**Deliverable Report**

**Extending Design Thinking with Emerging Digital Technologies**

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(Integration of emerging new technologies into education and training)

# Deliverable 2.2
# The Exten.(D.T.)$^2$ Framework [V1]

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|---|---|
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## Table of Contents

# 1 Abbreviations

| Abbreviation | Definition |
|---|---|
| AI | Artificial Intelligence |
| AR | Augmented Reality |
| DT | Design Thinking |
| ET | Emerging Technologies |
| EU | European Union |
| LA | Learning Analytics |
| TPD | Teacher Professional Development |
| VPN | Virtual Private Network |

## 2 Summary

This deliverable reports on the first version of the Exten.(D.T.)² Framework [V1] resulting from a two-stage approach, including a literature review and consultations from a participatory workshop. This first version [V1] is designed to primarily focus on stakeholders of design thinking (DT) learning (e.g., teachers, educational designers, policymakers, and all involved educational stakeholders) and especially teachers who may be interested in incorporating emerging technologies (ET) into their practices. Therefore, this deliverable aims to identify the critical elements as a starting base for addressing the specified requirements and supporting DT with ET as an overarching goal. These fundamental elements, including components, perspectives, and competencies, will be used for follow-up evaluation and validation in the next cycle of this project.

# 3 Introduction

As presented in the previous report (Deliverable 2.1: Report on the Theoretical Review), a multifaceted and enriching learning experience for students can be achieved by integrating diverse technological modalities, fostering efficacious and engaging learning, supporting self-efficacy and reflection, and ensuring equitable opportunities for all. In relation to teachers, best practices in the literature highlight the various possibilities for implementing suitable Frameworks and approaches to adequately prepare instructors who aspire to incorporate design thinking (DT) with emerging technologies (ET) and facilitate their growth via teacher professional development (TPD). Moreover, the involvement of diverse educational stakeholders is instrumental in supporting the successful implementation of DT activities. The best practice in this regard entails establishing a collaborative community and the active participation of stakeholders in facets such as the co-creation of activities and technological resources. Pertaining to ET, the literature showed many promises and benefits of those ET in education in general, such as 3D printing, Learning Analytics (LA), Artificial Intelligence (AI), educational (virtual) robotics, Augmented reality (AR) and motion sensors. In general, it is vital to start with easy-to-use ET helping students move from straightforward knowledge to more detailed knowledge and connecting the use of ET with DT skills acquisition.

Meanwhile, several acknowledged challenges in curriculum development, teacher professional development, and technology development might impede the successful implementations of DT with ET in education (Reported in D2.1). For instance, students may encounter frustration and confusion, need more dynamic engagement with digital resources and creative ideas, the conceptualisation of design outcomes, and the resolution challenges associated with teamwork and collaboration. Therefore, it is necessary to equip students with technology competencies, design literacy and 21st-century skills. The obstacles teachers face pertain to the need for more relevant experience, relevant knowledge, an apt mindset, assessment strategies, and training for the execution of DT activities in conjunction with ET. Consequently, the imperative lies in providing teacher support, exemplified by essential pedagogical considerations, enhancing digital competencies, establishing connections with curricula and school contexts, and monitoring activities concerning student experiences, progress, and collaboration, in tandem with outcome evaluation. Another requirement concerns coordination and cooperation between all stakeholders (e.g., teachers, principals, instructors, leaders, and researchers) to support the feasibility and sustainability of actions together with knowledge transfer. When it comes specifically to technology and tool development, a discernible deficiency persists in the availability of appropriate tools and the realisation of the full potential of ET for DT. Consequently, the requirements derived from the possibilities that each ET relevant to the project has and can be used, for example, the LA component and the real-time monitoring.

To summarise, the previous report (D2.1) identified the following five priority requirements in the first version of the Framework, which at this stage of the project (given the ongoing first cycle implementation), are considered essential:

- Enhance competencies (and relevant skills, knowledge, and literacy) in students, teachers, and related educational stakeholders.
- Support teachers with essential pedagogical consideration and connecting DT with ET to curricula and school contexts.
- Facilitate students' teamwork and stakeholders' collaboration.
- Empower progress monitoring and assessment with Learning Analytics (LA) component during DT.
- Cultivate school values, culture and visions on DT and the adoption of ET.

Given that the intended goal of the theoretical review (D2.1) is to inspire and provide requirement analysis for the follow-up Exten.(D.T.)$^2$ Framework, we used these critical requirements listed above as guiding questions (see the methods section 4) in conceptualising the Exten.(D.T.)$^2$ Framework. The following subsection outlines the objectives of this deliverable.

## 3.1 Objectives of this Deliverable

As mentioned in the project proposal, the overall objective of the Exten.(D.T.)$^2$ Framework is to identify the key components, perspectives, and competencies for supporting DT Learning with ET. Furthermore, this Framework aims to consider the inclusion of all genders, hard-to-reach populations, and geographical and societal obstacles regarding the access and use of the proposed technologies.

More specifically, this Exten.(D.T.)$^2$ Framework is aimed at stakeholders of DT learning (e.g., teachers, educational designers, policymakers, and all involved educational stakeholders) and especially teachers who may be interested in incorporating ET into their practices. This Framework aims to allow these practitioners to zoom in on specific elements (e.g., components, perspectives, and competencies) essential for supporting DT Learning with ET. In this way, this Framework aims to facilitate the implementation of DT activities, the adoption of ET, and the integration of DT with ET for all children, all genders and in different (online and blended) learning environments.

The Exten.(D.T.)$^2$ Framework will be provided in two versions, the initial version (V1. Month 9) before the end of activities implementation (WP5 and WP6) and the consolidated one (V2. Month 35) after the evaluation and validation of the approach. Correspondingly, this present deliverable reports on the development of the initial version of the Exten.(D.T.)$^2$ Framework. This deliverable aims to identify the critical elements as a starting base for addressing the specified requirements and supporting DT with ET as an overarching goal. These fundamental

elements, including components, perspectives, and competencies, will be used for follow-up evaluation and validation in the next cycle of this project.

## 3.2 Relationship to Other Deliverables

The Exten.(D.T.)² Framework (WP2) will be inspiring and insightful for other WPs (as illustrated in Figure 1 below). For example, the Framework provides the foundation for the design and development of WP4, which aims to enhance learning technologies (e.g., nQuire platform, associated game apps, 3D printing application, Virtual Robotics and Authorable Learning Analytics and Dashboard) and WP3, which concerns DT activities, resources, and material, and making use of the learning technologies from WP4. Furthermore WP4 and WP3 provide input for implementing WP5 and WP6 (school interventions and teacher Professional Development) and informing the evaluation process in WP7. In turn, WP7 evaluates the experiences of WPs 5 and 6 and informs the further development and refinement of the Exten.(D.T.)² Framework (WP2), the educational resources (WP3) and the technologies (WP4).

