behavioral Research, 47*(5), 667–696. https://doi.org/10.1080/00273171.2012.715555

Reise, S. P., Moore, T. M., & Haviland, M. G. (2012). Bifactor models and rotations: Exploring the extent to which multidimensional data yield univocal scale scores. *Journal of Personality Assessment, 92*(6), 544–559. https://doi.org/10.1080/00223891.2010.496477

Rodriguez, A., Reise, S. P., & Haviland, M. G. (2016). Evaluating bifactor models: Calculating and interpreting statistical indices. *Psychological Methods, 21*(2), 137–150. https://doi.org/10.1037/met0000045

UNESCO. (2023). *Global education monitoring report 2023: Technology in education—A tool on whose terms?* UNESCO Publishing. https://doi.org/10.54676/UZQV8501

van Dijk, J. A. G. M., & van Deursen, A. J. A. M. (2014). *Digital skills: Unlocking the information society*. Palgrave Macmillan. https://doi.org/10.1057/9781137437037

Vuorikari, R., Kluzer, S., & Punie, Y. (2022). *DigComp 2.2: The digital competence framework for citizens: With new examples of knowledge, skills and attitudes* (EUR 31006 EN). Publications Office of the European Union. https://doi.org/10.2760/115376