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MetaFramEdu: A Competency Framework for the Metaverse in Education

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Abstract: The emergence of virtual worlds in the Metaverse introduces new possibilities-and demands-for educators designing learner-centered digital experiences. However, a structured framework covering the pedagogical, technological, social and ethical competencies necessary for the educational use of the Metaverse is lacking. This study presents MetaFramEdu, a multidimensional competency framework developed to support educators and educational institutions in the effective and responsible integration of virtual worlds into educational practice. Based on existing digital competency frameworks and recent research in immersive learning, MetaFramEdu defines core and specialized competency areas such as: (1) Virtual Environment Design, (2) Pedagogical Implementation, (3) Technological Dimension, (4) Digital-Social Management, (5) Ethics, Safety and Inclusion, etc. For each domain, performance indicators and proficiency levels are proposed. This paper outlines the theoretical underpinnings, development methodology, framework structure, and implications for teacher education and professional development.

Keywords: Metaverse, digital competence, immersive learning, teacher frameworks, virtual environments.

I. INTRODUCTION

The rapid growth of Metaverse platforms – such as Meta Horizon, Microsoft Mesh, Spatial, FrameVR and Engage – has sparked global interest in their potential as educational tools [1]. These 3D environments based on avatars, i.e. virtual representations of users, encourage new forms of interaction, immersion and action by students [2]. However, the effective use of the Metaverse in formal education requires teachers to develop a new set of skills that go beyond traditional ICT competencies [2].

As educational institutions increasingly embrace the metaverse as a viable learning medium, the need for a well-defined competency framework for teachers becomes paramount [1]. This framework should include a broad range of skills, knowledge and attributes that enable teachers to effectively navigate the metaverse and harness its potential to improve their students' learning outcomes [40].

While the existing frameworks such as DigCompEdu [3] and TPACK [4] offer strong constructs for general digital competencies, they do not deal with the special characteristics of the Metaverse, especially spatiality, multisensory access, and immersive capabilities. Filling this gap, we introduce MetaFramEdu (Metaverse Competence Framework for Education): this is a framework structured for assessing and developing competencies required to integrate Metaverse environments into education.

The MetaFramEdu framework adds value by providing a specialized, evidence-based conceptual background-theory-that guides the making of educational policies and the design of training for all educational levels, heavily emphasizing the use of the metaverse. The framework acts as a reference model; educational institutions, researchers, and organizations can swiftly and accurately develop assessment and training tools based on the framework's rendered output. They may adapt to specific needs and contexts without having to build a new conceptual framework from scratch.

The terminology and coherent framework logic introduced by MetaFramEdu will improve interoperability, facilitate scientific dialogue and enhance the exchange of best practices between educational and research communities at national and international levels.

This study has the following structure: Section II is the literature review and related contexts, section III is the methodology for developing the framework, Section IV is the results of developing the framework, section V is the discussion of the framework, and Section VI is the conclusions, limitations, and future actions.

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II. LITERATURE REVIEW AND RELATED CONTEXTS

2.1. Immersive Learning and the Metaverse

The metaverse is a virtual space in three dimensions where users can create their avatars, interact with each other and digital objects, and enjoy varied experiences [41]. It is a multisensory virtual shared online space that combines 3D graphics, either on a screen or in virtual reality devices [5,6].

The metaverse is a persistent, shared, 3D virtual world that users can access through the Internet [7]. A new world birthed at the intersection of physical and digital lives, the metaverse is an expanding ecosystem of 3D virtual worlds where individuals can socialize, interact, conduct business, and participate in activities as they see fit [8]. In this manner, the Metaverse is another way to engage reality in all of its forms, real, augmented, virtual or in mixed form [9].

The role of the metaverse in education can revolutionize learning for students by creating engaging, immersive and personalized learning experiences. Metaverse platforms enable student-centered and constructivist learning approaches such as problem based learning, gamification, and simulation based learning. Studies indicate enhanced motivation, spatial comprehension and collaborative engagement [10].

The introduction of the metaverse is a paradigm shift in how we understand and engage with the virtual world, requiring a critical re-examination of the role and potential of educators in the new world. The immersive quality, interactive ability, and connectivity of the metaverse bring amazing possibilities and intricate challenges for education [11]. The metaverse allows a unique combination of education and play, making learning environments more stimulating and encouraging students to engage [12].

2.2. Digital Competency Frameworks

The development of competency frameworks for the digital age has been a field of intense research over the past two decades, with the introduction of new technologies constantly requiring new approaches and adaptations.

Structures like **DigCompEdu** [3] and **TPACK** [4] offer valuable structures but do not include indicators for avatar based navigation, presence, the integration of 3D content or social norms in virtual environments. The spatial and immersive capabilities of the metaverse and social interaction parameters of 3D virtual world environments are underrepresented.

The TPACK (technological pedagogical content knowledge) framework is one of the most well-established theoretical frameworks which stressed the interconnection of technological knowledge with a teacher's pedagogical and content knowledge [13]. TPACK has been a significant stepping stone for understanding how to incorporate technologies within the educational process, while paying attention to the teacher competence to combine these three areas [32]. TPACK is concerned primarily with technology usage in the classroom setting, and fails to address some of the new directions and complications presented by the metaverse, including digital citizenship approaches, security, and socializing in multi-user virtual environments [14].

Simultaneously the DigCompEdu [31] frameworks (https://joint-research-centre.ec.europa.eu/digcompedu_en) and ISTE Standards [33] (International Society for Technology in Education) provide a structured approach to digital competences for teachers and students [23]. DigCompEdu covers digital competence skills, communication, security and problem solving. However, these frameworks do not extend analytically to the educational use of the metaverse, where 3D interaction, immersion and digital identity management add new levels of complexity.