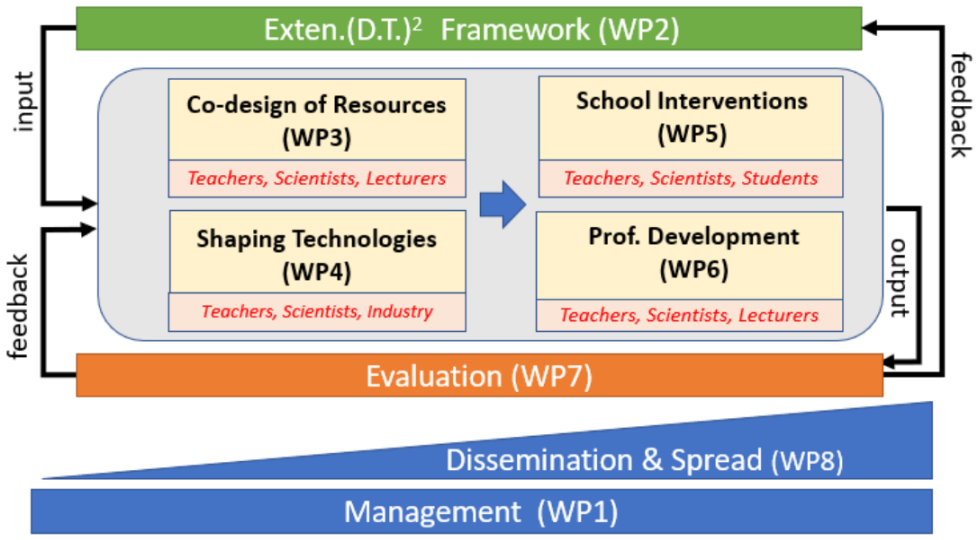


Figure 1. Pert diagram showing the project's WPs and their interrelation (Source: the Exten.(D.T.)² project proposal)

## 3.3 Structure of this Deliverable

The present report constitutes the following four parts:

- Introduction: This section shows the objectives of this deliverable (in subsection 3.1), the relation of the deliverable with other WPs (in subsection 3.2) and the structure of this deliverable (in subsection 3.3).

- Methodology: This section describes the methods used for the deliverable, which concerns a two-phase approach:
    - Stage one (a literature review): This subsection describes the approaches of the search strategy and data analysis used in this review.
    - Stage two (the consultations from a participatory workshop): This subsection documents the procedure and approaches to implementing a participatory workshop.
- Results: This section describes the results from the above two stages:
    - Result from stage one (a literature review): This subsection describes the themes emerging from our literature review regarding components, perspectives, and competencies. Finally, based on the results, section 5.1.4 presents the working draft of the Exten.(D.T.)$^2$ Framework [V0.1].
    - Result from stage two (the consultations from a participatory workshop): This subsection reports the new and overlapping elements emerging from the workshop regarding components, perspectives, and competencies. Based on insights gained from the workshop, section 5.2.4. presents the working draft of the Exten.(D.T.)$^2$ Framework [V0.2].
- The Exten.(D.T.)$^2$ Framework: This consists of the following five subsections:
    - Overview conceptualisation: This section briefly presents the aim and scope of the Framework (subsection 6.1.1) and the metaphor and interconnected structure of the elements listed in the Framework (subsection 6.1.2).
    - The Exten.(D.T.)$^2$ Framework [V1]: This section presents the visualisation and structure of the first version of the Exten.(D.T.)$^2$ Framework [V1] based on the insights from the literature, the workshop, and the metaphor.
    - Components: This section outlines the six critical components for enhancing DT with ET, including the actor, learning environment, materials and resources, platform and infrastructure, professional development and learning, and evaluation.
    - Perspectives: This section reports the four perspectives, that of students, teachers, educational stakeholders, and technology development, respectively, on enhancing DT with ET.
    - Competencies: This section accordingly conceptualises the critical competencies in four broad categories, including digital and technological, professional, pedagogical, and personal and ethical competencies.
- Conclusion: This section summarises the key findings of the deliverable and how the future works of this project can contribute to a solid Exten.(D.T.)$^2$ Framework.

# 4 Methodology

Overall, the Framework's development will follow a design-based, participatory-research approach, including iterative consultations involving stakeholders, as well as evidence-based iterations reflecting findings from the implementation of pilot activities (WP5) at schools and teacher training (WP6) and their evaluation (WP7).

For the first version of the Framework, we went through two stages. In stage 1 we completed a review of related Frameworks to generate a draft Framework with main elements. In stage 2 we engaged researchers, educational experts, and stakeholders through a participatory workshop to test, refine, and finalise the Framework.

## 4.1 Stage One: A Review of Literature

In this stage, we included relevant works from our previous report (D2.1 A theoretical review) and reviewed relevant sources of evidence in the context of digital competencies, digital citizenship, and design thinking using the keyword “Framework” in searches. The scope of the reviewed works for this deliverable report includes:

- Scientific and peer-reviewed publications (N= 18)
- Open access reports and frameworks, including those developed by the Europe Union, OECD, and UNESCO (N= 20)
- Publicly accessible, relevant frameworks from Google search (N= 4)

The review in this stage was guided by the following questions to help us with this first draft of the Framework. We summarised the answers to the first three guiding questions regarding components (section 5.1.1), perspectives (section 5.1.2), and competencies (section 5.1.3).

(1) What are the critical components in the relevant Frameworks to enhance educational values and involve digital technology in educational contexts?
(2) What key competencies are known and reported in the context of educational settings in the existing Frameworks? What needs to be considered to empower and enhance competencies (and relevant skills, knowledge, and literacy) in students, teachers, and related educational stakeholders?
(3) What perspectives need to be considered for including all genders, hard-to-reach populations, and geographical and societal obstacles regarding the access and use of technologies?

In total, we screened 42 records (as seen in Appendix A). Following the qualitative thematic analysis (Braun & Clarke, 2019) we organised the extracted information (e.g., competencies, perspectives, components, elements, and guidelines) from all documents, striving for high-level conceptual synthesis. The documents were grouped thematically, and text units were coded and categorised inductively. Our analysis did not commence with preconceived ideas

regarding how the data should be clustered. Instead, the themes (as illustrated in Tables 3-5) emerged distinctly from the dataset and underwent refinement through multiple collaborative iterations and revisions. In addition, we also created a PowerPoint slide to illustrate the potential examples of components, perspectives, and competencies for the participants of the workshop in the next stage (see section 4.2).

## 4.2 Stage Two: A Participatory Workshop

In Stage 2, for the purpose of testing, refining, and finalising the Framework developed in Stage 1, we engaged experts (N = 13) from the Exten.(D.T.)$^2$ project partners; from research, education, and industry with high levels of domain knowledge in Mathematics, Computer Science, Informatics, Educational Technology, Digital Technology, Design Thinking (DT), as shown in Table 1, in a participatory workshop lasting for 3 hours.

**Table 1. Demographics of participants in the participatory workshop**

| No. | Participant Information | Expertise Keyword |
|---|---|---|
| 1 | 7 years as primary teacher, and 13 years post-doctoral research and teaching experience | Education, Research |
| 2 | Math, Design Thinking, pedagogical design of constructionist media , design research | Mathematics, Research, Digital Technology, DT |
| 3 | Lecturer in Computer Science, Data Science (Data mining, machine learning, information visualization), 5 years PhD, 2 years of Post Doc in Data Science projects (data-driven applications, machine learning). Teaching: data mining, machine learning, information visualization, database, Python, web, and mobile development | Computer Science, Informatics, Educational Technology, Education, Research |
| 4 | Academic 5 years, Teacher training 8 years: post-primary in-service Teacher Education/Training, CS/STEM education, Coding, Mechatronic Engineering, Constructionist Approaches to Learning, Educational Technology, Design Thinking, 21st Century Skills Development, Project Based Learning, Challenge Based Learning, 3D Printing | Education, Research Computer Science, Informatics, Educational Technology, DT |

