e-DigCompEdu: Validation of a Framework for Online Higher Education Through a Delphi Panel

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Abstract: This paper addresses the growing importance of digital competence for higher education professors due to the increasing technology integration in this sector. Existing frameworks, such as the European Framework for the Digital Competence of Educator (DigCompEdu), present limitations for higher education, particularly regarding the use of online and blended learning approaches, immersive technologies, and artificial intelligence. Such limitations motivated the development and validation of the e-DigCompEdu, an extended framework specifically designed for this context. The validation process employed a Delphi panel with international experts in distance education, initially involving 29 participants. The selection of specialists was based on their publication records across 40 high-impact distance education journals, involving the analysis of 25,980 authors. The experts evaluated the extended version of the DigCompEdu, with 12 new competencies, specifically considering three aspects: title and description, related activities, and proficiency levels. Experts were asked to rate the competence adequacy on a five-point scale and to offer qualitative feedback. Results showed overall improved adequacy scores, from the first to the second round, as well as an increasing positive evaluation of the competences relevancy. Although some competences experienced a slight reduction in mean scores, they showed decreased variance, demonstrating greater expert consensus. Ultimately, all 12 new competences were enhanced by expert contributions (qualitative) and subsequently validated (quantitative). The validated e-DigCompEdu framework effectively addresses the digital competence requirements from professors in the online education setting. It provides a robust resource for guiding professional development and informing institutional policies regarding the digital transformation of higher education practices.

Keywords: Digital competence, Teacher digital competence, DigCompEdu, Online education, e-Learning, Higher education

1. Introduction

Since the 1990s, the integration of digital technologies into higher education has grown substantially; presently the digital competence of educators is seen as paramount, given the escalating role of technology within educational practices (Palacios-Rodríguez et al., 2024). This expansion has been accelerated by the advancement of new digital technologies, broadening the scope of teaching and learning and fostering innovative pedagogical approaches in onsite and online education. In an increasingly digital society, these technologies are not merely supplementary, they have been reshaping educational practices, expanding access, and supporting new forms of knowledge creation and dissemination. Their integration into higher education frameworks ensures that both educators and learners develop the necessary digital competencies to navigate and thrive in contemporary academic environments (Modise & Molotsi, 2022; Nadzir & Bakar, 2023). In this context, technology and innovation have become increasingly crucial to the success of online learning. In the current digital era, technological advancements have transformed education, presenting new opportunities and challenges for students, educators, as well as institutions. With a wide range of digital tools and platforms available, students can access educational resources and engage in learning activities at their own pace and convenience. The ability to harness these competencies enhances students' capacity to benefit from the flexibility and convenience of online education, ultimately leading to a more positive and enriching learning experience (Nadzir & Bakar, 2023; Sattayaraksa et al., 2023).

Professors (meaning academics, lectures or other teaching professionals) face continuous challenges in integrating emerging technologies into the educational process, such as Learning Management Systems (LMS), mobile phones, and more recently, artificial intelligence-based solutions (Alainati et al., 2023; Farooq, Zaidi &

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Shah, 2024). In the context of online higher education, the increasing use of digital devices and web-based learning technologies highlights the importance of students' digital competences, as they play a crucial role in facilitating effective engagement and academic success (Kallas & Pedaste, 2022). Digital competence stands out as an essential skill, indispensable across all spheres of academic and professional life. It is also fundamental for the exercise of a full citizenship and for problem-solving in various daily life situations. Furthermore, it is recognised as one of the key competences for 21st-century learning (Chatwattana, 2021; Kassymova, Tulepova & Bekturova, 2023; Morachat & Seechaliao, 2024). Within the European Union context, since 2006, digital competence has been listed as one of the eight key competences for lifelong learning (Council of the European Union, 2018; European Parliament and Council of the European Union, 2006). It is also considered transversal to other key competences, as it is closely linked to the understanding and the use of digital technologies within these (Chatwattana, 2021; Karakış, 2022).

Just as the term 'digital competence' lacks consensus within the scientific community, a fact evidenced by the interchangeable use of terms such as Digital Literacy, eLiteracy, e-Skills, eCompetence, Technology Literacy, and Media and Information Literacy (Ferrari, Punie & Redecker, 2012), the same applies to the concept of Teacher Digital Competence (Benali & Mak, 2022; Cabero-Almenara, Romero-Tena & Palacios-Rodríguez, 2020; Horváth et al., 2025), which is the terminology adopted in this study.

Teacher Digital Competence (TDC) is defined as the set of knowledge, skills, and attitudes related to technological, informational, and communicative aspects applied within the professional context of teaching staff at all levels and sectors of a country's educational system (Benali & Mak, 2022; Cabero-Almenara, Romero-Tena & Palacios-Rodríguez, 2020; Horváth et al., 2025). This competence integrates scientific/content, pedagogical and didactic criteria to ensure the conscious and effective use of these elements in the teaching and learning processes, considering their implications for the development of students' digital competence.

It is important to highlight that the concept of digital competence is considered highly dynamic as it evolves and updates in parallel with the sociotechnological advancements (Moreno-Guerrero et al., 2021). This fact highlights the need for constant adaptation by both professors and students as new tools, platforms, and digital methodologies transform the teaching and learning process.

Digital competence, both of professors and students, plays a crucial role in performance within online learning environments, where technology-mediated interaction is essential. Proficiency in technology facilitates adaptation to the different challenges that may arise in these environments. When they possess adequate levels of digital competence, all individuals involved in online learning platforms become effective agents in the educational process, contributing to a more integrated and successful teaching and learning experience (Zabun, 2022).

This proficiency is even more significant in higher education, where timely and targeted interventions aimed at enhancing students' digital preparedness can lead to higher academic performance, greater satisfaction with courses, and a more positive perception of their own competences (Cabero-Almenara, Barroso-Osuna & Palacios-Rodríguez, 2021; Reyes-Millán et al., 2023; Santos, Pedro & Mattar, 2021; Moreira, Nunes & Casanova, 2023). Esteve-Mon, Llopis-Nebot and Adell-Segura (2020) further highlight that professors in higher education must increase their level of proficiency in digital competences to respond to new challenges and demands—an issue that has been widely discussed since the turn of the century and more intensively in the post-pandemic context (de Wit & Altbach, 2023).

To effectively address these new challenges and demands in technologically advanced learning environments, professors must integrate new technologies into their teaching practices (Aydın & Çelik, 2020). The development of digital competence among higher education professors thus plays a strategic role in fostering these competences in students, enabling them to meet the academic and professional demands of the contemporary world (Rintamäk, 2019). It is important to consider that many young people enter university without the minimum digital competence required to operate effectively in academic and professional contexts (Biel & Ramos, 2019). This scenario underscores the urgent need to train professors to promote the development of these competences in students, ensuring that technological management in the educational domain aligns with the demands of the 21st century.

Students' motivation in online learning environments is directly linked to their digital competence. According to Karakış (2022), there is a positive and statistically significant relationship between students' levels of digital competence and their motivation in online learning. Also, the quality of education, enhanced by the professors' mastery of digital knowledge and competences, plays a fundamental role in increasing student satisfaction and

engagement (Maulana & Arli, 2022). It is essential for the success of distance education to emphasise the importance of preparing both students and professors for the effective use of digital technologies.

Using a scale adapted from Ng (2012), which considers attitudinal, technical, cognitive, and social dimensions of digital literacy, Kayaduman, Battal and Polat (2023) found that students with higher levels of digital competence demonstrate greater self-regulation in online interactions, a crucial aspect in distance education. These skill sets are positively correlated with students' perceptions and have a direct influence on online learning. When combined with positive attitudes towards technology and advanced technical skills, they contribute to more effective interactions between student-content, student-professor, and student-student.

It is important to highlight the clear distinction between Emergency Remote Teaching (ERT) and planned, structured online education. While ERT was implemented as an improvised measure to ensure the continuity of lessons during the COVID-19 crisis, relying on available resources in an ad-hoc manner and without in-depth pedagogical planning, properly prepared online education requires an advanced set of digital competences (Bond et al., 2021; Hodges et al., 2020). Planned online education requires educators to strategically apply carefully selected pedagogical strategies and properly configured digital tools to design meaningful learning experiences, assess outcomes, and adapt methodologies to learners' needs (Holik et al., 2023).

High-quality online learning depends not only on institutional support and access to digital technologies, but also on educators' digital competence, which are essential for effective mediation, engagement, and student support in virtual environments. Online learning tools are only effective if users possess the skills to operate them; hence, it is crucial that educators continuously refine their digital competences through their everyday teaching practices, particularly in a rapidly evolving technological landscape (Getenet et al., 2024; Mudau & Modise, 2022; Nadzir & Bakar, 2023).