Furthermore, Puentedura's (2006) **SAMR** (Substitution, Augmentation, Modification, Redefinition) model provides a practical approach to integrating technology into education, but does not specifically address the skills required for the versatile use of the metaverse as an educational medium [15]. In addition to DigCompEdu (which is the best-known European digital skills framework), and the other models mentioned above, there are several other international and thematic frameworks related to skills in digital and educational environments. Some of the most important are:

1. The **ACRL Framework for Information Literacy** [34] (https://sandbox.acrl.org/): It comes from the Association of College & Research Libraries and focuses on information literacy and the ability to critically analyze digital content [16].
2. The **UNESCO ICT Competency Framework for Teachers** (https://www.unesco.org/en/digital-competencies-skills/ict-cft): It is a guide to developing ICT [35] skills for teachers and includes three approaches: technological literacy, knowledge deepening and knowledge creation [17], [22].3.The **AECT Standards (Association for**

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Educational Communications and Technology) (https://www.aect.org/home), which focuses on instructional design, material development and evaluation of digital learning experiences [18], [36].
4. The **TARC (Teachers' Augmented Reality Competency Framework)**, which is a specialized framework for teachers' competencies in augmented reality, which includes technical, pedagogical and design skills [19].
5. The **P21 Framework for 21st Century Learning,** which includes 21st century skills: critical thinking, communication, collaboration, creativity, along with technological literacy [37] (https://static.battelleforkids.org/documents/p21/p21_framework_definitionsbfk.pdf).
6. The **European e-Competence Framework** (https://esco.ec.europa.eu/en/about-esco/escopedia/escopedia/european-e-competence-framework-e-cf), which focuses on ICT skills for IT professionals, but also includes elements related to education [20].
7. The **Digital Literacy Global Framework** (https://uis.unesco.org/sites/default/files/documents/ip51-global-framework-reference-digital-literacy-skills-2018-en.pdf), which unifies various digital skills frameworks and sets global standards [21], [24].

III. RESEARCH METHODOLOGY

The development of the MetaFramEdu framework followed a three-phase methodology:

- **Phase 1 — Needs Analysis:** A qualitative review of the relevant literature was conducted with the aim of capturing existing theoretical and practical approaches and existing similar frameworks.
- **Phase 2 — Framework Design:** The main dimensions, indicators and levels of the framework were identified, through a thematic analysis of the findings.
- **Phase 3 — Specification and Operationalization:** The dimensions and indicators were converted into operational definitions and measurable elements, ensuring the practical applicability of the framework.

The research questions guiding this research are the following:

1. What are the necessary dimensions of a competency framework in the educational metaverse?
2. What are the requirements for each dimension of the framework?
3. What are the levels of digital proficiency in the educational metaverse?
4. What are the necessary skills that educators at basic and advanced levels must possess in order to effectively utilize the metaverse?

IV. RESEARCH RESULTS

MetaFramEdu proposes a holistic approach that combines the technological, pedagogical, social and ethical dimensions of metaverse use, with measurable levels of proficiency. This multidimensional framework fills a significant gap in the literature and offers a tool that can support both practice and academia in the digital age.

4.1 Framework requirements

The development of a comprehensive and effective framework for the educational metaverse requires the coverage of specific requirements, which concern both the technological infrastructure and its pedagogical, organizational and social dimensions (Fig, 1). These requirements are specified and reflected in the following dimensions:

1. The pedagogical dimension of the framework must include methodological approaches, such as experiential learning in virtual environments, exploratory and discovery learning, collaborative learning in virtual spaces and personalized learning paths. At the same time, the design of learning experiences can be based on the creation of interactive scenarios, simulations of real situations and the use of gamification techniques and educational games.
2. The technological dimension considers how the technical specifications, such as appropriate VR/AR equipment, network infrastructure, bandwidth, and coverage, as well as compatibility across platforms and devices, influence the environment. Also, technically selecting the appropriate metaverse platforms, 3D content creation tools and learning management systems (LMSs), integrated with the virtual environment will also be relevant.
3. The user experience (UX/UI) dimension concerns the design of user-friendly interfaces, accessibility for people with disabilities and the enhancement of the experience with augmented and virtual reality elements. Personalization, with customizable avatars, personalized environments and multiple levels of interaction, enhances engagement and participation.
4. The social dimension includes interaction and collaboration in multi-user virtual environments, the use of communication tools and the development of learning communities [26]. In addition, digital ethics, the prevention of cyberbullying and respect for diversity are critical elements.

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5. The security and safety dimension focuses on the protection of personal data, encryption, secure identification and special protocols for minors [27]. Digital identity management, access control and GDPR compliance are key parameters for privacy.

6. The evaluative dimension covers the assessment of learning through analytics and performance metrics, formative and summative assessment, as well as real-time progress monitoring. At the same time, the evaluation of the effectiveness of experiences, the measurement of educational outcomes, the collection of feedback and the estimation of return on investment (ROI) are examined.

7. The economic dimension concerns the cost and sustainability, including initial investments in equipment, operating costs and financing models, as well as scalability and sustainable development for a large number of users.

8. Compliance to the law and educational regulations - copyright, and international standards and certifications - is the **education policy dimension**. The dimension also includes the integration strategy to ensure curriculum integration and the teacher training and transitional stage to implementation.

9. The research dimension encourages the evaluation of new developments and the use of experimental applications, data collection and ongoing development, and collaboration with research agencies. The scalability of the framework promotes adaptation to new technologies and update of content and practice.

10. Finally, the cultural dimension emphasizes interculturality, offering multilingual content, respect for cultural differences and global accessibility.

All these dimensions must work in combination, creating a coherent and effective framework for the educational metaverse, which will yield substantial learning and social benefits.

