KATERYNA HOLUBINKA

HOLISTIC INTEGRATION OF DESKTOP VIRTUAL REALITY TECHNOLOGY IN HIGHER EDUCATION

A DESIGN-BASED RESEARCH APPROACH



Propositions

Accompanying the thesis

Holistic Integration of Desktop VR Technology in Higher Education: A Design-Based Research Approach

Kateryna Holubinka
18 June 2026

1. Making pedagogical purpose of a desktop VR tool explicit and translating it into teacher-usable templates supports its integration in the educational practice (present thesis).
2. Integration of desktop VR technology into educational practice demands institutional coordination of five areas: Evaluation, Institutional Requirements, Maintenance and Training, Student Requirements, and Affordances and Infrastructure (present thesis).
3. The process of integrating desktop VR technology into educational practice depends on iterative evaluation that examines not only whether it works, but for whom, under which conditions, at what cost, and with what institutional consequences (present thesis).
4. Because education is inherently value-laden and future-oriented, the integration of technology must involve explicit negotiation between the values upheld by the educational context and the values inscribed in the technology (present thesis).
5. The educational value of VR does not follow from immersion alone, but from instructional designs that use presence, agency, spatial representation, and interaction to support learning-relevant cognitive and affective processes.
6. Educational practice without theoretical foundations risks becoming quackery in place of medicine; responsible education requires the deliberate alignment of teaching experience, theoretical understanding, and reflective judgement (based on Konstiantyn Ushinsky, 1857).
7. Data gains educational significance when it is made analysable, interpreted into knowledge, and reflectively aligned with values, context, and pedagogical purpose in support of educational practice (based on "science gathers knowledge faster than society gathers wisdom" Isaac Asimov, 1988).
8. You cannot be the Human in the Loop if you do not know how the loop is supposed to loop (NOLAI meeting, 2026).
9. The curriculum is so much necessary raw material, but warmth is the vital element for the growing plant and for the soul of the child (Carl Gustav Jung, 1970).
10. The future belongs to those who can imagine it better and have trust in working toward it (Kateryna Holubinka).

Holistic Integration of Desktop Virtual Reality Technology in Higher Education: A Design-Based Research Approach

Kateryna Holubinka

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We are dealing with the most complex, most invaluable, most precious thing in life – the human being. On us, on our ability, mastery, art, and wisdom, depend their life, health, mind, character, will, civic and intellectual identity, their place and role in life, and their happiness. The final result of pedagogical work cannot be seen today or tomorrow, but only after a very long time. What you have done, said, and managed to instil in a child sometimes reveals itself only after five or ten years.

Vasyl Sukhomlynsky (1918 – 1970)

Technology is the campfire around which we tell our stories.

Laurie Anderson (born 1947)

Preface

The cover of this dissertation presents plants rooted in a circuit-like ecosystem as a visual metaphor for technology integration. A plant may hold potential, but that potential can only be realised under suitable conditions. Its growth depends on soil, care, climate, surrounding life, and the wider system in which it is embedded. The same logic guides this dissertation's understanding of educational technology.

Human history shows why this matters. Long before agriculture, we gathered, selected, moved, protected, and managed plants in many ways. The later shift toward agriculture was not a sudden invention or a simple story of progress. It involved a different relation to plants, land, labour, time, and collective responsibility. We began to ask not only what could be taken from the environment, but how environments could be cultivated around the futures we wanted to secure.

The transition was also a shift in mindset, involving values, coordination, and a new understanding of our own role. We became not only users of what was available, but cultivators of conditions. Agriculture created new possibilities, including storage, settlement, and more complex forms of social organisation associated with the emergence of early civilisations. It also created new dependencies, inequalities, and risks. Cultivation therefore changed not only plants. It changed the ways societies could organise their futures.

This dissertation, first zooming into a desktop VR technology at a distance university, then zooms out, inviting you to take a similarly broader perspective on educational technology. We should not only ask how a tool can be used. We should ask which educational futures we value, what role we want technology to play in those futures, and which pedagogical, organisational, technical, and ethical conditions need to be cultivated to support them.

Meaningful integration is therefore not the mere presence of technology in education. It is the mindful and intentional alignment of values, practices, resources, and responsibilities. Through that alignment, technologies can support forms of education that are not only effective, but also worth sustaining. Since education helps shape the knowledge, values, and ways of working on which future societies depend, the question of technology integration is also a question of the future we are preparing to live in.

Following this line of thought, the present dissertation begins by examining how DVR-enhanced presentation technology can be meaningfully integrated in a distance-learning university and gradually broadens toward a framework for educational technology integration. At its centre is the question of what needs to be cultivated around technology so that it can serve worthwhile educational purposes: appropriate pedagogical choices, workable technical arrangements, supportive institutional conditions, shared values, and management work that sustains use over time.

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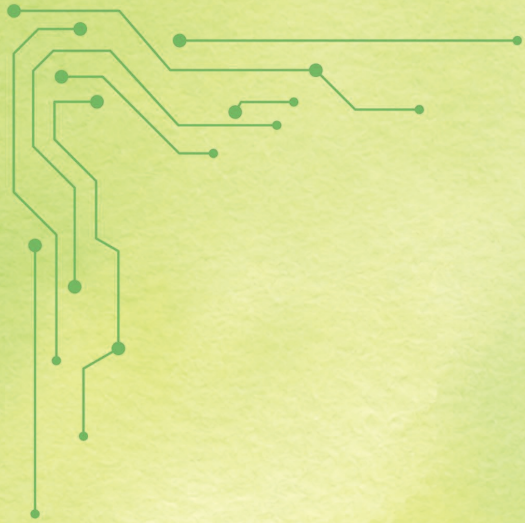
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General Introduction