| | | |
|---|---|---|
| 5 | Professor in artificial intelligence and human learning, 20 years of experience in the field developing novel approaches to designing AI systems applied in Education | Education, Research, Educational Technology |
| 6 | Expertise in education, technology, and design for 10 - 15 years | Education, Educational Technology, DT |
| 7 | Working in the field of Technology Enhanced Learning or more than 2 decades. Research interests include the areas of advanced HCI and novel uses of Big Data techniques and mobile technologies in the fields of Education. Involved in more than 10 EU projects in the field of TEL and published over 250 scientific articles in this field | Education, Research, Digital Technology, Educational Technology |
| 8 | An Educator for the past 30 years. Specialise in educational technology and research focuses on intelligent and adaptive support in exploratory learning environments. Currently work both in industry and in the academia as a lead software engineer and researcher | Education, Research, Educational Technology |
| 9 | Mathematician with an experience of 12 years in teaching mathematics in after school settings (secondary and high school), PhD student in digital technologies in mathematics | Mathematics, Research, , Digital Technology |
| 10 | Mathematician with 8 years of experience in teaching mathematics in after school curriculum (private lessons) and robotics (in groups). PhD student in digital technologies in mathematics (creativity-math-dance-trigonometric functions) | Mathematics, Research, , Digital Technology |
| 11 | Lecturer of computational literacy in education and a post-doc researcher focusing on emerging technologies and authoring systems for education. Participated as a researcher in 7 EU projects and 3 national projects. For the last 3 years teaching 2 Masters Courses on transforming education with | Computer Science, Digital Technology, Education, Research |

| | | |
|---|---|---|
| | digital technologies, and in the last year 3 pre-graduate courses. Also worked as a software developer for the industry for 3 years | |
| 12 | Mathematician and Master student in digital technologies (now). 6 years of experience in teaching mathematics (private lessons) | Mathematics, Research, Digital Technology |
| 13 | Bachelor's degree in informatics, teaching computer science in Primary School (3 years) and in after-school settings of Secondary students (5 years) Master's degree is dedicated to Transforming Education through Technology (2 years) | Computer Science, Informatics, Educational Technology |

The schedule of sessions in this workshop is outlined in Table 2. At the beginning of the workshop, we presented the main take-away messages from stage 1 (for more details, see section 5.1.) and showcased the working draft of the Framework and how we derived it with examples (as shown in Figure 2). In the next session, we asked the participants to add one to two general comments and thoughts on the draft Framework and add elements relevant to each component they edited. Next, they were asked to work in a group (size of 2-4) to review all the added elements through their group, categorise these elements, analyse the similarities and differences, and then discuss the motivation behind these similarities and differences. Finally, we engaged the participants in a group presentation about their outcomes (as detailed in section 5.2) and this was followed through with an open discussion among all the participants.

**Table 2. Schedule of activities in the participatory workshop**

| Number | Activity | Expected outcome |
|---|---|---|
| 1 | Presentation of relevant Frameworks to participants | Establishing common ground among all participants on their understanding of the key relevant works |
| 2 | Introduction to the working draft of the Exten.(D.T.)$^2$ Framework | Creating a common starting point to brainstorm, contribute and provide inputs |
| 3 | Participants were asked to review and improve the draft Framework by adding, renaming, | Generating ideas on what is important to be considered and what is missing in the |

| | | |
|---|---|---|
| | changing, or deleting the elements that they find relevant or irrelevant | working draft of the Exten.(D.T.)² Framework |
| 4 | Presentation of group outcomes and open discussion among all participants | Facilitating idea exchanging and gaining a more in-depth understanding of how to improve the working draft of the Exten.(D.T.)² Framework and how these elements can be linked to the guidelines. |

The insights gleaned from the workshop were systematically classified into thematic categories and compared with pertinent elements of the existing Framework. A comparative analysis was conducted to discern how these statements aligned with or diverged from the preliminary version of the Framework. Redundant or overlapping assertions were duly noted and kept. Novel and distinct statements were duly categorised according to their thematic relevance.

# 5 Results

## 5.1 Results from Stage One (A Literature Review)

### 5.1.1 Key Components Based on Reviewed Relevant Work

This section presents the answers to the guiding question mentioned in section 4.1: "What are the critical components in the relevant Frameworks to enhance educational values and involve digital technology in educational contexts?"

Table 3 illustrates the main relevant themes regarding the components (including people, technology and infrastructure, learning environment, materials and resources, guidance, and evaluation) synthesised from our review.

**Table 3. Themes in relation to components synthesised from the relevant frameworks**

| Themes | Brief description | Key resource |
|---|---|---|
| People | A component describes the people who are involved in a certain context of learning or educational activities.<br>For example, "people" presented in the relevant Frameworks vary from students, teachers, teacher educators, learning designers and facilitators. | (Bekker et al., 2015; Caena & Redecker, 2019; Falloon et al., 2020, p. 12; Fragou et al., 2016; Joint Research Centre (European Commission) et al., 2017; Kandemir et al., 2021; Kapor Center, 2021; OECD, 2018, 2019b, 2022; UNESCO, 2018, 2019, 2022) |
| Technology and infrastructure | A component includes all the digital and instructional tools, technology infrastructures, digital co-working space that are used during learning and teaching. | (Bekker et al., 2015; Oyelere et al., 2022; Saikatikorn et al., 2021; Teo et al., 2021; UNESCO, 2022; Tondeur et al., 2012) |
| Learning environment | A component labelled as the learning environment which is extended from the classroom context to any environment learning may take place including classroom-based learning, face-to-face online blended courses, human-coached ubiquitous online and open learning. | (Battelle for Kids, 2019, p. 21; Bekker et al., 2015; Falloon et al., 2020; National Council for Curriculum and Assessment (NCCA), 2020; OECD, 2020; Saikatikorn et al., 2021; UNESCO, 2022) |

| | | |
|---|---|---|
| Materials and resources | A component that includes a set of educational materials and resources that are used during teaching and learning.<br>For example, system-led provision of educational resources, media and content, lesson plan and materials, learning and project brief. | (Bekker et al., 2015; Koh et al., 2015; UNESCO, 2022) |
| Guidance | A component that describes the pedagogy, instruction for students (coaching from the teacher on the tasks), teacher professional development and training. | (Battelle for Kids, 2019, p. 21; Bekker et al., 2015; Caena & Redecker, 2019; Teo et al., 2021; UNESCO, 2019; Tondeur et al., 2012) |
| Evaluation | A component about the learning analytics, learning goals and assessment of students learning or certain skills, and pedagogical evaluation on teachers. | (Battelle for Kids, 2019, p. 21; Bekker et al., 2015; Caena & Redecker, 2019; Cukurova et al., 2016; Fragou et al., 2016; Grover, 2021; Grover et al., 2017; National Council for Curriculum and Assessment (NCCA), 2020; OECD, 2006, 2019a, 2015; Oyelere et al., 2022; UNESCO, 2016, 2019, 2022) |

### 5.1.2 Key Perspectives Based on Reviewed Relevant Work

This section presents the answers to the guiding question mentioned in section 4.1: “What perspectives need to be considered for including all genders, hard-to-reach populations, and geographical and societal obstacles regarding the access and use of technologies?”

Despite the fact that the “perspective” does not appear as an independent element in the reviewed Frameworks, this aspect has been addressed in the form of design principles, considerations or (sub)elements of a Framework. Table 4 illustrates the main themes regarding the perspectives (including inclusivity and diversity, student agency and voice, collaboration and transferability between educational stakeholders, and ethics and flexibility of using or adopting technologies) that emerged from our review.