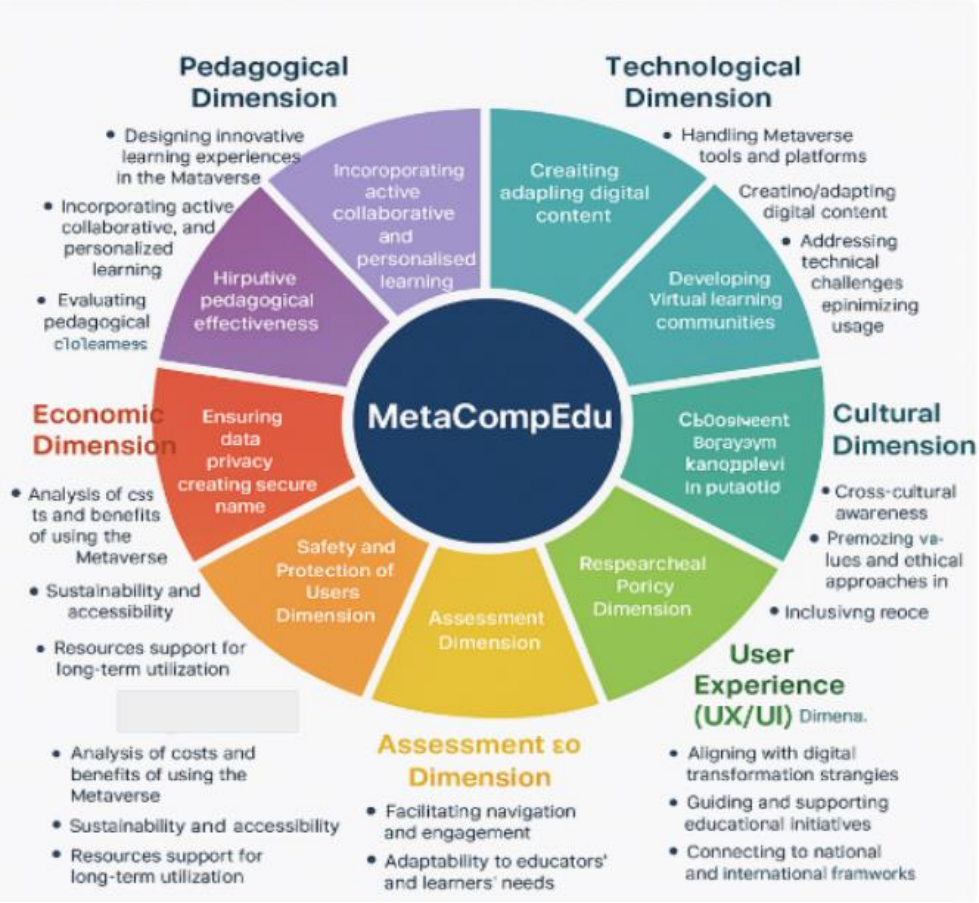

Figure 1. MetaFramEdu Dimensions

4.2 Competency Framework for Educators in the Metaverse

A full-fledged competency framework for educators in the metaverse should include qualified teaching and curriculum understanding in relation to pedagogies related to teaching and learning.

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Educators must be competent to adjust their teaching strategies to the dimensions of the metaverse, for example, with interactive simulations, virtual tours, collaborative projects that actively engage learners, and subsequently impactful learning outcomes.
Educators should also have strong learning design capabilities to develop an engaging metaverse learning environment, aligned to curriculum, that encompasses many learner types and needs.

Additionally, they must learn to create and curate digital educational materials that are suited specifically for the metaverse environment. These can include interactive simulations, virtual tours and far more immersive learning experiences that are specific to the metaverse.

They will must learn to critically evaluate and curate digital education materials for accurate, relevant, and that which hits learning outcomes for new learning for learners in the metaverse. They will also must learn to foster strong digital literacy skills that will allow them to learn how to best use all the tools and platforms in the metaverse. This includes learning how to use virtual reality software, augmented tools, and metaverse technologies.

Interpersonal communication skills are necessary for metaverse educators to develop the type of learning community to engage and motivate learners for success. They also must effectively communicate with learners in a virtual metaverse and have the ability to lead discussions, and provide feedback and encouragement through the virtual worlds of the metaverse.

Educators should also be aware of the ethical and social ramifications of the metaverse, which would encourage them to use these technologies again in a responsible manner and positively foster digital citizenship within their students. Awareness of the risks and challenges that come with using the metaverse in education is also important to the learning environment. Risks that educators should be aware of in this space include cyberbullying, online victimization, and misinformation by certain means that permeates online spaces. Addressing these issues can help provide a safe space for their learning.

A **comprehensive competency framework** for educators in the metaverse should go beyond basic digital skills and encompass **pedagogical expertise, curriculum integration, technological fluency, ethical awareness, and interpersonal capacity**. This holistic framework ensures that educators are not only capable of navigating immersive environments but are also able to design meaningful, inclusive, and impactful learning experiences.

1. Pedagogical and Curriculum Integration

- Educators must demonstrate **deep pedagogical knowledge** and the ability to align metaverse-based learning activities with curriculum standards and subject requirements.
- They should be competent in **adapting instructional strategies** to exploit the affordances of immersive environments, such as:
    - interactive simulations that enable experiential learning,
    - virtual field trips that broaden cultural and disciplinary horizons,
    - collaborative projects that foster co-construction of knowledge and problem-solving,
    - gamified learning tasks that enhance engagement and retention.
- The ultimate aim is to generate **measurable and impactful learning outcomes** that connect directly with real-world competencies.

2. Learning Design and Instructional Innovation

- Strong **learning design skills** are essential to create **engaging, multimodal metaverse learning environments** that cater to diverse learner needs, abilities, and preferences.
- Educators must develop the ability to **integrate multimodal instructional materials** (visual, auditory, haptic) to support differentiated instruction.
- They should leverage **learning analytics** within metaverse platforms to monitor learner progress, identify gaps, and provide targeted interventions.

3. Digital Content Creation and Curation

- Educators must master the skills of **designing, creating, and curating digital educational resources** suited specifically for metaverse environments.
- Examples include:
    - immersive 3D simulations for science, history, or engineering,

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- augmented overlays that contextualize real-world content in virtual form,
- narrative-driven VR experiences that foster empathy and perspective-taking.

- Beyond creation, they should also be able to **critically evaluate digital content** for accuracy, relevance, inclusivity, accessibility, and alignment with desired learning outcomes.

4. Digital Literacy and Technological Fluency

- Educators need to cultivate **strong digital literacy skills**, enabling them to:
  - operate VR/AR software and devices effectively,
  - navigate diverse metaverse platforms,
  - troubleshoot technical challenges,
  - integrate digital safety and data protection principles in practice.
- They should model and teach **responsible, critical, and creative use** of digital technologies, ensuring that students can confidently use metaverse tools for learning, collaboration, and innovation.

5. Interpersonal and Community-Building Skills

- Since learning in the metaverse is highly interactive and social, educators must possess **advanced communication and facilitation skills**.
- They should be able to:
  - foster **inclusive virtual learning communities**,
  - lead meaningful discussions that stimulate critical thinking,
  - provide effective feedback and encouragement in immersive environments,
  - promote empathy, collaboration, and shared responsibility among learners.

6. Ethical Awareness and Digital Citizenship

- Educators must understand and address the **ethical and social implications** of metaverse technologies, including:
  - issues of data privacy, surveillance, and identity management,
  - risks such as cyberbullying, online victimization, and misinformation,
  - questions of equity, access, and inclusion across diverse learners.
- They should actively promote **positive digital citizenship**, teaching students to respect others, behave responsibly, and contribute constructively to online communities.
- Awareness of these challenges enables educators to create **safe, respectful, and resilient learning ecosystems** in the metaverse.

7. Cognitive Load Management and Well-being Awareness

- Educators must be aware of the **cognitive load** that highly immersive, multi-sensory metaverse environments can impose on learners.
- They need to design learning activities in ways that **reduce unnecessary complexity** and balance sensory input, ensuring that students can process information effectively without being overwhelmed.
  This involves:
  - segmenting content into manageable learning chunks,
  - using scaffolding strategies to support gradual mastery,
  - providing clear guidance and navigation cues in virtual environments,
  - monitoring learners for signs of overload or disengagement.