General Introduction

Virtual Reality (VR) has become a prominent example of how emerging technologies promise to reshape education in the context of rapid social and technological change. As societies move from the efficiency-focused Fourth Industrial Revolution toward a more human-centric vision of Industry 5.0, educational institutions are expected to prepare learners for increasingly complex and unpredictable realities while navigating ongoing digital transformation (European Commission, 2021; Schwab, 2017). Within this landscape, Virtual Reality (VR) has attracted growing attention in educational research and practice, as reflected in a growing body of systematic reviews and meta-analyses across school and university contexts (D. Hamilton et al., 2021; Jensen & Konradsen, 2018; Luo et al., 2021; Mikropoulos & Natsis, 2011; Radianti et al., 2020; Stracke et al., 2025). Some of the illustrative uses highlight how VR can enable instruction in otherwise inaccessible contexts, including virtual field trips to remote or fragile locations (Makransky & Mayer, 2022; Petersen et al., 2020), three-dimensional reconstructions of historical sites and artefacts (Anwar et al., 2025), and simulated practice in domains where physical access is constrained, among others (García-Robles et al., 2024; Kyaw et al., 2019). At the same time, literature reviews and meta-analyses commonly note that VR implementations are often short-term and only partially connected to curricula and routine teaching workflows, which keeps the conditions for meaningful, sustainable, and scalable integration insufficiently specified (Luo et al., 2021; Merchant et al., 2014; Radianti et al., 2020; Stracke et al., 2025). Against this background, the present thesis focuses on Desktop VR (DVR) as an accessible VR configuration and investigates DVR-enhanced presentation technology as a synchronous, teacher-led format in university teaching. It addresses two questions: (RQ1) what design requirements support meaningful, sustainable and scalable integration of DVR-enhanced presentations in higher education; and (RQ2) how a DVR technology can be meaningfully, sustainably, and scalably integrated into the teaching practice of universities.

1. Theoretical background

1.1. VR as an Educational Technology: Types and Definitions

Virtual Reality (VR) is commonly defined as a computer-generated, interactive three-dimensional environment that simulates real or imaginary settings and allows users to explore and manipulate digital content in real time (Mikropoulos & Natsis, 2011). In educational research, the term VR is used as an umbrella for multiple application types that share three-dimensional representation and real-time rendering but differ in the technology used, interactivity and pedagogical framing. Accordingly, VR is not reducible to a single hardware configuration or a single level of immersion. Illustrative examples include learner-centred applications such as (a) computer simulations

designed for experimentation and conceptual exploration, often supported by instructional guidance (de Jong & van Joolingen, 1998); (b) digital games and serious games, where game mechanics are deliberately aligned with learning objectives or training purposes (Connolly et al., 2012; Arnab et al., 2015); and (c) three-dimensional virtual learning environments and virtual worlds (including multi-user virtual environments), where users act through an avatar within a persistent 3D space that may support social interaction and collaborative activity (Dalgarno & Lee, 2010; Dickey, 2012). These examples are not exhaustive and do not imply a single activity structure for educational VR. Beyond learner-centred applications, VR has also been examined in teacher-led instructional uses, where educators orchestrate three-dimensional visualisation and real-time rendering to structure explanation and guide attention during instruction. This includes presentation-oriented uses in which the educator operates a desktop-rendered 3D environment and the composited output is delivered through established teaching infrastructures (e.g., streaming or video-conferencing), as reflected in work on desktop VR visualisation and presentation tools and related instructional virtual production systems (Holubinka et al., 2023; Méndez-Fernández et al., 2025; Nebeling et al., 2021).

Conceptual work in human-computer interaction and mixed-reality research situates VR within a broader reality–virtuality continuum, which ranges from purely physical environments through mixed-reality configurations to fully virtual environments (Milgram & Kishino, 1994). Building on -this, recent taxonomies conceptualise VR systems along dimensions such as world knowledge, immersion, and coherence (Skarbez et al., 2021). VR is also described along technological continua of immersion, interactivity, and representational fidelity, emphasising that different configurations can afford different types of learning activities (Dalgarno & Lee, 2010a; Luo et al., 2021; Makransky & Petersen, 2021; Radianti et al., 2020; Stracke et al., 2025). Although immersion and presence are frequently foregrounded as key mechanisms in this literature, immersion varies by configuration and is therefore best treated as a design variable rather than as a definitional criterion for whether an application is VR (Bowman & McMahan, 2007; Cummings & and Bailenson, 2016).

Against this background, there is a common distinction in the literature between two broader categories of VR based on hardware used: immersive VR or iVR and desktop VR or DVR. (1) iVR typically refers to head-mounted display (HMD) or CAVE™-like systems with stereoscopic vision, head and position tracking, and a wide field of view, which can visually and auditorily surround the learner (Bowman & McMahan, 2007; Limniou et al., 2008). (2) DVR, by contrast, usually refers to non-immersive or low-immersive configurations in which the virtual environment is rendered on a standard monitor and navigated using conventional input devices such as keyboard, mouse, joystick, or touch screen, sometimes accompanied by headphones (E. A.-L. Lee & Wong, 2014; Makransky & Petersen, 2019a; Mikropoulos & Natsis, 2011). DVR therefore occupies a position at the lower end of immersion, but retains key affordances such as three-dimensional visualisation, spatial orientation, and interactive exploration of virtual objects and spaces, which have been linked to presence, improved conceptual understanding and learning

outcomes when appropriately embedded in instruction (E. A.-L. Lee & Wong, 2014; Makransky & Petersen, 2019a; Merchant et al., 2014; Smetana & Bell, 2012; Stracke et al., 2025). In this thesis, DVR is treated as a VR configuration in its own right and is the primary configuration of interest, while acknowledging its lower-immersion position within the broader VR landscape.

To locate the core instructional format studied in this thesis within this definitional space, we introduce the term *DVR-enhanced presentation technology,* which refers to a teacher-led, synchronous lecture format in which a presenter operates within a desktop-rendered 3D environment (DVR) while students access the session through standard streaming or video-conferencing platforms. The defining feature is that the presenter's instructional control is maintained during the live presentation phase, while DVR is used to augment explanation through spatialised 3D representations and dynamic viewpoints. This positions DVR-enhanced presentations as conceptually distinct from many VR learning applications that emphasise individual learner interaction with a virtual environment as the primary activity structure. The rationale for DVR-enhanced presentation is therefore not that it is "more immersive," but that it enables DVR to be embedded within scalable synchronous teaching arrangements already used in university settings, thereby foregrounding accessibility and implementation feasibility alongside pedagogical design.