1.1 Frameworks

The development of frameworks focused on digital competence in education, whether for professors or educational organisations, has gained momentum through the support of official institutions that both promote and demand the advancement of these competences in a society increasingly immersed in digital Technologies (Díaz, Reche & Rodríguez, 2019).

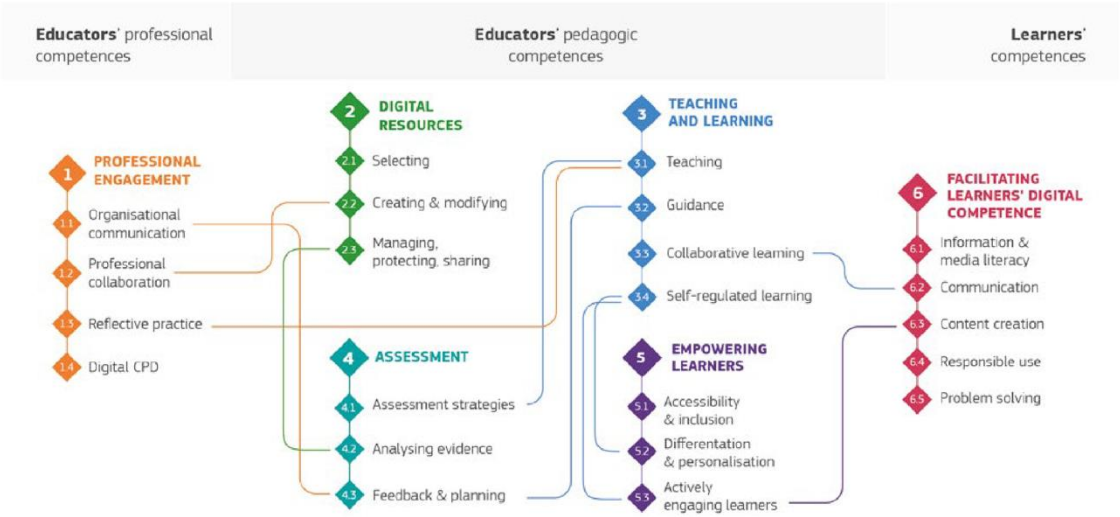
Based on the *DIGCOMP A Framework for Developing and Understanding Digital Competence in Europe* (Ferrari, 2013), several other frameworks have been developed for education, including the *European Framework for the Digital Competence of Educators: DigCompEdu* (Redecker, 2017), and the *European Framework for Digitally-Competent Educational Organisations* (DigCompOrg), aimed at educational organisations (Kampylis, Punie & Devine, 2015). Additionally, *DigComp 2.2: The Digital Competence Framework for Citizens* (Vuorikari, Kluzer & Punie, 2022), although primarily intended for the public, started to be applied to both professors and students, given that the former are responsible for fostering these competences in the latter (Pedro, Santos & Mattar, 2023).

1.2 DigCompEdu

Inspired by the *DigComp 2.1: The Digital Competence Framework for Citizens* (Carretero, Vuorikari & Punie, 2017), DigCompEdu focuses on enhancing the digital competences of educators across all levels of the educational system. This framework is structured into 22 competences, divided into six areas (Figure 1), encompassing six proficiency levels and employing a model of cumulative progression of the digital competence development.

DigCompEdu reflects a growing awareness among European member states of the importance of establishing specific actions for the promotion of digital competences for the teaching professionals. This framework aims to guide education professionals in adopting practices that harness the potential of digital technologies to enhance and innovate the educational process.

Although the European Union has developed several frameworks on digital competences for education, no specific framework explicitly considers online higher education. While DigCompEdu is designed to be applicable across all educational levels, it lacks key elements for addressing distance learning or blended learning (Mattar et al., 2020; Viñoles-Cosentino, Sánchez-Caballé & Esteve-Mon, 2022); also, it does not address emerging technologies such as Generative Artificial Intelligence, Immersive environments, among others.



Source: Redecker (2017, p. 8).

Figure 1: DigCompEdu

It has also been used as a central element in the development of extensions, incorporating new competences and transforming them into a highly specialised framework. Examples include the *Supplement to the DigCompEdu Framework: Outlining the skills and competences of educators related to AI in education* (Bekiaridis, 2024), and the present study, which aims to validate the *e-DigCompEdu: Digital Competencies for Online Higher Education extension*.

1.3 DigCompEdu as Reference for new Frameworks and Extensions

This framework has been widely used both within the European Union and world-wide. As an intrinsic characteristic of DigCompEdu, its applicability across all levels of education has allowed it to serve as a foundational framework for the development of new frameworks, as well as a central element for the creation of extensions. Notably, DigCompEdu has emerged in the literature as a central reference for the development of more specialised competence frameworks, both at macro and institutional levels. Some examples consider:

- "DigCompEdu-FyA", targeting university educators (Castañeda et al., 2023);
- *"Marco de Referencia de la Competencia Digital Docente"*, aimed at non-university Educators (INTEF, 2022);
- "*Pedagogical DigCompEdu Reloaded*", which focuses exclusively on the pedagogical dimension and is applicable across all levels of education (Moreira et al., 2024);
- *DigCompEdu Supplement: Defining Educators' AI Skills and Competences* (Bekiaridis, 2024);
- *Defining XR-Specific Teacher Competencies: Extending the DigCompEdu Framework for Immersive Education* (Rutten & Brouwer-Truijen, 2025).

The e-DigCompEdu presented in this article offers an extension of the original DigCompEdu framework, expanding and adapting its structure to address a specific educational context.

1.4 e-DigCompEdu

The development of e-DigCompEdu was carried out in three distinct phases, as illustrated in Figure *2*.

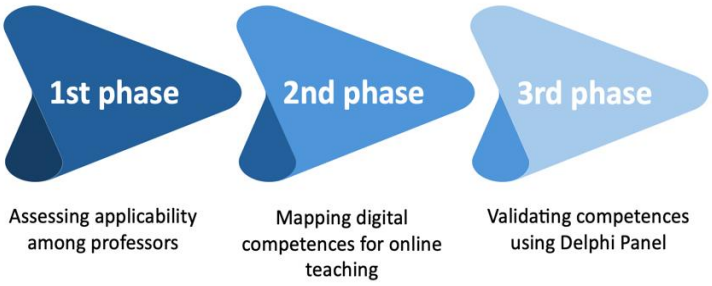


Figure 2: Phase of e-DigCompEdu construction

The e-DigCompEdu is structured around 12 new competences, with six of them being distributed across four existing areas of DigCompEdu, and numbered sequentially. The remaining six competences, due to their specific characteristics, have been grouped into two newly established areas: the scientific digital literacy and the digital management of online teaching and learning, as illustrated in Figure 3.

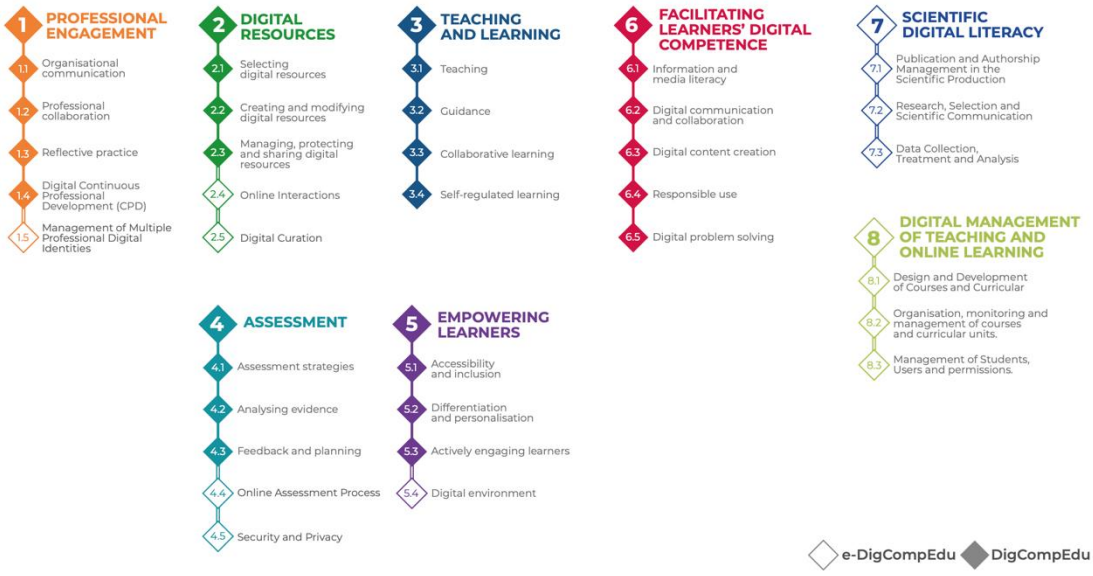


Figure 3: Integration of new competences and areas on DigCompEdu, resulting in the creation of e-DigCompEdu

In addition to expanding the scope of DigCompEdu, e-DigCompEdu emphasises the application of digital pedagogical strategies that foster accessibility, inclusion, and personalised learning. It provides detailed descriptors, activities, and proficiency levels, enabling professors and online higher education institutions to utilise the framework as a tool for training, assessment, and strategic planning.