**Table 4. Themes in relation to perspectives synthesised from the relevant frameworks**

| Themes | Brief description | Key resource |
|---|---|---|
| Inclusivity and diversity | A prerequisite for achieving inclusive education, encompassing aspects such as language and culture diversity, disability inclusion, and gender equality, and the adoption of the Universal Design for Learning (UDL) Framework. | (Kapor Center, 2021; UNESCO, 2019; Council of Europe, 2019) 30/05/2023 16:34:00 |
| Student agency and voice | In order to motivate students and acknowledge their existing knowledge, abilities, beliefs, and principles, the curriculum ought to be developed with a student-centred approach. | (Kapor Center, 2021; OECD, 2018, 2019b) |
| Collaboration and transferability between educational stakeholder | International collaboration and technological advances support more flexible learning and extended schooling. | (Instefjord & Munthe, 2016; OECD, 2020) |
| Ethics and flexibility of using or adopting technologies | This element includes considerations on data and cyber security, risk management and assessment, and the transparency of collected data from young students. (In the case of children interacting with AI systems, it is important to ensure that they are provided with clear and straightforward information about the system's nature and capabilities.) | (DiPaola et al., 2023; OECD, 2022; UNESCO, 2022) |

### 5.1.3 Key Competencies Based on Reviewed Relevant Work

This section presents the answers to the guiding question mentioned in section 4.1: "What key competencies are known and reported in the context of educational settings in the existing Frameworks? What needs to be considered to empower and enhance competencies (and relevant skills, knowledge, and literacy) in students, teachers, and related educational stakeholders?"

We found many relevant works on conceptualising and defining competencies for education, all citizens, lifelong learning and similar. Table 5 illustrates the common themes with respect to the competencies (including digital, pedagogical, and personal-professional competencies) in the context of DT with ET that emerged from our review.

**Table 5. Themes in relation to competencies synthesised from the relevant frameworks**

| Themes | Brief description | Key resource |
|---|---|---|
| Digital competencies | This competence includes the ability to use technology, access data information, and navigate interactively and effectively online. | (Caena & Redecker, 2019; Council of Europe, 2019; Falloon, 2020; Ferrari, 2013; Instefjord & Munthe, 2016; Joint Research Centre (European Commission), 2015; Joint Research Centre (European Commission) et al., 2017, 2017; Kotzebue et al., 2021; The International Labour Organisation, 2021; Vuorikari et al., 2022; Common Sense Education, 2017; Kotsiou et al., 2022) |
| Pedagogical competencies | This competence concerns the ability to plan a learning program, relate DT activities to learning goals and possible school curricula subject, manage and guide the learning process, and perform an assessment. | (Falloon et al., 2020; UNESCO, 2019) |

| | | |
|---|---|---|
| Personal-professional competencies | This element includes specific competencies such as collaboration and work with others, presentation and communication, reflection and documentation, positive acceptance of failure, adaptability, and time management. | (Bianchi et al., 2022; Falloon et al., 2020; Instefjord & Munthe, 2016; Kotzebue et al., 2021; OECD, 2005; Sala et al., 2020) |

### 5.1.4 A Working Draft Version of The Exten.(D.T.)$^2$ Framework [V0.1]

In summary, after several rounds of initial sketches (see Appendix B), we drafted a conceptual diagram of the Exten.(D.T.)$^2$ Framework [V0.1] to describe the key components we identified from this stage, along with the dimension of perspectives and competencies, as illustrated in Figure 2.

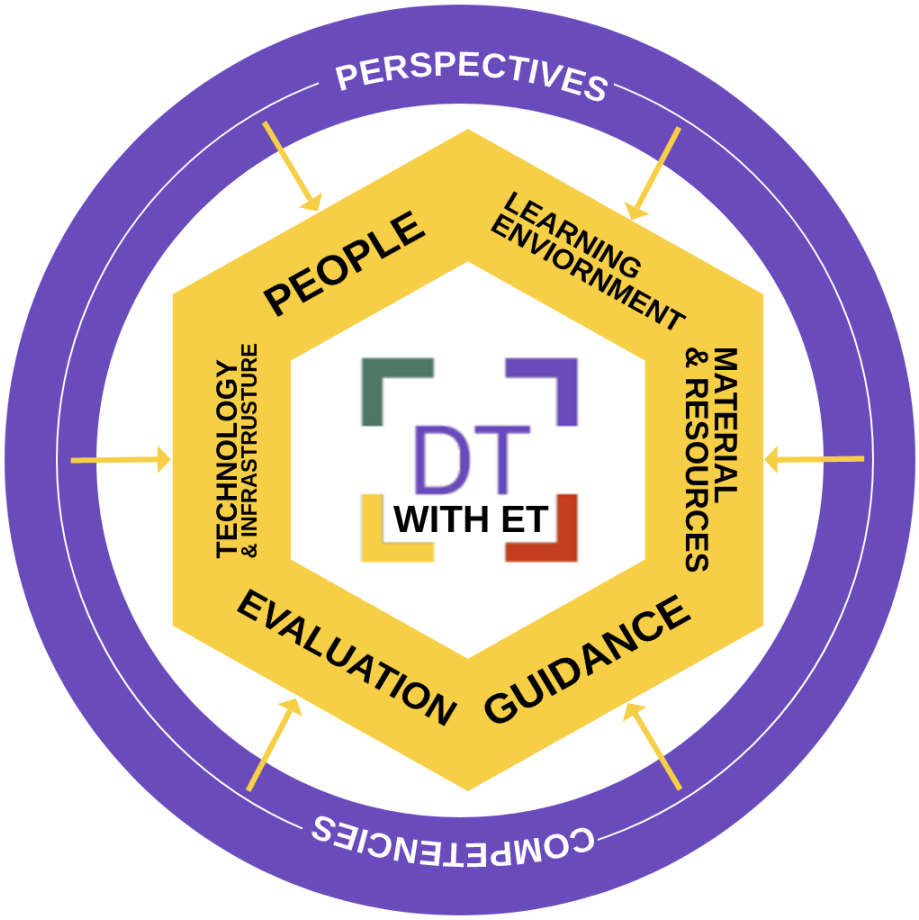


**Figure 2. A working draft of the first version of the Exten.(D.T.)$^2$ Framework [V0.1]**

Based on the insights obtained from relevant works in this stage, we correspondingly formulated six key **components** below to be included in the working draft of the Framework [V0.1]:

- **PEOPLE:** This refers to critical actors involved in the DT (learning) with ET (e.g., teachers, instructors, facilitators, headmaster/leader, policy maker, and the students).
- **TECHNOLOGY AND INFRASTRUCTURE:** This refers to the overall platform and types of ET involved in DT.
- **LEARNING ENVIRONMENT:** This consists of the environments in which learning may take place online, blended or physically.
- **EDUCATIONAL MATERIALS AND RESOURCES:** This includes the pedagogy activity plans and lesson plans.
- **EVALUATION:** This refers to the assessment of learning, for example, of the activity per se and the students' outcome (e.g., skills, attitudes).
- **GUIDANCE (FOR TEACHERS):** This refers to the teacher's professional development and support materials like video tutorials.

Regarding the perspectives and competencies, this working Framework [V0.1] focuses on the interrelation between them and the main components. Rather than listing them all in the diagram of the working Framework [V0.1], we outlined some of the key perspectives and competencies inspired by our review results (as shown in Tables 4 -5) on the PowerPoint slide presentation to the participants at the expert consultation workshop in Stage Two.

## 5.2 Results from Stage Two (A Participatory Workshop)

We collected nine Framework ideas (see Appendix C) from our participatory workshop and analysed and classified them into thematic categories. Below, we present the results according to the dimensions of components, perspectives, and competencies. Lastly, we summarised and reflected on what was missing and what was essential that remain in the first version of the Exten.(D.T.)$^2$ Framework.

### 5.2.1 New and Overlapping Components from the Participatory Workshop

Our analysis revealed that, to different extents, all the components in the first draft of the first version of the Exten.(D.T.)$^2$ Framework [V0.1] had been acknowledged by the nine groups of the workshop participants. For example, all groups addressed the components of Technology and Infrastructure, while less recognised the component of People (N=4), Guidance (N=4), Evaluation (N=6), Learning Environment (N=7), and Materials and Resources (N=8).