1.2. State of research on VR in education

The current state of research on educational VR is synthesised in this section, with attention to evidence on affective outcomes, cognitive load, and learning effects across VR formats. Then, the conditions under which VR supports knowledge gain are identified, alongside limitations that constrain routine educational use.

The affective potential of VR is widely discussed in empirical studies, reviews, and conceptual work, but reported effects vary by VR format, task, and study design. Empirical studies report that VR environments can be associated with more positive affect and higher self-reported engagement than comparison formats in specific instructional contexts (Allcoat & von Mühlenen, 2018a; Radianti et al., 2020). What is more, there is a reported increase in learners' motivation in VR conditions, as well as situational interest, and enjoyment relative to non-VR formats, with learners having higher engagement and emotional involvement during VR-based instruction (Allcoat & von Mühlenen, 2018; Fowler, 2015; Makransky & Petersen, 2019; Radianti et al., 2020). Research consistently identifies presence, immersion and interactivity as key mechanisms underlying these effects: by allowing learners to act within a coherent virtual space and experience a sense of "being there," VR can support feelings of agency, immediacy, and involvement, which in turn relate to intrinsic motivation and perceived value of the activity (Makransky & Petersen, 2021; Ryan & Deci, 2000).

At the same time, research grounded in Cognitive Load Theory and the Cognitive Theory of Multimedia Learning cautions that features which increase presence, such as visually rich scenes, dynamic viewpoints, and multiple simultaneous cues, can also add cognitive load when not carefully designed (Kalyuga, 2011; Mayer &

Moreno, 2003; Sweller, 2010). Experimental comparisons between iVR and DVR show this trade-off clearly: while iVR reliably increases presence and immersion, it can also lead to higher extraneous load and lower retention compared with equivalent desktop-based lessons (Makransky, Terkildsen, & Mayer, 2019; Parong & Mayer, 2018). Together, these findings seem to indicate that educational benefits do not arise from immersion per se but depend on aligning the level of immersion and interactivity with instructional goals, task complexity, and learner characteristics.

Meta-analytic and review evidence indicates that virtual reality (VR) can improve students' knowledge gain relative to non-VR conditions, but effect sizes are heterogeneous and depend on specific design features and contexts rather than being uniformly positive. (Merchant et al., 2014; Mikropoulos & Natsis, 2011; Radianti et al., 2020; Villena-Taranilla et al., 2022). A meta-analysis of VR-based games, simulations, and virtual worlds in K-12 and higher education found that all three categories produced statistically significant improvements in learning outcomes, but also reported substantial heterogeneity and moderator effects related to instructional design variables such as feedback type, collaboration, and format of use (Merchant et al., 2014). A more recent meta-analysis focusing on K-6 education similarly reported that VR, on average, led to higher post-test performance than control conditions, with stronger effects for immersive systems than for semi-immersive and non-immersive configurations, and for shorter (under two hours) interventions (Villena-Taranilla et al., 2022). Complementary evidence from another meta-analysis of elementary education studies showed that pupils learning with VR achieved higher knowledge scores than those in traditional classroom conditions (Lara-Álvarez et al., 2023). In higher education, a systematic review of immersive VR applications documented many reports of benefits for spatial reasoning, conceptual understanding, and motivation, but also emphasised that most implementations were experimental, only partially integrated into curricula, and often evaluated primarily in terms of usability rather than learning outcomes (Radianti et al., 2020). A more recent systematic review of iVR in higher education likewise concluded that, while numerous studies report increased motivation and engagement, findings for learning outcomes are mixed, with several studies showing no improvement or even lower performance compared with video-based instruction, and with persistent methodological limitations (Stracke et al., 2025). Taken together, these syntheses suggest that VR can support knowledge gain, typically operationalised as improvements on post-test measures of conceptual or procedural understanding, particularly in domains where spatial visualisation and contextualisation are central, but that its effectiveness is contingent on how VR is instructionally designed and embedded rather than guaranteed by the technology itself (Dalgarno & Lee, 2010; Merchant et al., 2014; Mikropoulos & Natsis, 2011; Villena-Taranilla et al., 2022).

In parallel with these empirical developments, several frameworks for designing educational VR experiences have been proposed. Dalgarno and Lee (2010) identified key learning affordances of 3D virtual environments – such as enabling spatial knowledge representation, experiential learning through rich contextualisation, and opportunities for collaborative learning – and argued that these affordances can support conceptual understanding and higher-order learning

when aligned with appropriate tasks and activities. Fowler (2015) further highlighted that the pedagogical value of virtual worlds depends on how learning activities are designed, introducing the notion of “pedagogical immersion” to stress that VR environments should be anchored in clear learning objectives and structured pedagogical strategies rather than in technological novelty alone. Mulders et al. (2020) proposed a framework for using iVR in learning environments that draws on the Cognitive Theory of Multimedia Learning and Cognitive load Theory, outlining design principles such as signalling, segmentation, and careful management of extraneous cognitive load in immersive scenarios. Building on this line of work, the Cognitive Affective Model of Immersive Learning (CAMIL) describes how immersive VR influences learning through intertwined cognitive and affective processes, specifying roles for presence, motivation, and self-efficacy as mediating mechanisms between technological features and learning outcomes (Makransky & Petersen, 2021). Taken together, these contributions converge on the view that VR’s educational value depends not on immersion level alone, but on how its technological affordances are orchestrated through coherent, theory-informed instructional design.

Despite these promising findings, several constraints and systemic challenges complicate the meaningful integration of VR in educational practice. Implementing high-immersion systems typically requires substantial investment in head-mounted displays, tracking equipment, and specialised software, as well as ongoing technical support, which limits scalability in many educational settings (Mujuru & Lopez, 2021; Radianti et al., 2020). Reviews of iVR in higher education also highlight health and safety concerns, including motion sickness, eye strain, and general physical discomfort during prolonged use, which can undermine feasibility for routine instruction (Makransky, Terkildsen, & Mayer, 2019; Radianti et al., 2020). Moreover, many VR initiatives in universities are reported as experimental or one-off projects, often developed for specific courses or grants in collaboration with technology providers, with limited integration into established curricula and organisational workflows (Fowler, 2015; Radianti et al., 2020; Stracke et al., 2025). Systematic reviews also point to a persistent pedagogical alignment gap: iVR activities are frequently developed and evaluated as experimental or laboratory-based interventions, with limited grounding in explicit learning theories and limited reporting on how they are integrated into regular curricula, study programs, and courses, and are seldom embedded as regular, theory-informed components of programmes (Radianti et al., 2020; Stracke et al., 2025).