The absence of a specific digital competence framework, tailored to the particularities of online higher education (Santos, 2023), has posed challenges to institutions and educators seeking structured guidance for pedagogical practices in virtual environments. While several frameworks address digital competences more broadly or across general educational levels, they often fail to incorporate essential components of fully online and blended learning contexts (Mattar et al., 2020). The development of the e-DigCompEdu aims to mitigate this absence by proposing a dedicated structure that integrates these missing elements and supports educators in navigating the specificities of distance higher education settings.

Accordingly, the aim of this article is to present the validation of e-DigCompEdu, an extension of the DigCompEdu specifically developed for online higher education. To that end, a Delphi panel of international experts in distance education is employed to appraise the clarity and adequacy of such a framework, i.e., its pedagogical relevance and utility, considering its alignment with the needs felt in higher education online teaching.

1.5 Validation Practices in Digital Competence Frameworks

The validation of any theoretical or conceptual framework is a fundamental pillar for ensuring its relevance, robustness, and scientific credibility. Validation processes typically involve a range of methodological strategies designed to guarantee the applicability and recognition of these models within educational and policy contexts.

A prevalent approach in such processes involves the collaborative consultation of groups of experts and stakeholders. The *DigCompConsumers, Digital Competence Framework for Consumers* (Brečko & Ferrari, 2016), for instance, was validated through workshops with experts and online consultations, engaging a select group of professionals in the areas of digital and consumer education. Similarly, the DigCompEdu (Redecker, 2017) underwent a rigorous scientific process, based on structured discussions and deliberations with European experts and dedicated working groups. Similarly, The *GreenComp: the European sustainability competence framework* (Bianchi et al., 2022) followed a consensus-building process, involving several rounds of consultations and workshops with experts in sustainability education.

Other commonly used methods for validation processes are literature reviews, inventories, and in-depth analysis of existing frameworks. These approaches were central to the development and validation of the DigCompOrg (Kampylis, Punie & Devine, 2015) and was complemented by expert consultations and thematic workshops. Similarly, the *EntreComp: The entrepreneurship competence framework* (Bacigalupo et al., 2016) employed a robust mixed-methods research design, validated through iterative consultation stages involving multiple stakeholders and online panel discussions.

In some cases, frameworks also integrate broad public engagement in their validation processes. The DigComp 2.2 (Vuorikari, Kluzer & Punie, 2022), and its update DigComp 3.0, currently under development, involved consultations with a wide range of stakeholders via a Community of Practice and interactive workshops, culminating in a public online survey to assess the relevance of the new proposed knowledge, skills, and attitudes.

1.6 Research Focus and Aims

Although multiple European initiatives address digital competence in education, there is no framework specifically oriented to online higher education. While transversal and widely adopted, DigCompEdu lacks key elements for fully or partially developed online education and does not incorporate new technological domains such as immersive technologies or generative artificial intelligence. These gaps motivated the development of the e-DigCompEdu presented in this article, which extends DigCompEdu with 12 new competences, organised across existing areas and two newly created areas, complemented by descriptors, activities, and proficiency statements targeted to the online higher-education context.

The aim of this article is to present the validation of the e-DigCompEdu as an extension of the DigCompEdu, specifically developed for online higher education, by using a Delphi panel. This validation process aims to ensure that the digital competences listed in such framework are aligned with the practical demands of online teaching, considering the specificities of this modality within the higher education context.

In this study, the term “adequacy” refers to the pedagogical relevance, usability, and alignment with the practical demands of online teaching in higher education. Specifically, this study seeks to: i. assess the adequacy of the proposed competences within the e-DigCompEdu, and ii. identify the level of consensus achieved regarding the framework.

By consulting a panel of international experts in distance education, this study seeks to refine and consolidate the framework, and, consequently, to assess its content validity for online higher education. The research question guiding this study is: To what extent does the e-DigCompEdu demonstrate content validity for online higher education, based on expert consensus on the adequacy of its title and description, related activities, and proficiency statements?

2. Methodology

This study adopts a mixed methodological approach, employing the Delphi panel as its data collection and analysis strategy. This method was selected for the validation and continuous refinement of the e-DigCompEdu through these experts' contributions. The panel of specialists iteratively reviewed and refined their assessments and recommendations throughout the different stages of the panel process.

This methodological choice was motivated by five main factors:

- Usefulness in the development of frameworks, one of the key expected outcomes of this approach when applied to educational and technological contexts (Almaiah et al., 2022; Oxley, Nash & Weighall, 2024):
- Ability to achieve consensus among experts, through a structured group communication process (Almaiah et al., 2022),
- Specific application in the validation of structures related to DigCompEdu (Munar-Garau, Oceja, & Salinas Ibáñez, 2024);
- Ability to incorporate multiple rounds of iterative feedback, allowing experts to review and refine their responses throughout the process, thereby enhancing the accuracy of the analysis (Malkawi, Bakar & Dahalin, 2023; Oxley, Nash & Weighall, 2024);
- Wide application to various scientific domains, including Education (Malkawi, Bakar & Dahalin, 2023; Niederberger & Renn, 2023; Oxley, Nash & Weighall, 2024), although its use is more firmly established in fields such as health, business, and technology (Malkawi, Bakar & Dahalin, 2023).

2.1 Delphi Panel

The name of this technique originates from the Oracle of Delphi, a sacred site dedicated to the god Apollo, where the ancient Greeks went to seek answers to complex questions. Its modern development began in the 1950s within U.S. defence institutions during the Cold War, with the objective of obtaining reliable consensus among experts on military strategies (Malkawi, Bakar & Dahalin, 2023).

In essence, the Delphi panel enables a structured, iterative, and systematic process, involving experts organised into a group, allowing for the progressive review and refinement of their assessments and recommendations. This process facilitates the development of informed consensus on complex issues and is widely applied in academic research, educational policymaking, as well as technological innovation (Almaiah et al., 2022; Malkawi, Bakar & Dahalin, 2023; Oxley, Nash & Weighall, 2024).

The iterative process, conducted across multiple rounds, allowed the consolidation of opinions between a carefully selected panel of experts, fostering a well-founded and robust consensus. This method is widely recognised for its ability to structure and progressively refine expert knowledge, enhancing decision-making through a structured and anonymous feedback process that reduces individual biases (Oxley, Nash & Weighall, 2024). The Delphi Panel is organised in rounds, where a group of experts is consulted to explore or resolve complex issues through the aggregation of their opinions. This process is typically iterative, allowing participants to adjust their responses based on the aggregated feedback received in previous rounds. The primary aim is to achieve a consensus or enhance understanding of a specific topic through the convergence of expert opinions.

According to Malkawi, Bakar and Dahalin (2023), the application of the Delphi panel requires the consideration of specific methodological parameters, such as the careful selection of the experts, the number of participants, the quality of the panel, the structuring of the iterative process in multiple rounds, and the criteria established for achieving the completion of the process. These aspects were rigorously followed in the present study to ensure the validity and reliability of the results, as recommended by Oxley, Nash and Weighall (2024).

Anonymity is a core feature of the Delphi panel, minimising the influence of social pressures and power dynamics, and promoting impartial contributions (Malkawi, Bakar & Dahalin, 2023). This principle was rigorously upheld throughout all stages of the panel, ensuring that expert feedback was guided solely by the merit of the content, free from external influence (Oxley, Nash & Weighall, 2024).

Regarding the number of rounds, Oxley, Nash and Weighall (2024) indicate that the exchange process may involve 3-4 rounds, since the results tend to stabilise rapidly after the third round. This iterative process offers experts multiple opportunities to adjust their responses based on aggregated feedback, sent between rounds, which promotes further refinement of contributions. On the other hand, Malkawi, Bakar and Dahalin (2023) emphasise that, unlike other methods, the primary aim of Delphi is not necessarily to reach a single response or an absolute consensus. Instead, the goal is to obtain a diversified, rich and high-quality set of insights.

In line with the commitment to ensuring anonymity throughout the process, a limited set of demographic data was collected exclusively for the purpose of profiling the specialists.

For this study, the Delphi panel was structured into five main stages (Figure 4), designed to obtain qualified contributions from experts. The following stages were carried out:

- Stage 1: Careful selection of experts, based on their expertise on the topic at hand, aligned with best practices described in recent references on Delphi panel (Malkawi, Bakar & Dahalin, 2023).
- Stages 2, 3, and 4 (Rounds): Focused on the iterative process of rounds, which is crucial for achieving consensus among experts, during which they had the opportunity to track and evaluate improvements based on the collective feedback obtained. Stage 2 involved the initial data collection from the panel, as suggested in best Delphi practices. During stage 3, suggestions and contributions collected previously across all rounds were analysed and integrated, promoting continuous improvement. At Stage 4, the consensus parameters were applied, and consolidation of opinions and identifications of points of convergence among the experts were developed. This iterative cycle allowed for a grounded and systematic progression towards reliable and consensual results.
- Stage 5: Consisted of drafting a final document based upon the consolidate inputs of the panel (final framework).