Newly appeared components, proposed by participants, were categorised into the following main themes:

- Digital and Educational Transformation (N=3)
- Professional Development/Training/Empowerment and Learning (N=4)
- Societal Challenges and Ethical Consideration of these challenges (N=3)
- Skill development initiative skills, persuasive management for teachers and 21st-century skills for students (N=3)

### 5.2.2 New and Overlapping Perspectives from the Participatory Workshop

While most of the ideas coming from the workshop tended to stick to the perspectives presented in the first draft of the first version of the Exten.(D.T.)$^2$ Framework [V0.1], a few explicitly mentioned the specific perspectives (e.g., equality, inclusivity, and ethics) we introduced at the workshop and added several more (e.g., resilience, mobility, sustainability). For example, one group explicitly emphasised the perspective of equality, diversity and inclusivity inspired by the Equality, Diversity, and Inclusivity (EDI) Framework[1] and also, this perspective stems from the Universal Design for Learning (UDL) Framework[2]. Another group explicitly mentioned ethics, equality, resilience, and mobility. These results confirmed the key perspectives we identified and further drew our attention to a few more aspects, such as resilience and sustainability.

We also noticed some new ways of presenting perspectives. As an illustration, according to the idea from one group, perspectives may be seen as sustainability, openness, diversity, and life-long learning, while these were also the objectives to achieve. Furthermore, in addition to the draft Framework, one group emphasised one's perspectives, for example from different stakeholders. This finding illustrates the way of presenting “perspective” depends on the person involved.

### 5.2.3 New and Overlapping Competencies from the Participatory Workshop

Slightly different from how the dimension of competencies is structured in the first draft of the Exten.(D.T.)$^2$ Framework [V0.1], three groups treated the competencies as part of the main components located on the loop of all the components. One of the three groups explicitly mentioned the competencies of students and teachers respectively. Similarly, another group positioned the competencies around the component of people. This result pointed out the need to articulate the relationship between competencies and components for those involved in DT.

[1] https://www.apa.org/about/apa/equity-diversity-inclusion/framework#:~:text=The%20EDI%20framework%20is%20an,coordinated%20strategy%20towards%20dismantling%20racism.
[2] https://udlguidelines.cast.org/

### 5.2.4 A Working Draft Version of The Exten.(D.T.)² Framework [V0.2]

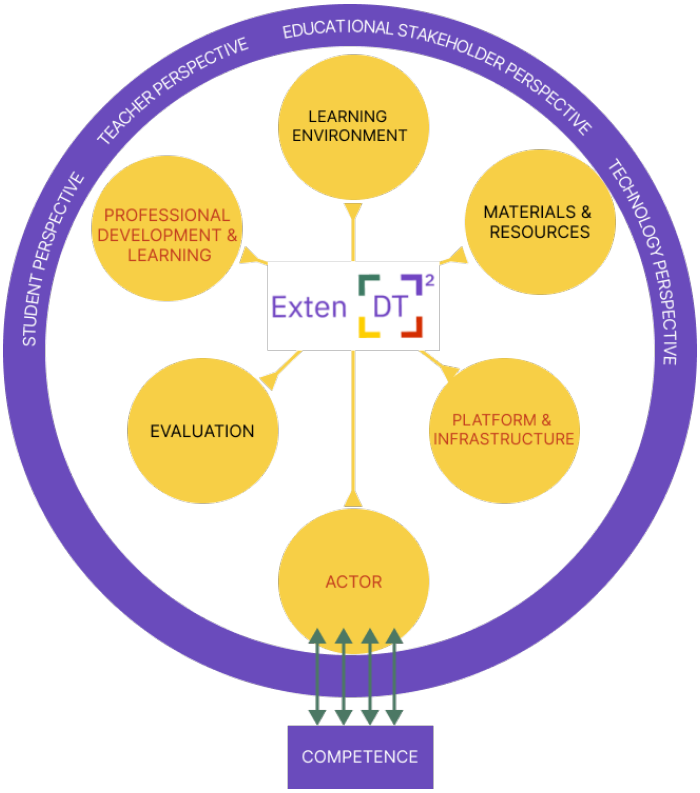


**Figure 3. A working draft of the first version of the Exten.(D.T.)² Framework [V0.2]: by adding changes inspired by the workshop**

As seen in Figure 3, we incorporated changes in the conceptual diagram of the Exten.(D.T.)² Framework [V0.2] to reflect the insights we gained from the participatory workshop. The changes regarding perspectives and competencies (in purple blocks) were intended to consider a new way of looking at the interrelation between them and components. Furthermore, all the changes to the components we made were marked in red texts. For example, we changed the component of guidance in the previous version of the Framework [V0.1] to professional development and learning. Second, we changed the people component into the actor component. Third, we changed the technology and infrastructure component into the platform and infrastructure component. The motivation for the above-mentioned changes was to consider improving the clarity of the presentation about the content of this component.

It is worth acknowledging that all the changes in improving the clarity of the presentation pointed out a need to visually explain the interconnected nature of the components, perspectives, and competencies in the Framework. This results in the introduction of a metaphor to symbolise the interrelation of all the elements presented in the Framework. More details about the use of metaphor are presented in the next section (6.1.2.)

# 6 The Exten.(D.T.)² Framework: The First Version [V1]

## 6.1 Overview and Conceptualisation

### 6.1.1 Aim and Scope of the Framework

Overall, this Exten.(D.T.)² Framework aims to reflect the ongoing digital transformation in education and the opportunities emerging in the context of education with the advancement of digital resources, media, and technologies.

The primary purpose of Exten.(D.T.)² Framework is:

- to allow these stakeholders to zoom in on specific elements (e.g., components, perspectives, and competencies) essential for supporting DT Learning with ET
- to facilitate the implementation of DT activities, the adoption of ET, and the integration of DT with ET for all children, all genders and in different (online and blended) learning contexts.

As mentioned earlier, at this stage, the Exten.(D.T.)² Framework is designed to mainly focus on stakeholders of DT learning (e.g., teachers, learning, policymakers, scientists, and all involved educational stakeholders etc.) and especially teachers who may be interested in incorporating ET into their practices.

### 6.1.2 Metaphor and Concept

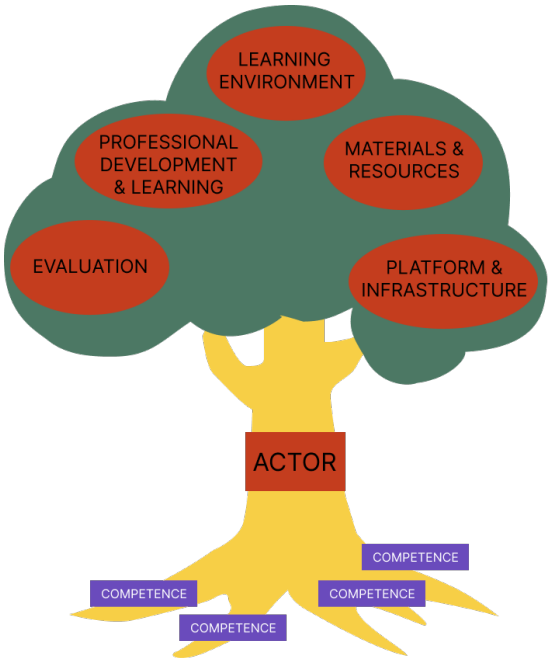


**Figure 4. A working draft of the first version of the Exten.(D.T.)² Framework [V0.3] by combining the metaphor of a tree**

The Exten.(D.T.)2 Framework [V1] uses the tree as a metaphor symbolising various aspects of supporting DT with ET, as shown in Figure 4. By employing the tree metaphor, the Framework aims to help visualise and understand the interconnected nature of various aspects of supporting DT with ET, emphasising the importance of a holistic approach to integrating ET in DT education.