1.3. DVR as a Pragmatic Configuration: Rationale and Research Gap

In the landscape of educational VR, DVR offers a pragmatic alternative that relies on widely available hardware while retaining several pedagogically relevant affordances. DVR typically renders a three-dimensional environment on a standard monitor and allows learners to navigate and interact using conventional input devices such as mouse, keyboard, joystick, or touch screen (Lee & Wong, 2014; Makransky

& Petersen, 2019; Mikropoulos & Natsis, 2011). Empirical work on desktop virtual environments and related computer-based simulations shows that such screen-based systems can support 3D visualisation, interactive exploration, and experimentation with virtual objects, leading to learning gains across science and engineering domains when instruction is well designed (Lee & Wong, 2014; Merchant et al., 2014; Smetana & Bell, 2012; Vogel et al., 2006). Because DVR can be implemented on standard computers, it is compatible with existing digital infrastructures including video-conferencing platforms. It thus provides a promising basis for exploring VR-enhanced presentation formats in distance higher education, where synchronous lectures are already mediated by digital tools. At the same time, reviews of educational virtual environments and iVR indicate that most studies still focus on short-term learning outcomes, usability, or user experience, with relatively little attention to how such systems – including desktop configurations – can be systematically embedded in institutional contexts and aligned with instructional principles over time (Mikropoulos & Natsis, 2011; Radianti et al., 2020; Stracke et al., 2025). Addressing this gap calls for approaches that couple conceptual clarity about VR types and affordances with iterative design and evaluation of VR-enhanced scenarios in authentic educational settings, as advocated in design-based research on technology-enhanced learning (Amiel & Reeves, 2008; McKenney & Reeves, 2019).

Taken together, the current landscape reveals clear tensions. On the one hand, iVR and DVR technologies seem to offer pedagogically valuable affordances that can support spatial visualisation, presence, and motivation. At the same time, iVR is most often implemented through head-mounted displays and can be resource intensive in terms of equipment. It can also be demanding in terms of access to suitable learning content and the specialist skillsets required to develop or tailor high-fidelity experiences, which can constrain sustained curricular embedding beyond short, isolated implementations (D. Hamilton et al., 2021; Jensen & Konradsen, 2018; Radianti et al., 2020). So, DVR configurations, although affording less immersion, still provide a scalable and technically feasible VR option, especially for distance-learning contexts. On the other hand, existing studies rarely examine how VR technologies can be embedded sustainably within institutional structures, aligned with instructional principles, or integrated into routine teaching practices over time. Systematic reviews across both iVR and DVR highlight that implementations are often isolated, short-term, and insufficiently connected to curricular goals, organisational processes, or teacher practice (Mikropoulos & Natsis, 2011; Radianti et al., 2020; Stracke et al., 2025). As a result, there remains limited empirical knowledge about how VR can be meaningfully integrated at scale in universities. In this thesis, therefore, we will focus on a DVR technology, which has higher accessibility and scalability potential than iVR, together with a lighter production workflow. For the context, we will focus on higher education, including distance learning, and aim at addressing the identified research gap by investigating the pedagogical, technological, and organisational conditions required for meaningful, sustainable and scalable integration of a DVR technology.

To clarify what is meant by meaningful integration at scale in this thesis, Normalisation Process Theory is used to define implementation, embedding, and integration processes and investigate how DVR can become part of everyday teaching (May et al., 2009; May & Finch, 2009). *Implementation* concerns the social organisation of the work required to introduce and enact DVR, *embedding* concerns the work through which DVR use becomes routine in instructional activity, and *integration* concerns sustaining embedded DVR practices within their wider organisational and social contexts (May et al., 2009; May & Finch, 2009).

Meaningful integration is understood as DVR use that is pedagogically purposive and evaluated against explicit educational aims rather than treated as inherently beneficial because it is technologically novel (Kirkwood & Price, 2014). The emphasis further lies on how DVR can be embedded sustainably and in a scalable way in regular instructional routines. Here, *sustainable integration* refers to routinised DVR practices that can be maintained over time because they are supported through appropriate institutional capacity and conditions; *scalable integration* is understood as more than growth in numbers, encompassing depth of change in practice, sustainability over time, spread across settings, and a shift in ownership from project champions to routine organisational responsibility (Coburn, 2003). With these terms defined, the thesis turns to two research questions:

RQ1: *What design requirements support meaningful, sustainable and scalable integration of DVR-enhanced presentations in higher education?*

RQ2: *How can a DVR technology be meaningfully, sustainably, and scalably integrated into the teaching practice of universities?*

To address these questions, the research was situated within an international transdisciplinary collaboration project that aimed to adapt a professional DVR technology for educational use in higher education. The following section outlines this project and the technological context in which the research was conducted, followed by the conceptualisation of the DVR-enhanced presentation technology.

2. Background

2.1. CloudClass Project Context

The research presented in this thesis was conducted in the context of the CloudClass project, an international Eurostars-funded collaboration that aimed at investigating how a DVR technology Edison [1] can be adapted for use in higher education. The underlying technology had originally been developed for television studios and professional production teams, relying on specialised hardware, controlled studio environments, and trained operators, which made it impractical for routine educational use. The technical goal of the CloudClass project is therefore to simplify the system, develop a lightweight version that teachers could operate independently,

[1] Edison is a commercial AR/virtual-environment platform designed to run immersive presentations; more detail can be found on the developer website https://www.brainstorm3d.com/products/edison/