8. Awareness and Prevention of Metaverse Overuse and Addiction

- Educators must also recognize the **risk of dependency and addictive behaviors** that may arise from prolonged or unsupervised engagement with metaverse platforms.
- They should integrate **responsible use practices** into their pedagogy, such as:
  - encouraging balanced screen time,
  - embedding reflective activities that draw learners back to the real world,
  - promoting digital well-being as part of digital citizenship.
- By modeling **healthy digital habits** and openly discussing these challenges, educators can help learners develop **self-regulation strategies** that foster sustainable and positive engagement with immersive technologies.

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4.3 Levels of Proficiency in the Educational Metaverse

Integrating the educational metaverse into educational practice requires teachers to have a specific set of digital skills, pedagogical approaches and willingness to adapt to ever-changing technology [25]. For development and integration of these technologies into practice, clear levels of "proficiency" must be determined. These proficiency levels taken together serve as a pathway of progression - covering everything from familiarization and experimentation, to fully and critically utilizing all of the possibilities of the metaverse. Each proficiency level specifies different characteristic of knowledge, skills and attitudes that provide a basis for self-reflection and resulting further development, which reflect the following levels of digital competence proficiency,(https://joint-research-centre.ec.europa.eu/digcompedu/digcompedu-framework/digcompedu-proficiency-levels_en):

Metaverse Beginner (A1): The Beginner has basic knowledge of the existence of virtual worlds and the metaverse, understands that they can be used for educational purposes, but his experience is minimal. His use is mainly limited to traditional digital tools and simple applications. He perceives the metaverse as something interesting, but has not integrated it into practice. He needs clear guidance, examples and support to start using it in pedagogical scenarios.

Metaverse Explorer (A2): The Explorer has recognized the possibilities of the metaverse and is starting to experiment with its basic functions (e.g., virtual classrooms, simple interactive experiences). He/She is seeking ways to incorporate them within specific learning activities but does not have a systematic or coherent approach yet. He/She is developing an interest in the pedagogical use of virtual worlds and leverages the benefit of exchanging experiences and wondering what colleagues do.

Independent Experience Creator (B1): The Independent Creator is taking `a gradual approach to adding the metaverse to the educational process`, first experimenting with scenarios, platforms and tools. They create or adapt activities to enhance collaboration, student interaction, and creativity. They still need time to determine the relevant platform or tool for each situation and to explore the potential for personalizing experiences.

Expert in the Pedagogical Use of the Metaverse (B2): The expert uses the metaverse with assurance, creativity and critical consciousness. Deliberately chooses appropriate technology or platform based on the learning outcome, at the same time knowing the strengths and weaknesses of every option. Designs elaborate activities that utilize authentic contexts, multimedia content and interactive components. Always searching for new ideas and acts as a conduit for sharing good practices in his organization.

Leader of Educational Innovation in the Metaverse (C1): The Leader adopts a comprehensive strategy for utilizing the metaverse in education. He has an extensive repertoire of tools and practices, which he flexibly adapts to the needs of different learning communities. Contributes to the design of training, guides colleagues, and is constantly informed about technological and pedagogical developments. His practice inspires and motivates others to adopt innovative solutions.

Metaverse Pioneer in Education (C2): The Pioneer creates new forms of learning and teaching by leveraging the most innovative and experimental capabilities of the metaverse (e.g., fully personalized virtual environments, integration of AI-avatars, immersive simulations). Challenges established practices, develops innovative pedagogical methodologies and actively contributes to international research and development. Acts as a catalyst for change, leading the educational community to new levels of experience and learning.

4.4 The MetaFramEdu Framework

The MetaFramEdu framework (Appendix A) clearly identifies the set of digital competencies required by educators to be able to adequately and effectively utilize the potential of the metaverse in education. The need for such a definition arises from the fact that the metaverse constitutes a multidimensional and technologically advanced environment, which combines virtual and augmented reality technologies, 3D visualization, real-time interaction and social networking. Its utilization for pedagogical purposes cannot be limited to basic technical knowledge, but requires a wide range of skills that include:

- **Technical skills:** ability to use and manage VR/AR equipment, select appropriate platforms and tools for 3D content creation, as well as solve technical problems.
- **Pedagogical skills:** designing learning experiences adapted to the virtual environment, applying experiential, collaborative and personalized learning methodologies.
- **Digital security and ethics skills:** protecting personal data, managing digital identity, applying rules of conduct and respect in online interaction.

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• **Assessment skills:** using analytical tools to monitor student progress and evaluate the effectiveness of activities in the metaverse.

• **Innovation and adaptability skills:** ability to experiment with new technologies, integrate innovative practices and adapt to evolving technological environments.

Through the systematic categorization of competencies into dimensions, this framework provides a professional development roadmap for teachers (Table I). It allows them to identify areas where further training is needed, to make the most of the possibilities of the metaverse, and to ensure that teaching and learning in these environments is pedagogically sound, safe, and effective.

Table I. Digital Proficiency Levels in the Metaverse

Level	Descriptive Index	Indicative Evaluation Criteria
A1 – Beginner	Knows the basic existence of the metaverse and some of its capabilities. Uses limited digital tools for lesson preparation and communication, without active use of virtual environments.	- Can describe what the metaverse is in general terms. - Has an account on at least one metaverse platform but does not use it systematically. - Does not yet integrate the metaverse into teaching or learning activities.
A2 – Explorer	Has started to experiment with basic metaverse features (e.g., virtual classrooms, avatars) and integrates some activities into learning scenarios.	- Has participated in at least 1–2 educational activities in the metaverse. - Uses basic features (creating avatars, moving around virtual spaces). - Adapts ready-made scenarios for simple use in the classroom.
B1 – Independent Creator	Systematically uses the metaverse in a variety of scenarios, creates or adapts activities, and enhances interaction and collaborative learning.	- Creates his/her own simple virtual environments. - Integrates the metaverse into at least 30% of his/her lessons. - Uses collaboration tools (e.g., shared tasks, breakout spaces).
B2 – Expert	Consciously selects the appropriate metaverse platforms and technologies per learning objective. Designs complex and authentic learning experiences, knows the limits and capabilities of each technology.	-Selects platforms based on pedagogical criteria and not only technical characteristics. - Designs multi-level scenarios (e.g., role-playing games, simulations). - Adapts technologies to learning needs.
C1 – Leader	Guides colleagues, designs strategies for integrating the metaverse into educational organizations, stays informed and disseminates best practices.	- Organizes training for colleagues. - Develops guides and user frameworks. -Advises organizations on the integration of the metaverse.
C2 – Pioneer	Creates new pedagogical approaches and innovative applications in the metaverse. Participates in or leads international research and development projects.	-Develops new functions or scenarios that do not exist elsewhere. -Participates in international projects or publishes scientific articles. -Presents innovative practices at conferences and networks.