- Roots: The roots signify the foundational competencies that students, teachers, or educational stakeholders possess. These suggest that branches should be connected to the roots; and they are the essential building blocks for further growth and development and underpin effective DT learning with ET.
- Trunk: The trunk symbolises the different actors in this context who will be empowered by their competencies to actively engage in the DT activities with ET.
- The cluster of leaves: The cluster of leaves represents the five core components that are related to the actor component and are essential for supporting DT with ET. In addition, the leaves on the outside layer signify the specific sub-elements in each core component.

Perspectives are listed around the tree as crucial considerations (next to the components), which symbolise the air to promote the growth of the tree.

## 6.2 The Exten.(D.T.)$^2$ Framework [V1]

After a few iterations (see Figures 2-4), the deliverable eventually introduces the Exten.(D.T.)$^2$ Framework [V1] based on insights gained from the review and the workshop. Additionally, we incorporated the metaphor of a tree to the working framework.

Figure 5 below visualises the constructs and the interconnectedness of the elements presented in this Exten.(D.T.)$^2$ Framework [V1]. For example, one of the core elements is the components which are presented in the red bubbles and block. In the next section (6.3), we present six key components and the sub-elements that consist of each component. Another element is the perspectives, which are presented in the green text, lines, and arrows. In section 6.4, we present four key perspectives and the sub-elements that consist of each perspective. The last core element concerns the competencies, which are presented in the purple boxes with arrows. In section 6.5, we present four key competencies and the sub-elements that consist of each competence.

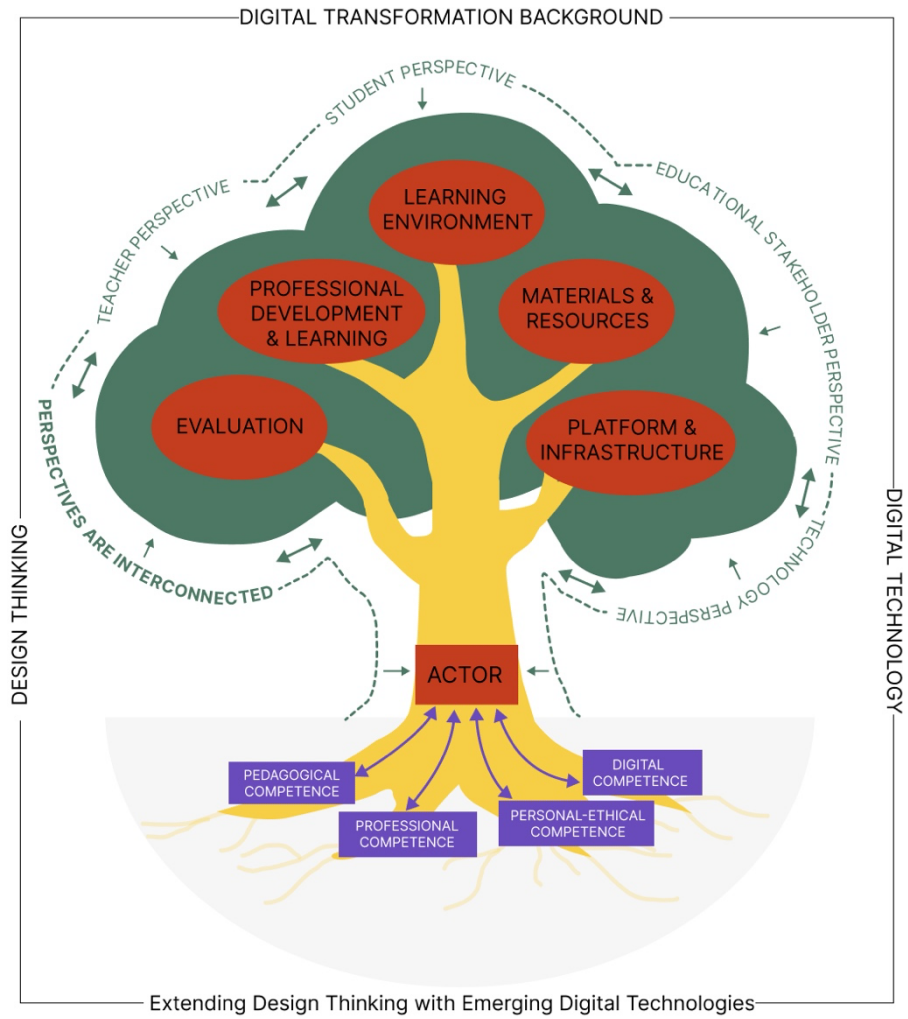


**Figure 5. The Exten.(D.T.)² Framework [V1]**

## 6.3 Components of the Framework

### 6.3.1 Definition of Component

A component in this Framework refers to a distinct part or element that contributes to the overall structure or functioning of the Framework. Components can be different aspects or dimensions of the Framework and are often interconnected and work together to support the implementation of the Framework.

### 6.3.2 Key Components in Six Categories

The Exten.(D.T.)² Framework [V1] complied the key components that need to be taken into account for supporting DT with ET in a set of six categories based on comparing the results from the reviewed literature and participatory workshop. This approach aimed to lay a good foundation for future development in both a practical and theoretical manner.

- **ACTOR**

  Actors are the end-users and stakeholders involved in the learning and teaching processes. This refers to any individual that plays a role or has an active involvement in the DT activities with ET.

- **LEARNING ENVIRONMENT**

  Learning environment refers to the (physical or virtual) place and context where learning and teaching may occur. The context can vary widely, including traditional classrooms, online learning, or workshops.

- **MATERIALS AND RESOURCES**

  Materials and resources refer to a wide range of resources (e.g., financial, physical, human, and other educational resources) and various forms and formats of materials (e.g., physical, or digital lesson plans and activity plans etc.) that are needed or related to support teaching and learning.

- **PLATFORM AND INFRASTRUCTURE**

  Platform and infrastructure include feature-rich platforms, technology-empowered infrastructure, educational tools and technologies, and repositories that are essential in enabling efficient interactions and operations and maintaining digital ecosystems. A platform can provide a software system or environment for applications and services, while infrastructure encompasses the physical and virtual parts supporting the functioning of systems.

- **PROFESSIONAL DEVELOPMENT AND LEARNING**

  Professional development and learning refer to how teachers (or other relevant educational stakeholders) are being prepared for the instruction regarding the learning tasks, pedagogical objectives, and experience, implementation, and guidance.

- **EVALUATION**

  Evaluation refers to assessing DT learning with ET from multiple sources and diverse angles, such as regarding outcomes for the students (e.g., learning, skills, and attitudes), the effectiveness of TPD in integrating DT with ET, the role of the platforms and infrastructure and other aspects that each stakeholder may think are relevant of evaluation in their context.

## 6.4 Perspectives Dimension of the Framework

### 6.4.1 Definition of Perspective

Perspective in this Framework refers to a particular point of view or way of looking at a potential problem or issue. It can refer to the beliefs, values, attitudes, and assumptions that underpin a particular approach to a problem, as well as the theoretical or conceptual Frameworks that guide that approach. Understanding different perspectives can help to ensure that the Framework is comprehensive and reflects the diversity of views and approaches to the problem or issue being addressed. Perspectives can be influenced by a range of factors, including cultural, social, political, and economic contexts, as well as individual experiences and backgrounds.