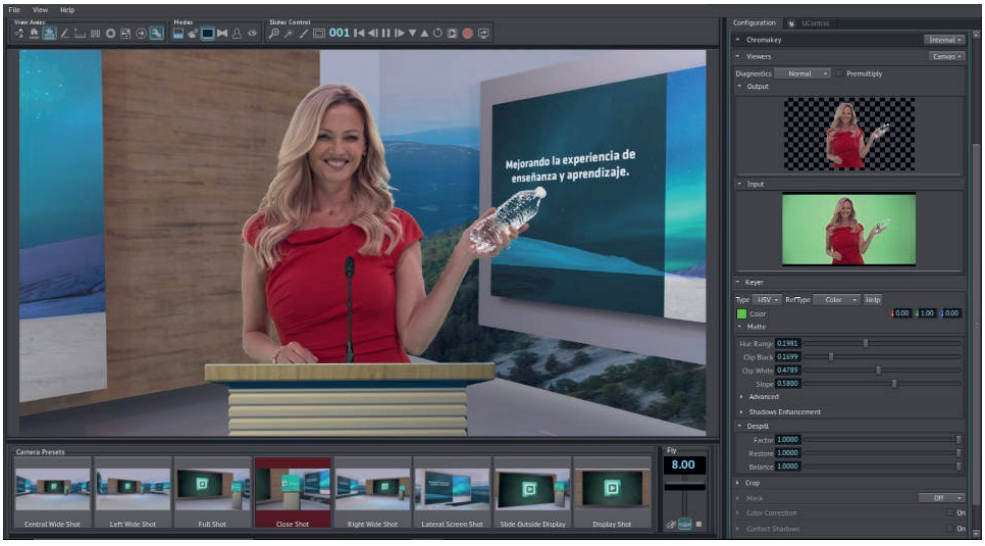
without studio support or high-end professional equipment. This project provided the technological and organisational context for the studies reported in this thesis, which investigates how Edison as a DVR technology can be meaningfully, sustainably and scalably integrated into the teaching practice of universities.

In technical terms, Edison combines real-time 3D graphics, chroma key (green-screen) compositing and integrated video streaming to place a live or prerecorded presenter inside a virtual scene (see Figure 1).

In the context of this thesis, Edison functions as the technological engine that enables the integration of a presenter's live or prerecorded video into a virtual instructional environment, allowing the teacher or student to appear situated within a digitally rendered space (see Figure 2). Within these environments, a wide range of visual elements can be incorporated as part of the presentation. These include 3D objects, still images, dynamic screens and displays, each of which can host diverse content sources such as webpages, slide decks, simulations, or externally streamed video. These modalities can be combined flexibly to support different forms of visualisation and to structure complex visual explanations within the virtual space.

Figure 1

Edison interface with a presenter integrated from a green-screen feed into a virtual set.



Edison also offers camera-tracking and spatial alignment features that allow the presenter to interact naturally with virtual elements, resulting in a high-fidelity composite that preserves communicative cues such as pointing, gesture and spatial referencing. At the same time, the system can scale to lower-fidelity configurations that run through standard video-conferencing platforms (e.g., Zoom, Teams) by routing the output through a virtual webcam. This makes the technology operable in ordinary teaching setups without requiring studio infrastructure, ensuring compatibility with common synchronous online teaching practices. Throughout the CloudClass project, these technical developments were informed by ongoing input

from researchers and university teachers and piloted in a range of courses, with the explicit aim of producing a system that is realistically usable within higher-education teaching and learning workflows rather than only in experimental studio conditions.

Figure 2

Lecture on media history featuring a 3D model demonstration (film projector) within a virtual environment in Edison.



The CloudClass project was implemented as an industry–university consortium. The partners included three companies: Brainstorm (Spain), White Loop (United Kingdom) and Stryme (Austria), and the Open University of the Netherlands (OU), with the University of Santiago de Compostela and the University of Alicante (Spain) participating as collaborating test sites in campus-based higher education.

For the work reported in this thesis, Brainstorm delivered the core technical solution underpinning the DVR–enhanced presentation system and supported technical skills training and support for the teachers and researchers. White Loop supported data collection and dissemination by coordinating activities with educational stakeholders across the settings. The participating universities provided pilot contexts and test beds, collaborated in data collection, and contributed to the development of educational scenarios and associated research activities. Within this consortium, the present doctoral research focused on the exploration of pedagogical and institutional conditions for meaningful integration of Edison in the context of higher education, as well as development and evaluation of the educational solutions.

2.2. Edison as a DVR-enhanced presentation technology

In this thesis, the Edison technology is conceptualised, instructionally embedded and evaluated as a synchronous, teacher-led DVR-enhanced presentation format rather than as a conventional video-production or post-processing system. DVR is

therefore used to enrich visual explanation while maintaining centralised instructional control. Situated within VR taxonomies that distinguish systems by immersion, interactivity and representational fidelity (Dalgarno & Lee, 2010a; Luo et al., 2021; Makransky & Petersen, 2021; Radianti et al., 2020), Edison occupies the non-immersive or DVR segment: it renders a 3D virtual environment on a standard screen, supports real-time navigation and camera control, and enables on-the-fly manipulation and spatial arrangement of virtual elements, while relying on conventional monitors and input devices rather than head-mounted displays (Cummings & and Bailenson, 2016; E. A.-L. Lee & Wong, 2014; Limniou et al., 2008). In teaching practice, the lecturer (or student presenter) operates within this 3D environment during the session, positioning themselves, models and displays, adjusting camera viewpoints, and coordinating how visual information unfolds over time. Students, by contrast, receive the composited output as a live video stream within familiar platforms such as Zoom or Teams, but their experience is still shaped by the affordances of DVR with the spatialised explanations, dynamic viewpoints and integrated 3D representations, rather than by a static, pre-authored video sequence.

When recorded, the output may resemble an instructional video; however, we conceptualise this format as a DVR-enhanced presentation not only for its synchronicity and presenter interactivity, but also for its potential to support student-centred scenarios where, following the presentation phase, control can be given to students in a number of ways. Not only can students access the exported 3D models or environments to individually or collaboratively explore them outside Edison, potentially supported by instructional tasks; students could also take the presenter role and create their own presentation or exploration resources. Taken together, these characteristics position Edison as a DVR environment that can be incorporated into university teaching workflows, with affordances that are distinct from both traditional videoconferencing and fixed audiovisual materials. In this thesis, however, the main focus is on the development and evaluation of the DVR-enhanced presentation format for synchronous, teacher-led delivery during the presentation phase.