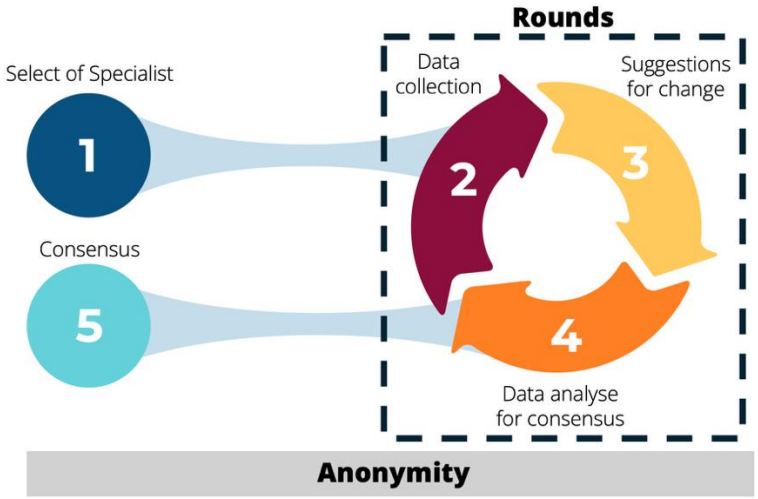


Figure 4: Five stages of the Delphi Panel

2.2 Stage 1: Selection of Specialist

Based on a bibliometric analysis conducted by Santos, Pedro and Mattar (2024), 40 high-impact journals in the field of distance education were selected according to SCImago rankings. The analysis of articles published in these journals from 2018 to 2023 revealed a total of 25,980 authors across 12,947 articles published in such journals. Taking that number of authors in consideration, for this study, a specialist was defined as any researcher who contributed with at least five publications of this dataset, averaging one publication per year. Using this criterion, we identified 888 eligible authors. An exploratory web-search facilitated the mapping of names, affiliations, and email addresses for 816 of these authors, who were then invited by email to participate in the study. In the first round, 29 specialists participated (3.5%). In the second round, only the 29 specialists who had participated in the first round were contacted, and ultimately, 16 specialists took part in the second round. In Figure 5, we quantitatively display the selection and participation in the two rounds of the Delphi panel.

This criterion ensured impartiality and academic merit, functioning as a bias-reduction mechanism and reinforcing the credibility and methodological rigour of the expert panel involved in the validation process.

The literature suggests that the number of experts participating in a Delphi panel study typically ranges from 10 to 30. Numbers lower than 10 may compromise the effective consensus and the relevance of the information obtained, while numbers exceeding 30 make the administration and analysis excessively complex, which tends to result in limited production of new ideas (Malkawi, Bakar & Dahalin, 2023; Oxley, Nash & Weighall, 2024).

The invitations to experts were nominal, with the platform allowing the identification of specialists who completed each round. This information enabled the fact that, in subsequent rounds, only participants who had contributed to previous stages were invited to continue, thereby ensuring consistency and continuity in the expert group throughout the iterative rounds.

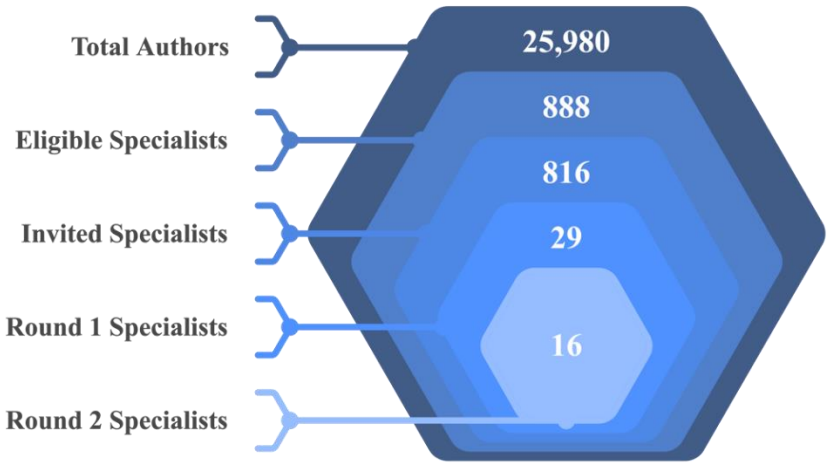


Figure 5: Selection of Specialists

2.3 Stage 2: Data Collection (Rounds)

Quantitative and qualitative (mixed methods approach) data were collected. The Delphi panel and the list of specialists (n=816), which includes names, affiliations, and email addresses, were integrated into the online data collection system LimeSurvey. This enabled personalised and individualised contact with the specialists, including personalised reminders for those who had not yet participated.

The survey was structured into two main blocks: “Block 1: Legal and Ethical Requirements and Participant Demographics”, which included the study presentation, the informed consent, and the data protection policy, ensuring fully compliance of the study with ethical standards. It also collected basic demographic information solely for characterising the panel, and “Block 2: Competence Validation”, which focused on the evaluation of the newly proposed e-DigCompEdu competences. Experts assessed each competence across three topics: title and description, related activities, and proficiency levels.

2.3.1 Question block 1: Legal and ethical requirements and participant's demographics

This section began with a brief description of the study, content that had already been provided in the email invitation. To proceed, participants were required to select the option "I accept to participate." On this page, the "Data Protection Policy" and the "Informed Consent Form" were also available for the specialists to read and to accept.

For the demographic characterisation of the specialist, only one question was presented focusing exclusively on the geographical location of their research activities ("In which region have you predominantly practised your research in the last 5 (five) years?") The options included regions such as Asia, Africa, America, Europe, Oceania, and Antarctica.

2.3.2 Question block 2: Competence validation

As previously mentioned, 12 new competencies were submitted for validation to the panel, with six integrated into the existing areas of the original framework (DigCompEdu) and six allocated across two completely new areas. Each digital competence (e.g. competence 1.5. Management of Multiple Professional Digital Identities) was assessed across three topics: 1. title and description (Figure 6); 2. related activities (Figure 7); and 3. proficiency statements (Figure 8).