### 6.4.2 Key Perspectives in Four Categories

The Exten.(D.T.)$^2$ Framework [V1] groups and restructures similar perspectives and values retrieved from both the review and expert consultation according to the views of different actors. In this way, this Framework intends to point out a focused way of understanding the integration of DT and ET.

- **STUDENTS** (Equality, Inclusivity, Diversity and Resilience)

  From the student's perspective, this includes perspectives on inclusive education (e.g., supporting persons with disability, language and culture diversity, and gender equality) and fostering resilience and persistence in students when facing failures and frustrations.

- **TEACHERS** (Mindset, UDL and EDI)

  From the perspective of teachers, this includes developing an open and growth mindset towards quick changing of teachers' roles, pedagogical considerations on using the Universal Design for Learning (UDL) Framework and Equality, Diversity, and Inclusivity (EDI) Framework to sustain an inclusive education for students.

- **EDUCATIONAL STAKEHOLDERS** (Collaboration and Transferability)

  From the perspective of educational stakeholders, this includes promoting and facilitating collaboration between educational stakeholders and the transferability of knowledge and best practices in different institutions.

- **TECHNOLOGY** (Ethics, Flexibility and Sustainability)

  The technology perspective refers to views on how technology supports DT with ET, including how data will be collected and analysed from especially young students and how this will impact people and society.

## 6.5 Competencies Dimension of the Framework

### 6.5.1 Definition of Competencies

In an increasingly interconnected and diverse world due to globalisation and modernisation, societies face challenges like balancing economic growth, environmental sustainability, and social equity. Also, individuals must adapt to evolving technologies and process much information (OECD, 2005). As a result, the competencies required have become more complex. It is widely acknowledged and universally recognised that the knowledge, skills, and competencies of individuals and society are crucial.

According to the OECD's Definition and Selection of Competencies (DeSeCo) Project[3], "A competency is more than just knowledge and skills. It involves the ability to meet complex demands by drawing on and mobilising psychosocial resources (including skills and attitudes) in a particular context. For example, the ability to communicate effectively is a competency that may draw on an individual's knowledge of the language, practical IT skills and attitudes towards those with whom he or she is communicating. (OECD, 2005, p5)"

### 6.5.2 Key Competencies in Five Categories

The Exten.(D.T.)² Framework [V1] classifies relevant competencies reported in literature into four main categories. Each category contains specific competencies for students, teachers, and educational stakeholders. To a certain extent, those competencies may have already been acquired and expected to be enhanced, targeting the aims of DT with ET.

- **DIGITAL COMPETENCIES**

  Digital competencies, such as ICT skills, literacy, and technology proficiency, are necessary to prepare students, teachers, and technologists to access data and navigate information and interactively and effectively use ET during DT.

- **PROFESSIONAL COMPETENCIES**

  Professional competencies for teachers include their abilities for professional engagement, such as organisational communication, professional collaboration, and reflective practice.

  For students, professional competencies refer to their abilities to carry out DT activities and learning effectively. This includes competencies such as planning and time management, reflection and documentation, collaboration and teamwork, presentation and communication, 21st-century skills, and design literacy.

[3] https://www.oecd.org/education/skills-beyond-school/definitionandselectionofcompetenciesdeseco.htm

- **PEDAGOGICAL COMPETENCIES**

  Pedagogical competencies refer to the ability to plan a learning program, relate DT activities to learning goals and possible school curricula subject, manage and guide the learning process, and perform an assessment.

- **PERSONAL AND ETHICAL COMPETENCIES**

  Personal and ethical competencies describe the abilities of students and teachers from the individual or collective level. This includes competencies in exercising digital citizenship, ethics and judgement, managing personal experience, safety and wellbeing, and positive acceptance of failure.

# 7 Conclusion

## 7.1 How the Main Elements of the Framework Address the Identified Requirements

As mentioned in the introduction (section 3), we identified five essential requirements as the priority in this first version of the Framework. Below, we explain how the Framework aims to meet such a requirement point by point.

> *"Enhance competencies (and relevant skills, knowledge and literacy) in students, teachers and related educational stakeholders." (p7; See the Introduction section)*

To potentially address this requirement on enhancing competencies, the Framework [V1] outlines the essential competencies, including digital, professional, pedagogical, and personal and ethical competencies (see more details in subsection 6.5).

> *"Supporting teachers with essential pedagogical consideration and connecting DT with ET to curricula and school contexts." (p7; See the Introduction section)*

To potentially address this requirement on supporting teachers, the Framework [V1] highlights the pedagogical competencies for teachers (see more details in subsection 6.5.2), and the component of professional development and learning (see more details in subsection 6.3.2).

> *"Facilitating students' teamwork and stakeholders' collaboration." (p7; See the Introduction section)*

The Framework [V1] can address this requirement on teamwork and collaboration in two ways. First, the component of professional development and learning can help prepare the teachers to facilitate and monitor students' teamwork. Second, the perspectives of educational stakeholders (see more details in subsection 6.4.2) can facilitate collaboration.

> *"Empowering progress monitoring and assessment with LA component during DT." (p7; See the Introduction section)*

The Framework [V1] can address this requirement on monitoring and assessment by taking into account the component of evaluation and the component of platform and infrastructure (see more details in subsection 6.3.2).

*"Cultivating school values, culture and visions on DT and adoption of ET." (p7; See the Introduction section)*

The Framework [V1] can address this requirement on values on DT and ET by taking good care of the perspectives of students, teachers, educational stakeholders, and technology (see more details in subsection 6.4.2).

## 7.2 Outlook and How the Future Work of this Project Can Contribute to the Next Version of the Framework

This section aims to give a high-level summary and mapping of the overall related means to reach Exten.(D.T.)$^2$ project objectives, as they are described in the proposal (see the texts below inside the tables), with what is presented in the Exten.(D.T.)$^2$ Framework [V1]. The focus is to reflect on how the next steps of this project can possibly provide inputs for the further development of the Framework [V1]. Below, we present the expected steps for each core component, perspective and competence.

### 7.2.1 Components in Relation to the Future Work of this Project

Regarding the components of LEARNING ENVIRONMENT, and PLATFORM AND INFRASTRUCTURE, the next expected steps of this project (WP4) include extending technological tools, and an online platform, developing an LA system, and an all-in-one platform.

*Related means to reach the project's objectives:*

- *Extend technological tools, namely MaLT2, ChoiCo, SorBET, and Cyberbotics, with emerging technologies that bring added value into DT, i.e., ARs, 3D printing/scanning and Virtual Robotics.*
- *Mobilising and extending the online platform nQuire, where tools and DT activities will become available for wide use and learning at scale and create a network of schools and out-of-school organisations connected. It will also be a safe space for students to share digital productions and engage in discussion.*
- *Developing a Learning Analytics (LA) system and a customisable dashboard.*
- *All digital learning environments will be tied together in one Learning Platform to generate and provide data for analysis that can streamline the experiences of students and teachers.*

Concerning the component of MATERIALS AND RESOURCES, the following steps of this project (WP3) include the co-design and co-development of educational activities about the project technologies and teacher training material.

*Related means to reach the project's objectives:*

- *Offering free online courses.*
- *Mobilising the co-creation planet, designed to support DT projects, to be used in teacher professional development courses.*
- *Producing a set of DT activities and associated material.*
- *Providing digital resources to support the digital implementation of DT activities.*

Concerning the component of PROFESSIONAL DEVELOPMENT AND LEARNING, the future works of this project (WP6) concern the support and professional development of teachers and teacher trainers.