The purpose of the framework is:

• To assess the competence of the teacher in Metaverse issues.

• To guide professional development and training in the utilization of the metaverse.

• To support the integration of virtual environments in a pedagogically documented manner.

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The framework can be used:

- By individual teachers for self-development.
- By school principals or trainers for needs diagnosis.
- In seminars/workshops for organizing thematic units.
- In European/research projects for mapping competencies.
- By educational institutions for the creation of curricula.

MetaFramEdu is suitable for several different educational and research contexts, because it has been designed with flexibility and adaptability. Specifically, it can be applied to:

1. School Education (Primary & Secondary): For integrating activities in the metaverse in subjects such as History, Natural Sciences, Geography, Arts. As a tool for self-assessment of teachers' skills.
2. Higher Education: In university programs in pedagogy, educational technology, digital art, game design, virtual/augmented reality. For research applications at undergraduate and postgraduate levels, e.g. in the context of diplomas or doctorates.
3. Teacher Training: In programs that aim to develop skills in designing learning experiences in the metaverse. As a tool for measuring progress before and after training.
4. Vocational Training & Lifelong Learning: In sectors such as tourism, health, military training, architecture, where virtual worlds are used for education.
5. Research Frameworks: To develop studies evaluating the impact of virtual worlds on learning, social interaction and innovation. As a common frame of reference for comparative studies between countries or cultural environments.
6. Educational Policy Design: To integrate objectives and indicators into national digital education strategies.
As a basis for guidelines for safe and pedagogically evidence-based use of the metaverse in schools.

4.5 Online application for assessing teacher competence in the Metaverse.
For the needs of this research, an online application for self-assessment of teacher competence was developed, which is based on the proposed MetaFramEdu framework. The aim of the application is:

- to capture in a reliable and valid way the level of digital and pedagogical competences of teachers in relation to the use of the Metaverse in education,
- to facilitate the identification of training needs and the development of targeted professional development strategies for teachers in the metaverse,
- to offer a tool for monitoring and comparative analysis of competences over time,
- to function as a mechanism for strengthening the reflective practice of teachers themselves, encouraging self-awareness and the design of personalized learning paths.

The application was implemented as a user-friendly web tool, with an HTML/CSS interface and JavaScript integration for automatic processing of responses. The scoring algorithm calculates the proficiency level based on predefined weighting factors per dimension (pedagogical, technological, social, cultural, research, evaluation, etc.), as defined in the MetaFramEdu framework. The system provides immediate feedback, displaying the proficiency level (beginner, researcher, expert, etc.).

The interface was designed with HTML5 and CSS3, following responsive design principles to be compatible with different devices (computers, tablets, mobiles) and to maintain high functionality regardless of screen resolution [44].

The logical processing of responses was integrated using JavaScript, which allows for direct interaction without the need to refresh the page. To enhance the user experience, input validation mechanisms were implemented to ensure that participants enter valid and complete answers before submission.

The scoring algorithm was designed to calculate the proficiency level of each user based on predefined weighting factors per dimension. Each dimension of the MetaFramEdu framework (pedagogical, technological, social, cultural, research, evaluation, user experience, security, etc.) corresponds to a set of questions that are rated on a Likert scale (1–5). The responses are normalized and averages are calculated per dimension, which are then weighted according to the importance of each dimension in the overall ability to utilize the Metaverse in education. The final score classifies the user into proficiency levels from beginner, explorer, to pioneer.

The implementation also includes a local storage mechanism, so that the user can return to the questionnaire without losing their progress, as well as the ability to export the results in PDF or CSV format for research purposes. For

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reasons of personal data protection, all data is stored anonymously, temporarily and in accordance with GDPR specifications.

The web application has been integrated into an organized digital repository for the purposes of transparency, accessibility and reuse. Specifically, the application is maintained in the project's digital repository [28] and specifically in the Metaverse collection (Fig. 2), which is available at https://dmagetos.eu/omeka/items/show/530 In addition, in order to be immediately usable by educators and researchers, the application has been published (Fig. 3) in a publicly accessible format at: https://dmagetos.eu/metacomp/MetaFramEdu.html.

This ensures that the tool is open, available and reusable, both for research purposes and for its practical application in the professional development of teachers. Its publication in an institutional repository also provides a documented reference, a permanent access point and the possibility of future upgrades. Overall, the application combines simplicity of use with advanced feedback and analysis functions, to constitute a comprehensive tool for assessing the competence of teachers in the use of the Metaverse.