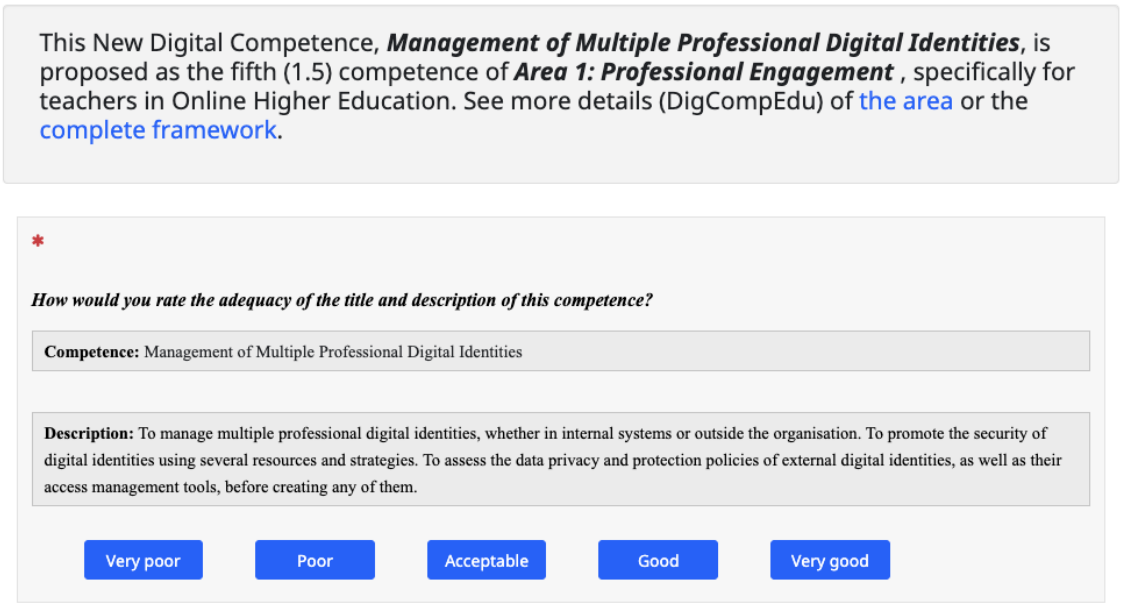


Figure 6: Example of competence title and description

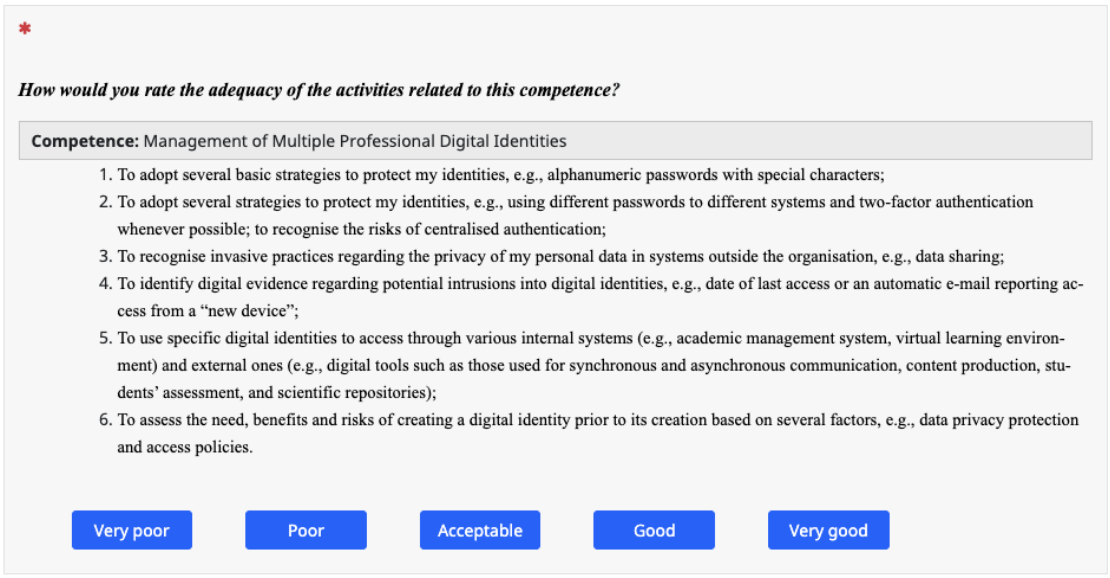
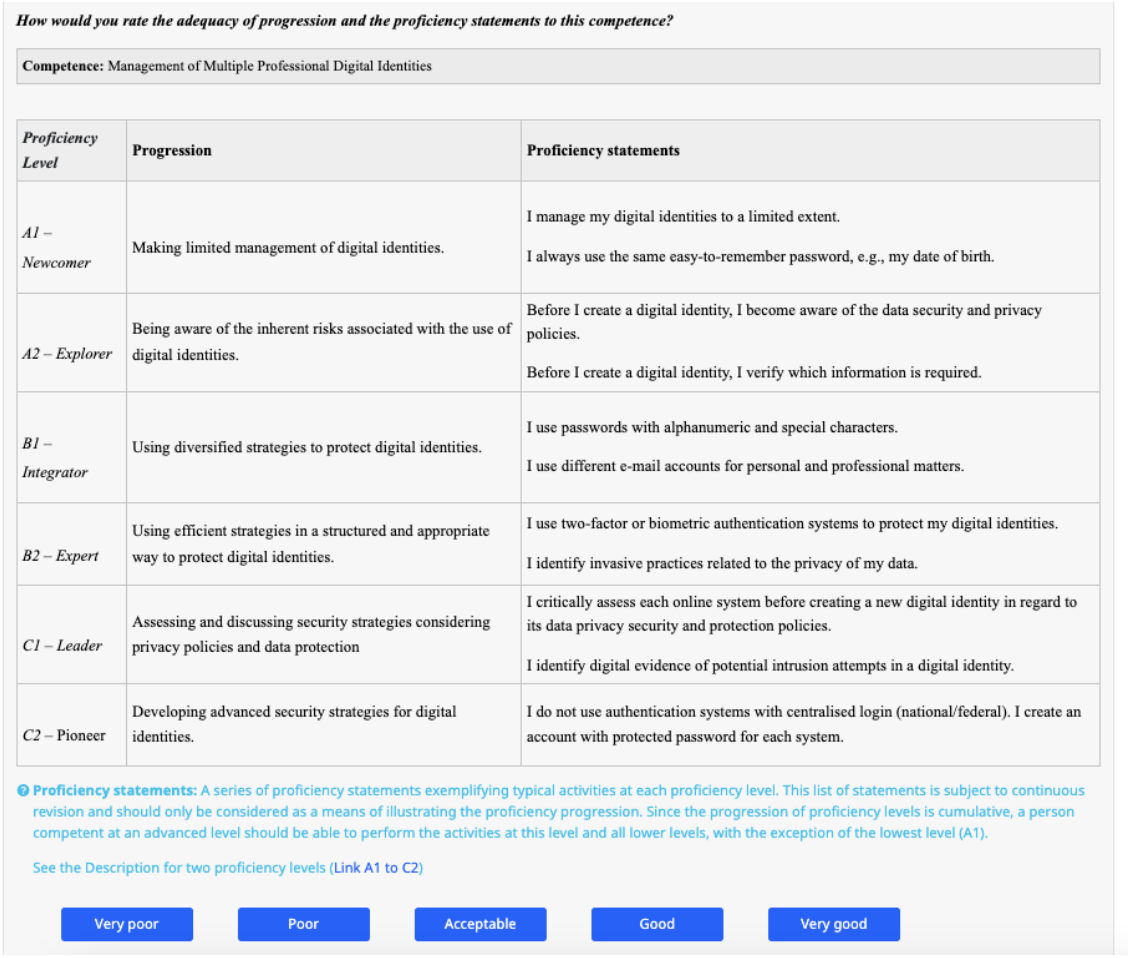


Figure 7: Example of competence related activities



How would you rate the adequacy of progression and the proficiency statements to this competence?

Competence: Management of Multiple Professional Digital Identities

Proficiency Level	**Progression**	**Proficiency statements**
A1 – Newcomer	Making limited management of digital identities.	I manage my digital identities to a limited extent. I always use the same easy-to-remember password, e.g., my date of birth.
A2 – Explorer	Being aware of the inherent risks associated with the use of digital identities.	Before I create a digital identity, I become aware of the data security and privacy policies. Before I create a digital identity, I verify which information is required.
B1 – Integrator	Using diversified strategies to protect digital identities.	I use passwords with alphanumeric and special characters. I use different e-mail accounts for personal and professional matters.
B2 – Expert	Using efficient strategies in a structured and appropriate way to protect digital identities.	I use two-factor or biometric authentication systems to protect my digital identities. I identify invasive practices related to the privacy of my data.
C1 – Leader	Assessing and discussing security strategies considering privacy policies and data protection	I critically assess each online system before creating a new digital identity in regard to its data privacy security and protection policies. I identify digital evidence of potential intrusion attempts in a digital identity.
C2 – Pioneer	Developing advanced security strategies for digital identities.	I do not use authentication systems with centralised login (national/federal). I create an account with protected password for each system.

Proficiency statements: A series of proficiency statements exemplifying typical activities at each proficiency level. This list of statements is subject to continuous revision and should only be considered as a means of illustrating the proficiency progression. Since the progression of proficiency levels is cumulative, a person competent at an advanced level should be able to perform the activities at this level and all lower levels, with the exception of the lowest level (A1).

See the Description for two proficiency levels (Link A1 to C2)

Very poor | Poor | Acceptable | Good | Very good

Figure 8: Example of competence proficiency statements

The specialists were consulted on each of these dimensions regarding three specific questions:

- Dimension 1: "How would you rate the adequacy of the <<topic>> of this competence?" Specialists could assess using a five-point scale ranging from a) Very poor, b) Poor, c) Acceptable, d) Good, to e) Very good, numerically corresponding from 1 to 5 points. Quantitative data were collected.
- Dimension 2: "Would you propose any changes to the <<topic>>?" Specialists had the options "Yes" or "No". If "Yes" was selected, dimension 3 would be activated; if "No", the contribution was concluded. Dichotomic data (Yes: 1; No: 0) were collected.
- Dimension 3: "What changes would you propose to the <<topic>>?" If changes were suggested (dimension 2 = "Yes"), a text box was made available for the specialist to detail their proposed modifications. This response field was conditional. Qualitative data were collected.

In Figure 9, we present the example of competence “1.5 - Digital Identity Management and Security”, specifically within the "title and description" topic, across its three dimensions.

Thus, considering the 12 competencies, the experts responded to 24 mandatory questions, and 12 conditional ones. The two new areas were assessed only in dimension 1, "title and description", resulting in four mandatory questions and two conditional ones. In total, the validation question block comprised 42 questions, of which 28 were mandatory and 14 were conditional.