*Related means to reach the project's objectives:*

- *Integration of the Exten.(D.T.)2 approaches and technologies in existing academic courses about effective pedagogies to pre-and in-service teachers.*
- *Designing and developing specialised TPD modules providing oriented knowledge.*
- *Providing teachers with Exten.(D.T.)2 experts research knowledge on teachers' needs and challenges and propose evidence-based mitigation actions.*

In terms of the ACTOR component, this project's future actions (WP3 and WP5) involve the iterative design and implementation of digital-based DT interventions with students and co-design with teachers and educational stakeholders.

*Related means to reach the project's objectives:*

- *Engaging students in co-creation projects following the DT process for creating a feasible solution to a socio-scientific problem.*
- *Actively involving teachers in a participatory process of design, data collection, analysis and feedback for DT activities.*
- *Enables different educational stakeholders to get involved in designing digital resources for DT with the capability of customisation.*

As for the component of EVALUATION, the next steps in the following cycles of this project (WP7) are the evaluation of students' knowledge, skills and attitudes and the analysis of the impacts of ET-empowered DT intervention.

*Related means to reach the project's objectives:*

- *Systematic evaluation of how students' design thinking knowledge, skills and attitudes are stimulated and enabled using technologies (e.g., LA, surveys, interviews).*
- *Critical analysis of the gendered, cultural, geographical and societal effects regarding the use of AI, AR, 3D printing and Virtual Robotics in DT activities.*

### 7.2.2 Perspectives in Relation to the Future Work of this Project

Regarding the perspective of students described in the Framework [V1], the future steps of this project (WP7 and WP4) include the following:

*Related means to reach the project's objectives:*

- *Critical analysis of the gendered, cultural, geographical, and societal effects regarding using technologies in DT activities.*
- *Use and evaluate the two online platforms, nQuire and co-creation planet as "safe spaces'' for communication and sharing of personal creations, that will enable large-scale democratised engagement with responsible, ethical, and personally relevant scientific investigation.*

Regarding the perspective of teachers and educational stakeholders described in the Framework [V1], the future steps of this project (WP5 andWP 3) include the following:

*Related means to reach the project's objectives:*

- *Actively involving teachers in a participatory process of design, data collection, analysis, and feedback for DT activities.*
- *Co-create DT cases and relevant educational material to mobilise 21st-century skills not only for the use of STEAM concepts but also for grappling with socio-scientific wicked problems such as climate change, migration, and biodiversity, with the use of emerging technologies, developing, and evaluating students' problem-solving skills and knowledge of these issues.*

Regarding the perspective of the technology described in the Framework [V1], the future steps of this project (WP4 and WP7) include the following:

*Related means to reach the project's objectives:*

- *Extend technological tools, namely MaLT2, ChoiCo, SorBET, and Cyberbotics, with emerging technologies that bring added value into DT, i.e. ARs, 3D printing/scanning and Virtual Robotics.*
- *Critical analysis of the gendered, cultural, geographical, and societal effects regarding using technologies in DT activities*.

### 7.2.3 Competencies in Relation to the Future Work of this Project

Regarding students' and teachers' digital-technological competencies and personal-ethical competencies described in the Framework [V1], future steps of this project (WP5 and WP6) are as following:

*Related means to reach the project's objectives:*

- *Extending a set of existing expressive digital constructionist learning tools designed to support the implementation of design thinking projects in online or blended learning settings and to foster 21st-century skills in students. Extend technological tools, namely MaLT2, ChoiCo, SorBET, and Cyberbotics, with emerging technologies that bring added value into DT, i.e. ARs, 3D printing/scanning and Virtual Robotics.*
- *Providing teachers with Exten.(D.T.)² experts' research knowledge on teachers' needs and challenges concerning the use of the project's technologies in the context of design thinking education which will be derived from the above channels, and proposing evidence-based mitigation actions emerging from the project evaluation.*
- *Developing an Authorable Learning Analytics (ALA) system and a customisable dashboard enabling different educational stakeholders to get involved in the design of digital resources for DT (teachers, researchers, educational designers) with the capability of customising the kinds of information they need to assess learner's creative learning and the types of automated reactions they wish the tool to provide to learners.*
- *Critical analysis of the gendered, cultural, geographical, and societal effects regarding using technologies in DT activities.*

Regarding teachers' pedagogical competencies and professional competencies described in the Framework [V1], the future steps of this project (WP6) around this include the following:

*Related means to reach the project's objectives:*

- *Integration of the Exten.(D.T.)2 approach and technologies in at least 5 existing academic courses about effective pedagogies to pre- and in-service teachers.*
- *Design and develop specialized TPD-accredited modules providing oriented knowledge and experience as well as support for infusing such an activity in mainstream institutions*

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# 9 Appendices

## 9.1 Appendix A: Relevant Frameworks

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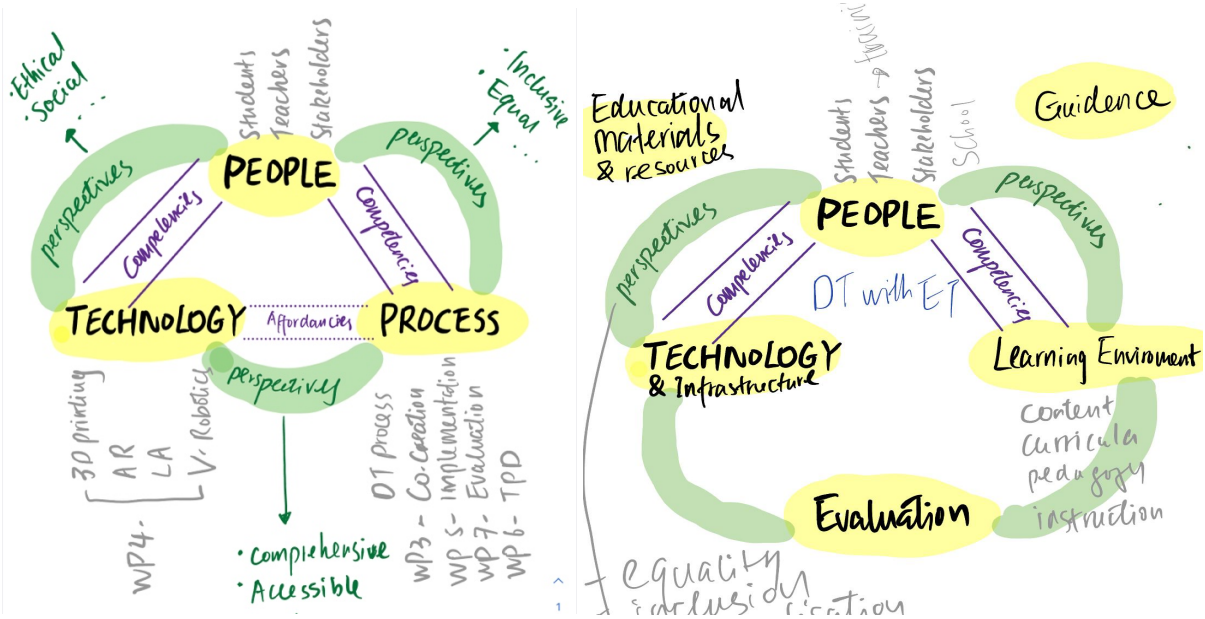
## 9.2 Appendix B: Initial Sketches before Drafting the First Draft of the First Version of the Exten.(D.T.)² Framework [V0.1]



## 9.3 Appendix C: Ideas from the Expert Consultation Participatory Workshop Participants Based on the Working Draft of the First version of the Exten.(D.T.)² Framework [V0.1]