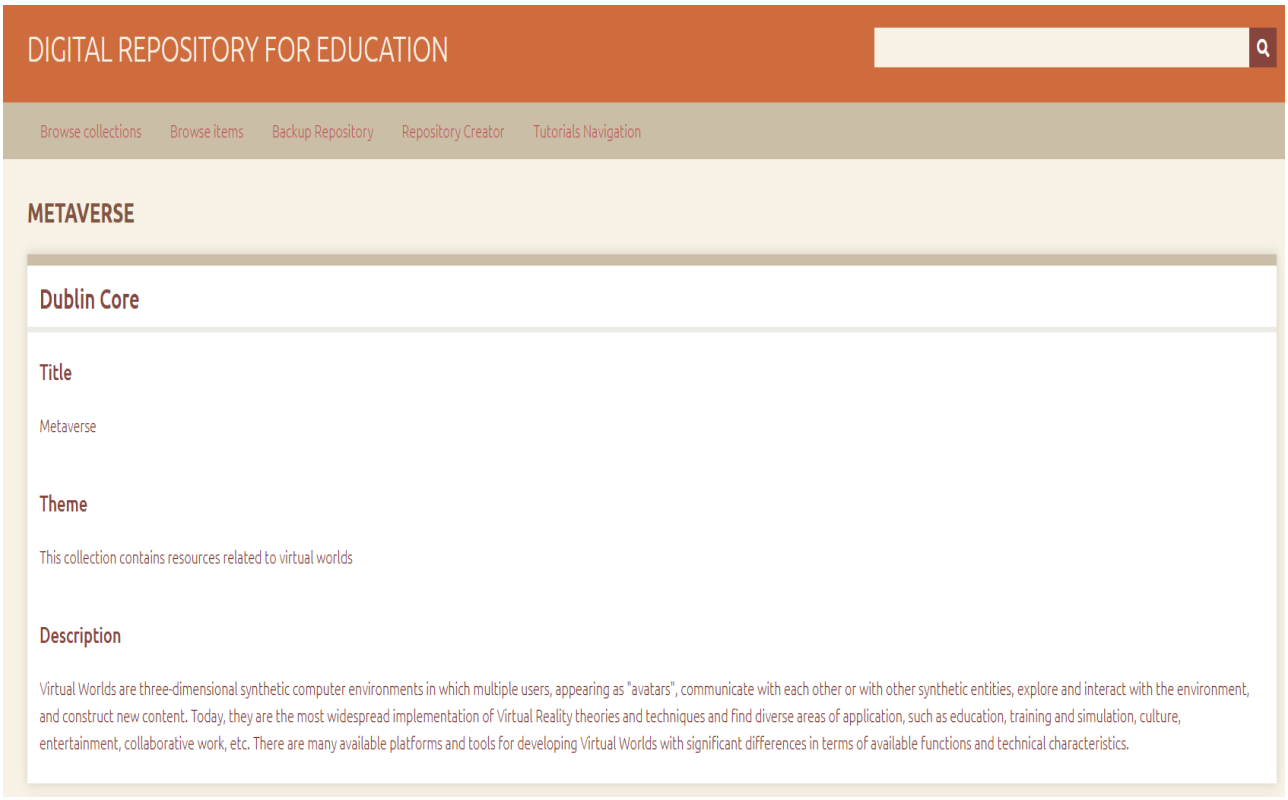

Figure 2. Digital Repository for Education (Metaverse collection)

V. DISCUSSION OF RESULTS

Teacher professional development in the metaverse is a complex process that requires cognitive and emotional engagement, both at the individual and collective levels [29].

Effective professional development must create opportunities for teachers to not only explore the metaverse, but also to develop an understanding of its affordances for teaching and learning. This should include opportunities for teachers to be immersed in metaverse learning environments, collaborate with peers and experts, and experiment with different teaching strategies [30].

Furthermore, professional development needs to work to develop knowledge, skills, dispositions within teachers that are necessary for engaging with instruction in the metaverse. This means teachers need to develop their understanding of pedagogy, develop their technology competency, develop their learning design practices, develop the skills to create digital content, promote digital literacy, and develop their relationships and interpersonal communication skills in the virtual spaces of the metaverse.

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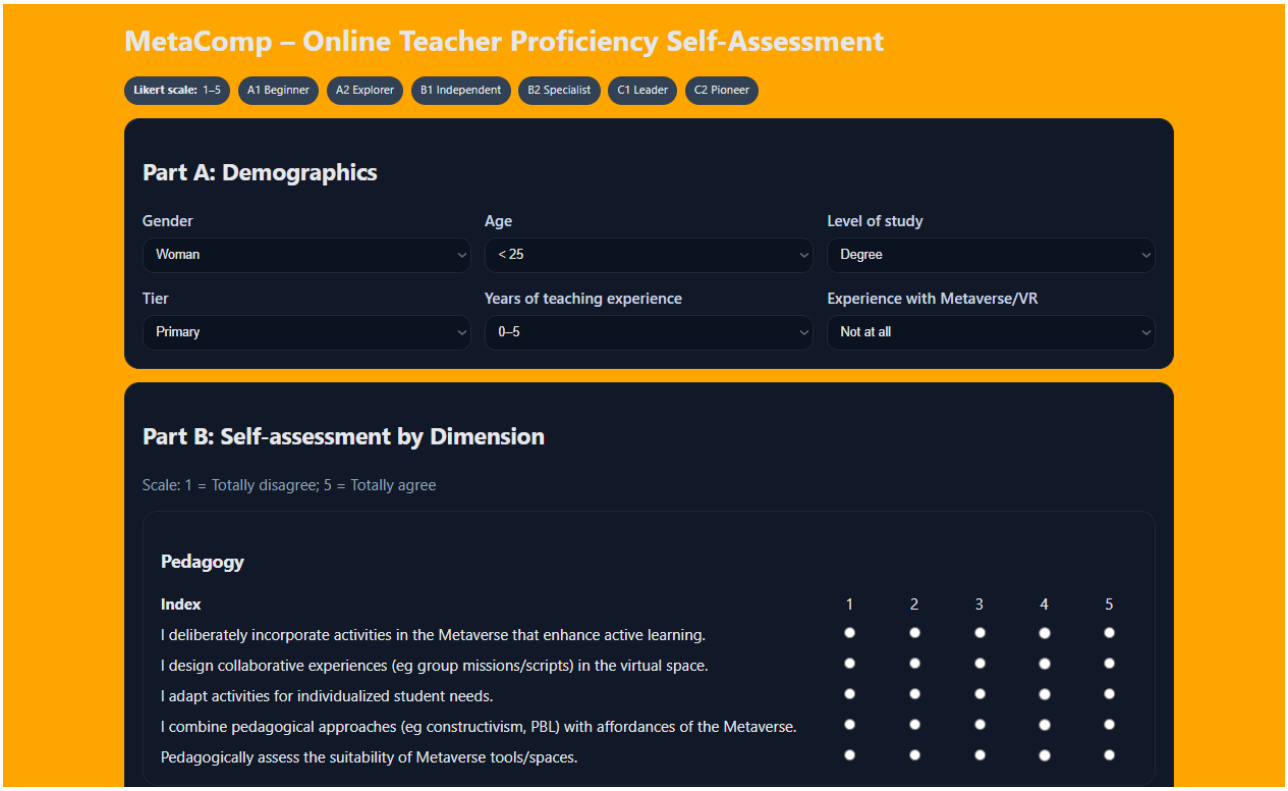

Figure 3. MetaFramEdu Online Self-Assessment

Similarly, it is important to understand that teachers may also have varying needs for professional development depending on their backgrounds, experiences, and teaching contexts. That is to say, professional development programs should be dynamic and responsive to teachers' individual needs and offer personalized learning for all levels of digital competence proficiency in the metaverse.

Researchers have examined the potential of metaverse learning in a highly robust way acknowledging its ability to complement and boost e-learning. The metaverse learning environments enhance their sense of social presence and may provide more immersive, inclusive and engaging e-learning experiences [43]. Qualitative research has been completed on the role of the metaverse in higher education and on analyzing its emerging potential, opportunities and challenges [42].