Overall, the context of the CloudClass project provides both the technological foundation and the institutional conditions necessary for investigating DVR integration challenges within authentic teaching workflows. Understanding how such a technology can be meaningfully, sustainably and scalably integrated into university practice requires a research approach suited for analysing existing pedagogical and organisational practices, collaboratively shaping design solutions with stakeholders, and iteratively refining these solutions through implementation in authentic settings. These requirements align closely with the logic of design-based research (DBR), which is specifically intended to address complex educational problems situated at the intersection of technology, pedagogy, and institutional structures (Euler & Sloane, 2014; McKenney & Reeves, 2019).

3. Thesis structure in relation to design-based research

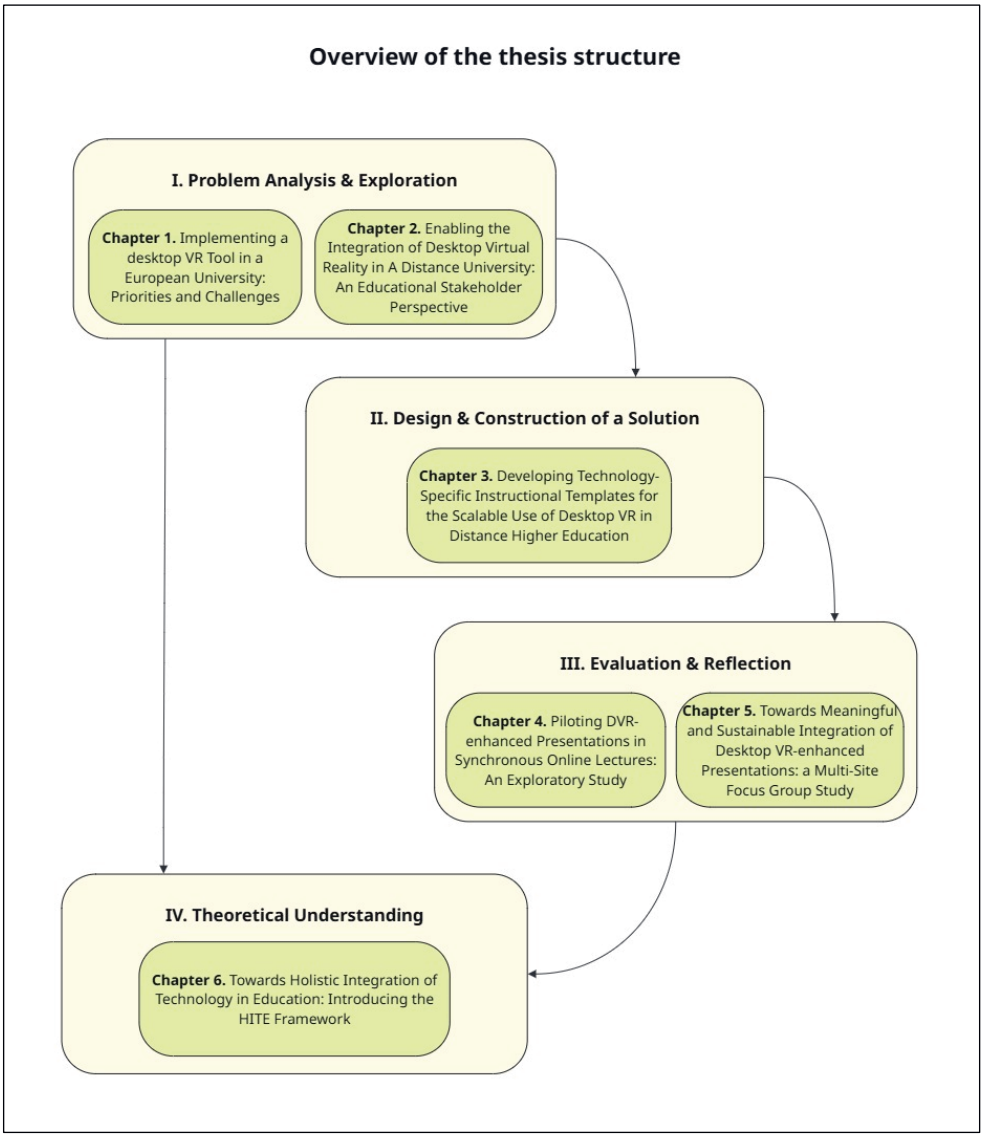
To address the research questions in an authentic institutional setting, the thesis adopts the model of educational design research also referred to as design-based research (DBR) (Euler & Sloane, 2014; McKenney & Reeves, 2019). In this model, DBR is organised into empirical cycles that comprise an analysis and exploration phase, a design and construction phase, and an evaluation and reflection phase; taken together over time, these cycles yield the dual outputs of maturing interventions and theoretical understanding (McKenney & Reeves, 2019). In line with this model, the DVR-enhanced presentation approach developed in the CloudClass project is treated as the central intervention, and the four parts of the thesis are explicitly aligned with these phases and outputs.

3.1. Part I: Analysis and Exploration

In the generic model, the analysis and exploration phase constitutes an empirical micro-cycle that includes problem identification and diagnosis in terms of the regulative cycle. In DBR traditions, this emphasis is closely connected to the field's commitment to producing interventions that are not only locally workable but also informative for broader theoretical understanding, by studying innovations in use and refining conjectures about how and why they function (Cobb et al., 2003). During this phase, in-house expertise and prior research are used to gain theoretical inputs that shape understanding of the problem, the context and other relevant topics; collaboration with practitioners is sought to deepen understanding of the educational problem, the target context and stakeholder needs; and, as understanding solidifies, similar problems and their solutions are explored in a more open-ended way (Anderson & Shattuck, 2012; Bakker, 2018; McKenney & Reeves, 2019). The main products are both practical and theoretical: from a practical perspective, a clear understanding of the problem and its origins, specification of long-range goals, partial design requirements based on opportunities and boundary conditions, and initial design propositions based on contextual insights; from a theoretical perspective, a descriptive and analytical understanding of a given class of problems as manifested in a particular context (Anderson & Shattuck, 2012; McKenney & Reeves, 2019).