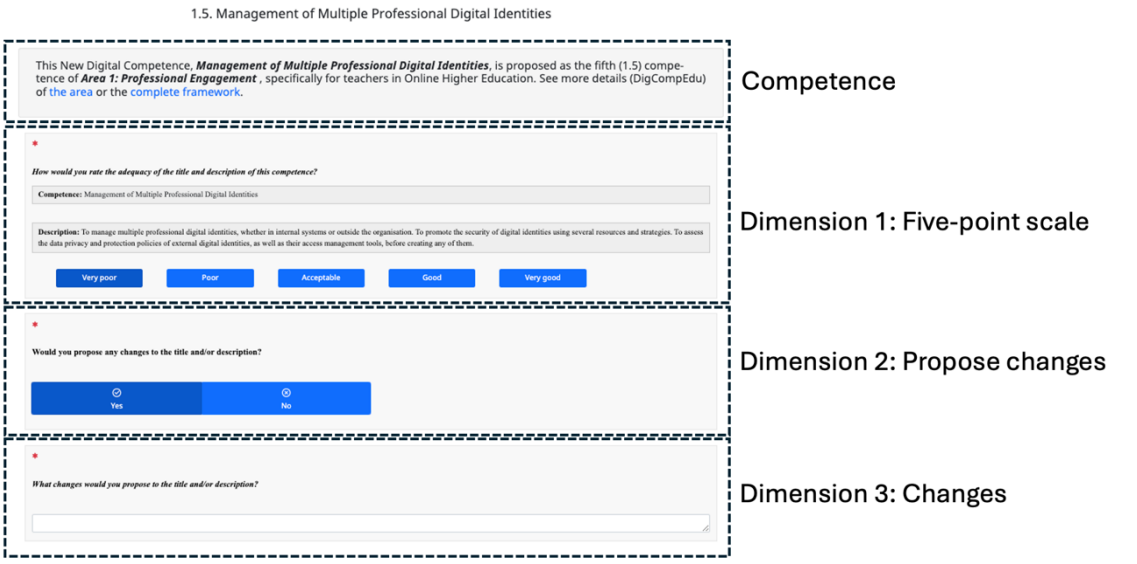


Figure 9: Example of the questions presented to experts

2.4 Stage 3: Suggestions for Change Analysis (Rounds)

During the analysis process, suggestions were reviewed for each dimension of the competencies and areas assessed. In Figure 10, we can observe the analysis and incorporation of suggestions from the specialists regarding the competency "4.5 Security, Privacy and Ethical Conduct" of topic "title and description", which received change suggestions from four specialists.

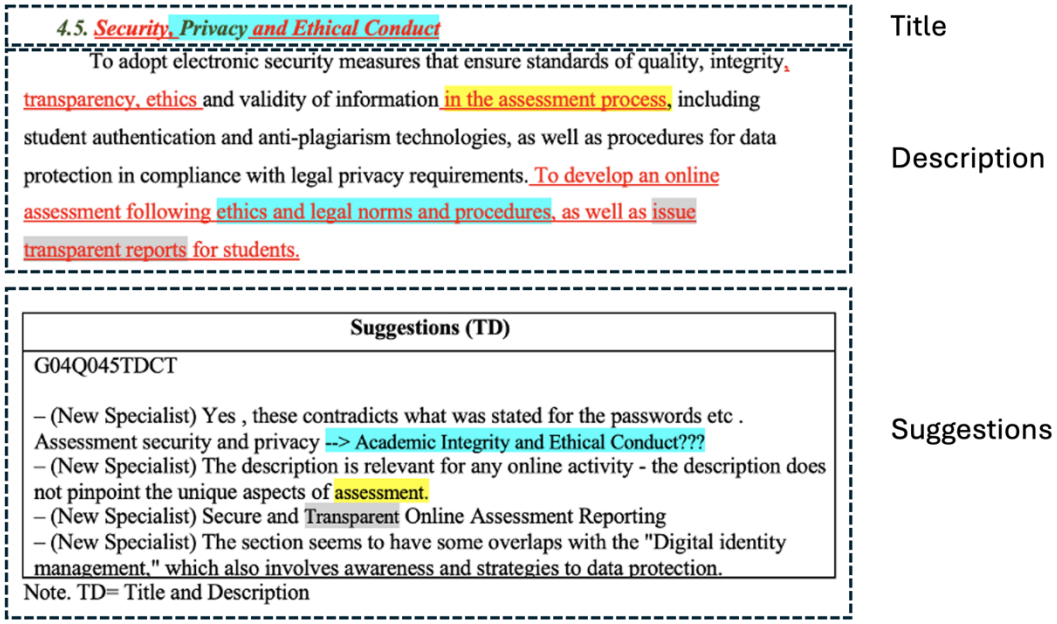


Figure 10: Example of the process of incorporating the suggestions

2.5 Stage 4: Data Analysis for Consensus (Rounds)

Throughout the rounds, both quantitative and qualitative (mixed methods approach) data were collected. The integration of these qualitative and quantitative insights across successive rounds enriches the process and improves the overall quality of the results. Quantitative analyses were performed in IBM SPSS Statistics, version 29, using descriptive parameters (mean and variance, i.e., the square of standard deviation) of consistency as defined by Delphi best practice. Qualitative data were organised and coded in NVivo, version 14, following

thematic content analysis aligned with the three topics assessed for each competence (title and description; related activities; proficiency statements).

Qualitative analysis procedure

In rounds, participants were invited to submit improvement suggestions for each of the 12 new competences and two new areas. These suggestions were treated as structured qualitative feedback for refinement. The analysis followed a reflexive thematic approach as proposed by Braun and Clarke (2022). Themes were reviewed to identify areas of convergence and actionable refinement, supporting the revision of the framework for Round 2. All contributions were anonymised, analysed and considered without any differentiation from authors' country/region.

Quantitative analysis procedure

Quantitative data were collected using a five-point (1-5) scale for Dimension 1, ranging from 1 "Very Poor" to 5 "Very Good". Descriptive statistical techniques, means (evaluation score) and variance (consensus score), were applied. This choice is supported by Malkawi, Bakar and Dahalin (2023), who reviewed 60 Delphi studies in higher education and identified mean, median, and standard deviation as the most frequently used statistical parameters.

2.6 Stage 5: Stopping Criteria

Descriptive statistical techniques were established as parameters for scoring panel's evaluation and consensus. Based on a 5 points scale, statistical parameters were calculated to quantify the assessment of the items adequacy and the consensus level achieved between specialists.

- **Evaluation of adequacy:** The adequacy of the competences was determined by the arithmetic mean of the responses on the scale. A high mean score indicates a positive evaluation of the item, suggesting that the specialists view it favourably (> 3.50 points). Conversely, a reduced mean score points to a less favourable evaluation.
- **Level of Consensus:** The variance of the responses measures consensus among the specialists. A higher variance indicates a reduced level of agreement, reflecting diverse opinions and a lack of consensus. On the other hand, a lower variance indicates a high degree of agreement, suggesting that the specialists are aligned in their assessments.

3. Results

The results obtained in this study are presented in three main sections, providing a detailed overview of the validation process of the e-DigCompEdu.

3.1 Characterisation of Specialists

In the first round, the respondents (n=29) included participants from all five continents. However, in the second round (n=16), only specialists from Asia (n=8) and Europe (n=8) participated (Figure 11).

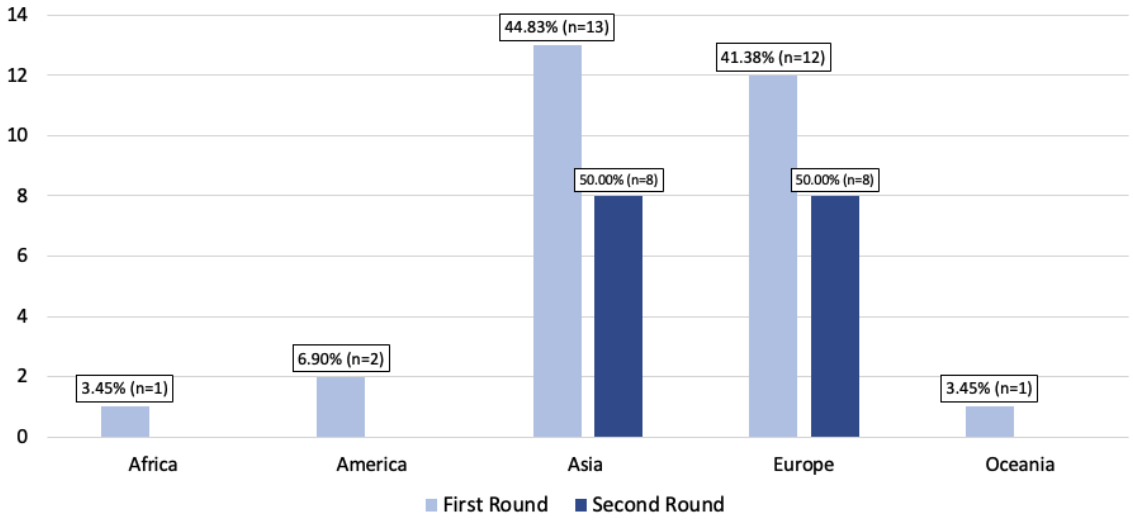


Figure 11: Geographic distribution of specialists

3.2 Evaluation and Consensus (Dimension 1)

In this study, two rounds were conducted:

- 1st Round – Data collection took place from September to December 2023. January 2024 was dedicated to processing this data and preparing for the second round.
- 2nd Round – Collection occurred between February and May 2024. The results of this round were pivotal in making the final decisions: the closure of the process.