The integration of the metaverse in education requires careful planning and consideration. The proposed MetaFramEdu framework enables the educational community to identify the necessary knowledge, skills and attitudes that educators need to have in order to pedagogically and effectively utilize virtual worlds in the metaverse to enhance learning and teaching.

VI. CONCLUSION-LIMITATIONS AND FUTURE RESEARCH

MetaFramEdu is a broad framework for developing digital competencies of teachers in the metaverse, addressing all major aspects: pedagogical, technological, social, economic, political, research, cultural, UX/UI, security and evaluation. The progressive development of proficiency levels from Beginner to Pioneer, allows for recognition of skills and skills development. It also offers user safety and protection, while promoting collaboration, active learning, and innovation. Finally, it offers capability for systematic evaluation and feedback, ensuring effective and purposeful use of digital technologies in education.

Despite the importance and originality of the MetaFramEdu framework, the framework faces certain limitations that require further investigation and improvement. First, the framework was developed and validated through its bibliographic and theoretical foundation, but has not been applied and tested in educational practice. Wider application and evaluation in different countries, levels of education and subjects is required to strengthen the validity and generalizability of the framework. Furthermore, the rapidly evolving technological environment of the metaverse creates challenges for the continuous updating and adaptation of the required competencies. The framework must

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remain flexible and open to revisions in order to respond to new functions, platforms and forms of interaction. Also, although MetaFramEdu covers multiple dimensions of competencies (technical, pedagogical, social, ethical), the development of support and training tools based on the framework remains at an early stage.

Future research could focus on the development of digital tools, seminars and interactive platforms that will help teachers and students develop these competencies in practice. Collecting skills assessment data in real metaverse environments is necessary but difficult, due to the variety of platforms, privacy concerns, and the need for long-term studies. Finally, investigating the impact of MetaFramEdu skills on educational performance, student engagement, and social interaction in the metaverse is a field that requires empirical research with a long-term and multi-methodological approach.

Overall, MetaFramEdu lays the foundation for a new generation of educational frameworks in the metaverse, but its continuous evolution and enrichment, combined with the expansion of its applications, are critical for its success and substantial contribution to the educational community.

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Appendix A

Extended MetaFramEdu Indicator Table

1. Pedagogical dimension	2. Technological Dimension
Basic Level (B) • B1.1 Can you identify basic pedagogical principles that apply to the educational metaverse? • B1.2 Are you able to distinguish when an activity in the metaverse favors active learning? • B1.3 Can you effectively participate in guided educational activities in the virtual space? • B1.4 Do you understand the importance of experiential learning in the metaverse environment? • B1.5 Can you follow basic instructions for using educational tools in the metaverse? **Intermediate Level (M)** • M1.1 Can you design simple learning activities that exploit the capabilities of the metaverse? • M1.2 Are you able to adapt existing educational content for the metaverse environment? • M1.3 Can you apply personalized learning techniques in the virtual space? • M1.4 Do you understand how to combine different pedagogical approaches (e.g. constructivism, collaborative learning) in the metaverse? • M1.5 Can you evaluate the pedagogical effectiveness of an activity in the metaverse? **Advanced Level (P)** • P1.1 Are you able to develop integrated learning scenarios that fully exploit the potential of the metaverse? • P1.2 Can you research and implement innovative pedagogical approaches specifically for the metaverse? • P1.3 Are you able to train other educators in the use of pedagogical strategies in the metaverse? • P1.4 Can you conduct research studies on the effectiveness of educational interventions in the metaverse? • P1.5 Are you able to contribute to the theoretical development of new pedagogical models for the metaverse?	**Basic Level (B)** • B2.1 Can you use basic VR/AR components (glasses, controllers) to access the metaverse? • B2.2 Are you able to navigate basic functions of a metaverse platform? • B2.3 Can you identify and resolve basic technical connection problems? • B2.4 Do you understand the minimum technical requirements for participating in an educational metaverse? • B2.5 Can you use basic communication tools (voice, text) in the virtual space? **Intermediate Level (M)** • M2.1 Are you able to configure and customize the settings of the metaverse environment? • M2.2 Can you create basic 3D content or import ready-made objects? • M2.3 Do you understand the compatibility of different devices and platforms? • M2.4 Are you able to manage users and access rights in virtual spaces? • M2.5 Can you evaluate and select appropriate technological solutions for educational needs? **Advanced Level (P)** • P2.1 Are you capable of creating and building technical solutions for specialized educational applications in Metaverse? • P2.2 Can you create custom-built tools and add-ons for metaverse platforms? • P2.3 Do you have profound knowledge of the architecture and technical specifications of the metaverse? • P2.4 Can you train technical staff with the administration of metaverse systems? • P2.5 Can you contribute to the creation of new technical standards for the educational metaverse?
3. User Experience (UX/UI) Dimension **Basic Level (B)**	**4. Social Dimension** **Basic Level (B)**