Part I of the thesis (Chapters 1–2), corresponds to this analysis and exploration phase. It situates the research questions in the higher education context and develops a descriptive and analytical understanding of the problems involved in integrating DVR-enhanced presentations at the meso level (Figure 3).

Figure 3. *Thesis structure aligned with phases of DBR research (McKenney & Reeves, 2019).*



Chapter 1 (*Implementing a Desktop VR Tool in a European University: Priorities and Challenges*) reports a Group Concept Mapping study that systematically elicits and organises stakeholder perspectives on factors they see as important for meaningful and scalable integration of a DVR tool in a university context.

Chapter 2 (*Enabling the Integration of Desktop Virtual Reality in a Distance University: An Educational Stakeholder Perspective*) deepens the analysis through a qualitative single-case study based on in-depth interviews with teachers, media design experts and institutional managers in a distance-learning university,

examining contextual, pedagogical, technological, organisational and value-related factors.

Together, the first two studies yield a context-specific problem definition, long-range goals for DVR-enhanced presentations, design requirements and initial design propositions, thereby realising the practical and theoretical products associated with the analysis and exploration phase (McKenney & Reeves, 2019).

3.2. Part II: Design and Construction

In the generic DBR model, design and construction is described as a coherent process followed and documented to arrive at a tentative solution to the problem (McKenney & Reeves, 2019). This micro-cycle resembles the creation of a conceptual model: it involves rational, purposeful consideration of available knowledge and puzzling over relationships and arrangements of concepts that are internally consistent and externally useful, described as a deliberative–generative cycle (McKenney & Reeves, 2019). During design, potential solutions are generated, explored and considered; core ideas underpinning the design, including their theoretical and practical grounding, are articulated so that the underlying design framework can be shared and critiqued; and guidelines for building the solution are delineated. Construction refers to taking design ideas and applying them to manufacture the solution, typically through prototyping and successive approximations of the desired solution (Anderson & Shattuck, 2012; McKenney & Reeves, 2019; Penuel et al., 2011). From a practical perspective, the intervention is conceived and assembled; from a theoretical perspective, the frameworks underpinning the design and the justification for design decisions are articulated (McKenney & Reeves, 2019; The Design-Based Research Collective, 2003; Wang & Hannafin, 2005).

Part II of the thesis (Chapter 3) corresponds to the design and construction phase. It takes the problem space, design requirements and initial design propositions from Part 1 and uses them, together with theoretical perspectives on cognitive load, situational interest and teacher presence, to generate and structure potential solutions for DVR-enhanced presentations in distance higher education. Chapter 3 (*Developing Technology-Specific Instructional Templates for the Scalable Use of Desktop VR in Distance Higher Education*) documents how DVR-based presentation scenarios are generated and explored, how the core ideas underpinning the design and their theoretical and practical grounding are articulated in the form of Technology-Specific Instructional templates, and how guidelines for constructing DVR-enhanced sessions are delineated. Through successive refinements and prototyping with stakeholders, this part of the thesis delivers a conceived and assembled intervention – a set of DVR-enhanced presentation templates and associated practices – and articulates the design and justifications for key design decisions, thereby fulfilling the practical and theoretical outputs associated with the design and construction micro-cycle (McKenney & Reeves, 2019).

3.3. Part III: Evaluation and Reflection

In the generic DBR model, evaluation and reflection also constitutes an empirical micro-cycle (McKenney & Reeves, 2019). Evaluation is used in a broad sense to refer to empirical testing conducted with a design (the frameworks underpinning the intervention) or with a constructed intervention (the embodiments of design in initial, partial or final form), and may focus on soundness, feasibility, local viability, broader institutionalisation, immediate effectiveness and longer-term impact, depending on the goals, type of intervention and stage of development (McKenney & Reeves, 2019; The Design-Based Research Collective, 2003). Reflection involves active and thoughtful consideration of what has come together in both research and development – including theoretical inputs, empirical findings and subjective reactions – with the aim of producing theoretical understanding; empirical findings and critical reflection are used to accept, refine or refute conjectures, frameworks or principles portrayed in design documents or embodied in prototypes (McKenney & Reeves, 2019; The Design-Based Research Collective, 2003). From a practical perspective, this phase leads to ideas for redesign and/or conclusions about an intervention; from a theoretical perspective, it contributes to broader theoretical understanding of the type of intervention or phenomena directly related to it (McKenney & Reeves, 2019; Penuel et al., 2011).

Part III of this thesis (Chapters 4–5) is aligned with this evaluation and reflection phase. It empirically tests the DVR-enhanced presentation intervention in authentic settings and reflects on its functioning at both micro and meso levels.

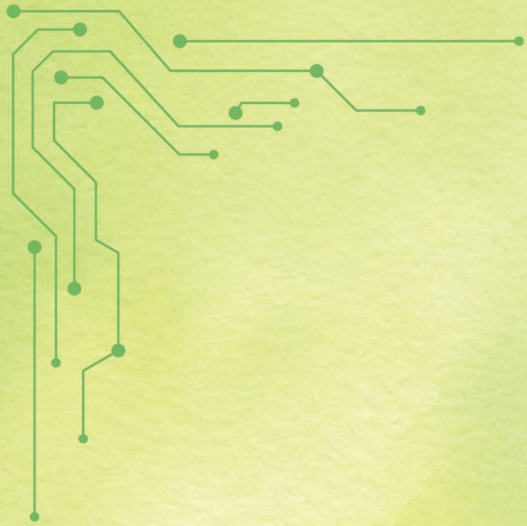
Chapter 4 (*Piloting DVR-enhanced Presentations in Synchronous Online Lectures: An Exploratory Study*) reports pilots in which a selected DVR-enhanced presentation template is implemented in synchronous online lectures at the distance-learning university, examining feasibility and local viability as well as immediate effects on students' learning processes, operationalised as knowledge gain, cognitive load and intrinsic motivation.

Chapter 5 (*Towards Meaningful and Sustainable Integration of Desktop VR-enhanced Presentations: a Multi-Site Focus Group Study*) extends evaluation to three European universities and focuses on broader institutionalisation and conditions for scaled integration by analysing how institutional arrangements, infrastructures and pedagogical practices influence the perceived value and feasibility of DVR-enhanced presentations. Across these studies, empirical findings and stakeholder reflections provide a basis for accepting, refining or qualifying the conjectures and design principles developed in earlier phases, and generate both ideas for redesign and contributions to a broader theoretical understanding of DVR-enhanced presentations as a type of intervention (McKenney & Reeves, 2019).