3.2.1 Overall

Considering the overall terms the mean score in the first round was 3.89, which is close to the "good" (4) rating on the scale. In the second round, the global results showed a mean of 4.07, thus consolidating the "good" classification and indicating an increase in the global mean between rounds.

3.2.2 Competences and areas

The general adequacy of the competences was calculated by averaging the scores assigned to the three topics evaluated for each item: title and description, related activities, and proficiency statements. Differently, on areas 7 and 8, the mean adequacy refers to the "title and description".

Results indicate that the mean adequacy was high in all the new competences (> 3.5 points) and also that it increased between the first and second Delphi rounds for 11 of the 12 competences demonstrating an overall improvement in clarity and alignment with the experts' expectations. The only exception was Competence 4.4, which maintained the same mean score across rounds. This trend is illustrated in Figure 12, which summarises the comparative means and highlights the progression toward consensus.

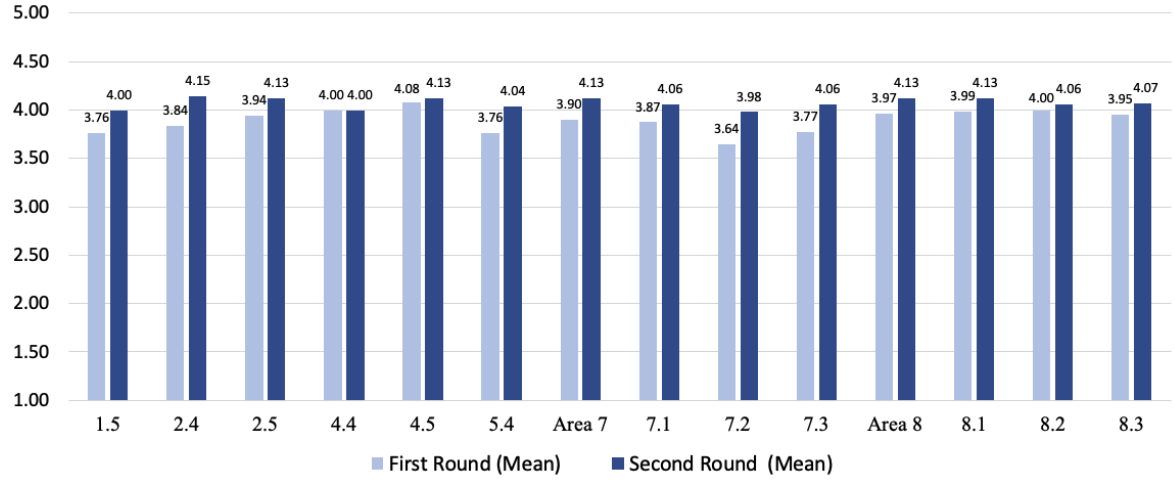


Figure 12: Means scores found in competences and areas on the two rounds

3.2.3 Topics (title and description, related activities, and proficiency levels)

As an initial parameter for analysing the determination to close the rounds of the Delphi panel, an increase in the mean across the various dimensions in which the competencies were assessed was considered. This suggests that the specialists view favourably the new version presented in the second round (Table 1). In cases where the mean did not show an increase, variance was checked, where lower variance indicates a higher degree of agreement (Table 2)

Table 1: Mean Competence

Competence / topic	First Round			Second Round		
	Title and description	Related activities	Proficiency statements	Title and description	Related activities	Proficiency statements
1.5. Digital Identity Management and Security	3.69	3.79	3.79	3.94	4.13	3.94
2.4. Online Engagement	3.76	3.83	3.93	4.13	4.38	3.94

Competence / topic	First Round			Second Round		
	Title and description	Related activities	Proficiency statements	Title and description	Related activities	Proficiency statements
2.5. Digital Curation	4.10	3.90	3.83	4.13	3.88 [a]	4.38
4.4. Online Assessment Process	4.00	4.03	3.97	4.06	3.88 [a]	4.06
4.5. Security, Privacy and Ethical Conduct	4.21	4.10	3.93	4.06 [a]	4.13	4.19
5.4. Digital Learning Environments Literacy	3.69	3.72	3.86	4.13	4.06	3.94
Area 7: Scientific Digital Literacy	3.90	-	-	4.13	-	-
7.1 Written and Management of Scientific Outputs	3.76	3.93	3.93	4.13	4.13 [a]	3.94
7.2. Research, Selection and Scientific Dissemination	3.45	3.76	3.72	3.94	4.00	4.00
7.3. Research Data	3.72	3.83	3.76	4.06	4.06	4.06
Area 8: Digital management of teaching and online learning	3.97	-	-	4.13	-	-
8.1. Design and Create Online Courses	4.03	3.97	3.97	4.06	4.13	4.19
8.2 Implement Online Courses	3.97	4.07	3.97	4.13	3.88	4.19
8.3. Management of Student's enrolment	4.03	3.90	3.93	4.06	4.00	4.06

Note. [a] Reduction in the mean between the first and second rounds.

Table 2: Mean and Variance of Competence

Competence	Topic	First Round Mean (Variance)	Second Round Mean (Variance)
2.5 Digital Curation (Area 2)	Activities	3.90 (0.645)	3.88 (0.359)
4.4 Online Assessment Process (Area 4)	Activities	4.03 (0.585)	3.88 (0.484)
4.5 Security, Privacy and Ethical Conduct (Area 4)	Title and description	4.21 (0.647)	4.06 (0.434)
8.2 Implement Online Courses (Area 8)	Activities	4.07 (0.409)	3.88 (0.234)

Of the 12 competencies submitted to the validation of experts through the use of the Delphi panel methodology, eight were considered validated based on the initial parameter, which is the high scores found in both rounds, and the increase in the mean scores from the first to the second round considering the three-topic analysed. The other four competences (Table 2), which showed a reduction in at least one of the topics, were analysed in terms of variance reduction, demonstrating a decrease in it. Based on these parameters, after the second round, it was considered unnecessary to conduct further rounds, concluding with the incorporation of the contributions in the last round and the full validation of the e-DigCompEdu.

3.3 Suggestions for Improvement (Dimension 2 and 3)

Regarding suggestions for changes to the topics presented in the first round, the specialists submitted 211 suggestions, averaging 7.24 suggestions per specialist. In the second round, 101 suggestions were received, averaging 6.31, thus representing a decrease in the mean number of suggestions made by the specialists. This reduction in both the total number of suggestions and the average per specialist can be interpreted as a possible indication of increase in consensus.

3.4 Final Version of e-DigCompEdu

The e-DigCompEdu was developed to complement the original DigCompEdu framework, incorporating 12 new digital competencies specifically created considering online higher education; six were integrated into the

existing areas of DigCompEdu, and the other six were distributed across two new areas created specifically to address such context.

The competences integrated into the existing areas included: Competence 1.5 which was incorporated into Area 1; 2.4 and 2.5 which were added to Area 2; 4.4 and 4.5 which were included in Area 4; and 5.4 which was integrated into Area 5. Additionally, Area 7, 'Scientific Digital Literacy,' and Area 8, 'Digital Management of Teaching and Online Learning, were created, integrating three competences each. In Figure 3, as mentioned above, it is possible to observe the integration of the 12 new competencies with the 22 existing competences of DigCompEdu.

4. Discussion

The methodological approach adopted in this study aligns with validation standards already established in the development of other digital competence-related frameworks, particularly in terms of expert consultation. Similar to frameworks such as DigCompEdu, GreenComp, and DigCompConsumers, this study involved a panel of specialists to ensure that the framework reflects relevant and context-sensitive competences for its intended domain. However, this work extends the common practice of qualitative expert feedback by incorporating quantitative adequacy assessments for each competence element, including titles and descriptions, related activities, and proficiency statements. By integrating both qualitative and quantitative methods within a Delphi panel structure, the study offers a methodologically robust validation process. This dual approach strengthens the reliability of the findings and contributes to the framework's credibility for potential adoption in varied institutional and international contexts. This methodology, widely recognised in research requiring complex analysis and evidence-based consensus (Malkawi, Bakar & Dahalin, 2023), proved to be particularly effective for the validation of the framework.