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• B3.1 Are you comfortable navigating the metaverse environment interface? • B3.2 Are you able to change basic settings to enhance the user experience? • B3.3 Do you understand the importance of ergonomics when using VR/AR technology? • B3.4 Are you able to identify and report usability concerns? • B3.5 Are you able to use accessibility tools when available? **Intermediate Level (M)** • M3.1 Can you design simple user-centric virtual interfaces for educational practices? • M3.2 Are you able to evaluate the success of different interface options? • M3.3 Do you understand and apply the concepts of human-centered design to the metaverse? • M3.4 Are you able to adapt environments to meet the users' needs? • M3.5 Are you able to gather and analyze user experience information? **Advanced Level (P)** • P3.1 Are you able to design and lead the development of innovative UX/UI solutions for the educational metaverse? • P3.2 Are you able to conduct empirical research to better understand and improve user experience? • P3.3 Do you have a significant understanding of the psychology and behaviour of users in the metaverse? • P3.4 Are you able to instruct UX/UI designers in unique metaverse design techniques? • P3.5 Can you help set new UX standards?	• B4.1 Are you able to participate in group activities in the metaverse? • B4.2 Are you able to follow basic rules of courtesy and behavior in the digital environment? • B4.3 Are you aware of the importance of collaboration in the virtual space? • B4.4 Are you able to recognize and respect cultural diversity? • B4.5 Are you able to communicate in the metaverse using avatars and virtual tools? **Intermediate Level (M)** • M4.1 Are you able to facilitate and coordinate group activities in the metaverse? • M4.2 Are you able to create inclusive virtual learning communities? • M4.3 Are you aware of the dynamics of social interactions in a virtual space? • M4.4 Are you able to address conflicts and behavioral issues in the metaverse? • M4.5 Are you able to facilitate intercultural collaboration and awareness? **Advanced Level (A)** • A4.1 Are you able to design and implement strategies to develop social skills in the metaverse? • A4.2 Are you able to conduct research on the social implications of using a metaverse in education? • A4.3 Do you have a thorough understanding of the sociological and psychological dimensions of virtual communities? • A4.4 Are you able to train others to manage the social dimensions of the metaverse? • A4.5 Are you able to develop policies and protocols for a socially responsible metaverse.
7. Ethical Competence Dimension **Basic Level (B)** • B1.1 Do you know the basic principles of ethics and good behaviour in the metaverse? • B1.2 Are you able to identify examples of unacceptable behaviour in the virtual environment? • B1.3 Can you safeguard your personal data and respect the privacy of others? • B1.4 Do you understand the importance of consent regarding the use of others' images, audio or content in the metaverse? • B1.5 Are you knowledgeable about issues surrounding misinformation and are you aware of major sources of misinformation that are unreliable?	**8. Cultural Competence Dimension** **Basic Level (B)** • B1.1 Are you aware that the metaverse can include cultural elements from different countries and communities? • B1.2 Are you able to recognize basic cultural references and symbolism in virtual environments? • B1.3 Are you able to respect cultural differences when interacting with others in the metaverse? • B1.4 Do you understand the importance of incorporating cultural diversity into educational activities in the metaverse? • B1.5 Do you know basic rules for avoiding cultural misunderstandings in the virtual space?

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Medium Level (M)

- M1.1 Are you capable of applying responsible behaviour and communication in collaborative environments of the metaverse?
- M1.2 Are you able to train students or colleagues about digital ethics in the virtual environment?
- M1.3 Can you identify and disengage yourself from content that promotes discrimination or violence?
- M1.4 Are you able to report breaches of ethical rules and assist victims of cyber-stalking or harassment?
- M1.5 Are you able to apply principles of transparency and honesty regarding the creation and availability of content in the metaverse?

Advanced Level (P)

- P1.1 Are you able to create ethical use policies for educational organizations in the metaverse?
- P1.2 Are you able to design and implement training on digital ethics or digital safety? educational organizations in the metaverse?
- P1.3 Are you able to manage complex ethical challenges related to virtual interaction?
- P1.4 Can you integrate ethical principles into educational scenarios and environments in the metaverse?
- P1.5 Are you able to influence and guide the strategy for ethical and responsible use of the metaverse at a broader policy or industry level?

Intermediate Level (M)

- M1.1 Can you design activities in the metaverse that incorporate elements from different cultures?
- M1.2 Are you able to recognize and avoid stereotypes or cultural biases in virtual environments?
- M1.3 Can you adapt educational content to be culturally sensitive and accessible?
- M1.4 Are you able to promote intercultural dialogue through collaborative projects in the metaverse?
- M1.5 Can you assess the cultural appropriateness of a virtual environment or educational scenario?

Advanced Level (P)

- P1.1 Are you able to lead projects that promote intercultural understanding and collaboration in the metaverse?
- P1.2 Can you develop educational scenarios that incorporate complex cultural dynamics and historical context?
- P1.3 Are you able to identify and resolve cultural conflicts or misunderstandings in virtual environments?
- P1.4 Can you positively influence the practices of other educators in integrating cultural diversity?
- P1.5 Are you capable of creating innovative cultural experiences in the metaverse that enhance learning and mutual understanding?

9. Educational Policy Dimension

Basic Level (B)

- B1.1 Can you identify the basic principles and directions of educational policy related to the use of the metaverse?
- B1.2 Are you able to understand how the regulations and guidelines of your organization affect the use of the metaverse?
- B1.3 Are you aware of basic regulations for data protection and privacy when using virtual environments?
- B1.4 Can you identify which bodies (local, national, international) define policies for the educational use of the metaverse?
- B1.5 Are you able to follow basic approval procedures for the implementation of activities in the metaverse?

Intermediate Level (M)

- M1.1 Can you integrate the official guidelines and strategies for the use of the metaverse into your learning practices?
- M1.2 Are you able to interpret and implement educational policies related to technology and

10. Financial Dimension

Basic Level (B)

- B1.1 Can you identify basic costs of carrying out activities in the metaverse?
- B1.2 Can you identify free or low-cost educational resources and/or tools in the metaverse?
- B1.3 Do you know the basic financial requirements for establishing a virtual learning space?
- B1.4 Do you know how to minimize unnecessary costs when selecting technological equipment for the metaverse?
- B1.5 Are you able to follow basic guidelines when managing the budget for a project in the metaverse?

Intermediate Level (M)

- M1.1 Are you able to create a basic cost estimate for the design and implementation of a metaverse activity?
- M1.2 Can you take advantage of existing funding opportunities or grants to support projects in the

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innovation? • M1.3 Can you adapt the design of activities in the metaverse to comply with legal and institutional frameworks? • M1.4 Do you know how to document the necessity of using the metaverse to secure institutional support? • M1.5 Are you able to assess whether an educational policy supports or limits the innovative use of the metaverse?	metaverse? • M1.3 Are you able to compare and contrast costs for various metaverse tools or platforms and select the most economical option? • M1.4 Do you know how to maximize the ways in which you use the available resources in order to reduce the financial burden? • M1.5 Are you able to evaluate the cost/benefit ratio for an educational opportunity in the metaverse?
Advanced Level (P) • P1.1 Are you able to actively participate in the formulation of policies for the educational use of the metaverse? • P1.2 Can you suggest changes or improvements to existing policies to enhance pedagogical and technological innovation? • P1.3 Are you able to develop guides or guidelines for the use of the metaverse at the organizational or system level? • P1.4 Can you evaluate and compare international policies to incorporate best practices into your own context? • P1.5 Are you able to lead initiatives that promote the institutional integration of the metaverse in educational policy?	**Advanced Level (P)** • P1.1 Are you able to develop and implement a strategic financial plan for the long-term use of the metaverse in education? • P1.2 Can you incorporate sustainable resource and cost management practices into virtual learning activities? • P1.3 Are you able to evaluate the long-term financial implications of using the metaverse in an educational organization? • P1.4 Can you negotiate with technology providers for better financial agreements and support packages? • P1.5 Are you capable of designing business models that combine educational goals and financial viability for the metaverse?