The careful selection of specialists was central to ensuring the credibility of the results. Defining the inclusion criterion as academic production in high-impact journals in the field of 'Distance Education' enabled the formation/selection of a highly qualified and representative panel. Additionally, the geographical diversity of participants enhanced the validity of the data by considering the inputs for subjects from different contexts and backgrounds. This methodological approach ensured that the contributions reflected a broad spectrum of practices and demands in online higher education.

Another important aspect of using the Delphi panel was its ability to integrate both quantitative and qualitative contributions. The combination of a numerical scale of responses with open-ended suggestions resulted in a robust analysis process, enabling the identification of points of convergence and divergence among the experts, and leading to the refinement of the framework. This iterative exchange of contributions among the experts fostered a collective and evidence-based construction process, demonstrated by the increase in mean ratings and the reduction in variances between rounds.

Variations in the digital competence levels among faculty have direct implications on their performance, particularly in the context of distance education (Maulana & Arli, 2022). According to Sever and Çatı (2021), there is a positive relationship between digital competence levels and faculty attitudes and satisfaction regarding online teaching and infrastructure. These findings reinforce that the increase in digital competences is directly associated with relevant improvements. To implement digital education effectively, it is essential to develop faculty digital competences, with an emphasis not only on the use of tools but also on pedagogically suitable content creation (Holik et al., 2023).

During the validation process of the competences, it was observed that some items showed a reduction in the mean rating scores (1-5) between the first and second rounds, which required careful analysis. Among these items are Digital Curation (Area 2 - Topic activities), in which there was a mean decrease from 3.90 to 3.88, while the variance dropped from 0.644 to 0.359; Online Assessment Process (Area 4 - Topic activities), with a reduction in the mean from 4.03 to 3.88 and in the variance from 0.585 to 0.484; Security, Privacy and Ethical Conduct (Area 4 - Topic title and description), which also had its mean decreased from 4.21 to 4.06, while the variance dropped from 0.647 to 0.434; and Implement Online Courses (Area 8 - Topic activities), which mean reduced from 4.07 to 3.88, while the variance dropped from 0.409 to 0.234.

Although the decrease in means initially suggests a less favourable evaluation, the reduction in variance indicates a greater alignment in the experts' opinions, signalling that the contributions made between rounds refined the items, promoting greater clarity and consensus. The Delphi panel allowed for a productive management of divergences, transforming the varied opinions into valuable contributions for adjustments,

enabling the dimensions comprising each of the 12 competencies and the two new areas created, to be better defined and to become more applicable within the context of online higher education.

Although there was a reduction in the number of specialists participating (attrition) in the second round, this phenomenon is a common and expected feature of the Delphi panel methodology, due to the demanding nature of iterative consultation (Almaiah et al., 2022; Malkawi, Bakar & Dahalin, 2023; Oxley, Nash & Weighall, 2024). This attrition does not compromise the validity of the results, as the expert panel in the first round already comprised specialists from all five continents, ensuring broad international representation. Furthermore, the foundation of the e-DigCompEdu was not built upon a single national search, but rather it was grounded in international literature and a generic competence mapping for online higher education. These elements strengthen the framework's global applicability and support its adaptability across diverse institutional and cultural contexts.

The progressive refinement and expert consensus achieved across the three core topics (title and description, related activities, and proficiency statements) indicate that the e-DigCompEdu demonstrates validity for the context of online higher education. The observed increase in mean adequacy, the decrease in variance and in the suggestions for improvement across rounds reflect not only a growing alignment among experts, but also the internal consistency and clarity of the framework's descriptors.

The organisation of the 12 validated competences in e-DigCompEdu reflects a logical and functional structure aimed at addressing the specificities of online higher education, following the DigCompEdu model. The competences were integrated into both the existing areas of DigCompEdu and the new areas created to fill the identified gaps. This organisation was based on the need to align the competences with the specific characteristics of online higher education, such as the management of virtual environments and the production of scientific content in digital formats. The distribution of competences across different areas enhances the clarity and applicability of the framework, making it practically useful for teachers and institutions.

The e-DigCompEdu is designed not only to support teachers' professional growth but also to guide the formulation of institutional strategies that foster the digital transformation of online higher education. Its application is considered essential to overcome challenges related to the quality of online education, such as the design of pedagogically thoughtfully planned online activities and the promotion of ethical and inclusive practices in virtual learning environments. To ensure effective and engaging online teaching experiences, it is necessary to invest in the continuous training of teaching staff as well as other support services (Maulana & Arli, 2022; Sattayaraksa et al., 2023). Changes in how teachers teach and how students learn in digital environments demand that today's educators not only enhance their academic profiles but also acquire and update their digital knowledge, essential for thriving on social media, immersive worlds and artificial intelligence-based solutions. These competencies, along with other professional attributes, are fundamental components for delivering quality online instruction (Lantaya, 2024).

5. Conclusion

Considering the study's objectives: i. assessing the adequacy of the proposed competences within the e-DigCompEdu framework and ii. identifying the level of consensus achieved regarding its structure, this concluding section reflects on the key findings and their implications.

The Delphi panel has proven to be an effective methodological approach for the validation of e-DigCompEdu. Its application facilitated the structured and iterative integration of contributions from international experts, resulting in a comprehensive and robust framework that effectively addresses the practical and global needs of online higher education.

The results directly address the research question by confirming that the e-DigCompEdu demonstrates content validity for online higher education. This was evidenced by the growing expert consensus on the adequacy of its three core components: title and description, related activities, and proficiency statements.

The results proved the complementarity between the e-DigCompEdu and the DigCompEdu frameworks, and validated the integration of specific aspects of online higher education. The e-DigCompEdu is intended to be globally applicable with contextual adaptation. Its core competence structure is conceived as universal, while descriptors, activity examples, and proficiency statements should be localised to national regulations and institutional arrangements. This intention (the global applicability) is supported by three elements of the study design and evidence: (i) the framework was grounded in international literature and in a generic mapping of competences for online higher education rather than any national syllabus; (ii) the validation drew on an

international expert panel—Round 1 included specialists from all five continents, and Round 2 involved two continents; and (iii) the mean adequacy scores generally increased while variances decreased between rounds, indicating a growing convergence. Together, these features provide evidence of content validity and transferability beyond Europe, while preserving room for contextual tailoring.

The contextual adaptation can be by national or institutional types, according to legal, cultural, or institutional constraints. For example, some digital competences within the framework may be delegated to technical teams or academic support staff rather than to educators themselves. This highlights the need for contextual adaptations to ensure the framework's relevance and applicability.

Given the rapid advancement of emerging technologies (such as generative artificial intelligence, data analytics, and immersive environments), it is essential that its descriptors undergo regular evaluation and adjustments. The continuous incorporation of new technological demands will not only ensure that the framework remains up to date but will also strengthen its alignment with the structural transformations in online higher education.

Despite the methodological robustness of the Delphi panel, this study is not without limitations. Participant attrition across multiple rounds is a common challenge due to the demanding nature of the process. Additionally, there is a potential for non-response bias, particularly related to participant dropout between rounds. While strategies such as personalized invitations and individual reminders were used to encourage continued participation, the absence of responses from part of the original panel may have, to some extent, influenced the final representativeness of the results. Nevertheless, the international composition of the first-round panel and the consistency of the procedures throughout the process help mitigate this limitation. The pursuit of consensus may also reduce the visibility of minority viewpoints, although all contributions were systematically analysed. The subjective nature of expert judgment, and potential individual biases, such as *pro domo* tendencies, may influence the outcomes, even though measures were taken to preserve anonymity and reduce such risks.

The e-DigCompEdu not only guides and structures the professional development of educators but can also serve as a foundation for the formulation of institutional policies aimed at faculty training and digital transformation. Institutions may begin its implementation by conducting a self-assessment or diagnostic process based on the framework, followed by the contextual adaptation of descriptors, if necessary, to local and institutional settings, and the progressive integration into training programs, faculty appraisal systems, and curriculum design processes. Its adoption may be strategic for the development of structured programmes focused on pedagogical innovation and the enhancement of online higher education quality. However, challenges related to institutional implementation must be considered, including resistance to the adoption of new technologies, gaps in teacher training, and limitations in technological infrastructure.

Future studies could explore strategies to overcome these barriers, such as institutional incentives, continuous training based on learning analytics, and policies tailored to the diverse realities of institutions. Another direction is the development of a proficiency-level assessment instrument based on the e-DigCompEdu framework, enabling educators and institutions to diagnose individual or collective gaps and to implement more targeted and effective training initiatives, to be piloted with distance education teachers and to undergo reliability and validity testing through structural equation modelling.

AI Statement: The authors declare that they have not used generative or assisted artificial intelligence tools at any stage of the paper's conception and revision. All content presented results exclusively from the author's autonomous work, which guarantees originality, integrity, and compliance with ethical and scientific principles.

Ethics Committee: The Ethics Committee of the Institute of Education of the University of Lisbon granted approval for the various stages of this research process (approval No. 2906)

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