3.4. Part IV: Theoretical Understanding

Within the DBR approach adopted in this thesis, the research process is expected to yield two interconnected outputs: maturing interventions and theoretical understanding (McKenney & Reeves, 2019). Maturing interventions are progressively developed and tested solutions that address a concrete educational problem in its authentic context and embody articulated design frameworks, whereas theoretical understanding consists of conjectures, design principles and conceptual frameworks that explain how and why particular interventions function as they do, providing building blocks for theory and informing subsequent design work (McKenney & Reeves, 2019). Both outputs are developed across multiple empirical cycles and may remain primarily local in scope or attain broader applicability; in this process, design principles and frameworks can serve as bridges between scientific knowledge production and practice design (Euler, 2017).

Part 4 of the thesis (Chapter 6) is concerned specifically with this second DBR output. It synthesises insights from the problem exploration in Part 1 and from the piloting and evaluation in Part 3 in order to develop a theoretically grounded account of meaningful and sustainable technology integration at the meso-institutional level. Chapter 6 (*Towards Holistic Integration of Technology in Education: Introducing the HITE Framework*) integrates empirical findings from the DVR case with the broader literature on technology integration and institutional change and articulates the HITE Framework as a set of conceptual dimensions – Technology, Pedagogy, Context, Values and Management – together with indicative integration workflows and requirements for aligning these dimensions in practice. The framework is grounded in the successive DBR cycles reported in earlier parts of the thesis, but its primary contribution lies in providing theoretical understanding of the factors and processes that appear necessary for meaningful technology integration in comparable institutional contexts, rather than in documenting a fully matured intervention (Euler & Sloane, 2014; McKenney & Reeves, 2019).





Part I
Analysis and Exploration

Chapter 1

Implementing a Desktop VR Tool in a European University: Priorities and Challenges

Virtual reality technologies in educational settings have demonstrated their potential to improve understanding, engagement, motivation and learning outcomes. However, there are multiple technical, pedagogical, and institutional challenges on the way of technology adoption in the education sector. In this group-concept-mapping study within the CloudClass project we aim at identifying the requirements for implementing a desktop VR tool (CloudClass) for education in the university context. Teachers, multimedia experts and managers from a Spanish and a Dutch university (a face-to-face and a distance learning one) were asked to complete the focus prompt "*To use/implement CloudClass in education it is required/ needed that…*". The generated statements were classified thematically and rated for importance and feasibility. 95 unique statements were generated and sorted statistically into 5 clusters: *Evaluation, Institutional Requirements, Maintenance and Training, Student Requirements, Affordances and infrastructure.* A strong correlation was identified between the importance and feasibility of the identified clusters. To ensure a sustainable implementation of a desktop VR tool like CloudClass in a university setting a holistic approach considering all identified clusters is needed. Clusters *Maintenance and Training* and *Institutional requirements* are the low-hanging fruits to invest in, as both clusters scored highest on importance and feasibility

This chapter is based on

Holubinka, K., Urlings, C., Stoyanov, S., Del Pilar Sosa-Fernández, R., Méndez-Fernández, R., Castelló-Mayo, E., Klemke, R., & De Groot, R. (2023). Implementing a Desktop VR Tool in a European University: Priorities and Challenges. In O. Viberg, I. Jivet, P. J. Muñoz-Merino, M. Perifanou, & T. Papathoma (Eds.), *Responsive and Sustainable Educational Futures* (Vol. 14200, pp. 104–117). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-42682-7_8

1. Introduction

Virtual reality (VR) technologies have become a powerful and promising tool in education because of their potential to enrich learning experiences with high immersion and presence experienced by learners (Fowler, 2015; Radianti et al., 2020; Villena-Taranilla et al., 2022). VR can be described as a mosaic of technologies that support the creation of synthetic, highly interactive three-dimensional (3D) spatial environments that represent real or non-real situations (Mikropoulos & Natsis, 2011). High-immersive VR environments (iVR) generally involve a head-mounted display (HMD), while low-immersive or desktop VR (DVR) is based on traditional widely accessible devices like mouse and keyboard (E. A.-L. Lee & Wong, 2014; Limniou et al., 2008).

Implementing VR in educational settings has been reported highly motivating, increasing student engagement, their presence and supporting the learning process by providing high-quality visualisations (Allcoat & von Mühlenen, 2018a; E. A.-L. Lee & Wong, 2014; Levin et al., 2015). Presence is considered as “the subjective experience of being in one place or environment, even when one is physically situated in another” (Witmer & Singer, 1998). Immersion, on the other hand, can be classified into *physical immersion*, a technological attribute that can be assessed objectively (Slater & Wilbur, 1997), and *mental immersion*, considered as a subjective, individual belief, i.e., a psychological phenomenon (Witmer & Singer, 1998). Several meta-analyses have reported positive educational outcomes when using VR, sometimes exceeding those associated with traditional classroom instruction (Merchant et al., 2014; Mikropoulos & Natsis, 2011; Smetana & Bell, 2012; Villena-Taranilla et al., 2022; Vogel et al., 2006). The field of higher education has experienced a growing interest in the use of VR technologies showing positive effect sizes in effectiveness of VR interventions in basic science, social science, and engineering (Luo et al., 2021). At the same time, using VR technologies in education should be a balanced decision that considers a multitude of factors including its positive and restrictive attributes (Fowler, 2015; Mulders et al., 2020). The drawbacks associated with utilizing VR technologies are mainly related to the time and costs required for the development of hardware and software (Mujuru & Lopez, 2021). Additionally, there may be potential health and safety concerns with iVR, as well as discomfort associated with wearing head-mounted displays (HMDs). The use of iVR environments may also lead to user distraction and overload, resulting in lower levels of learning comparing to less immersive VR environments (Makransky, Terkildsen, et al., 2019). There is also a reported lack in integrating VR into learning scenarios (Mulders et al., 2020; Radianti et al., 2020).

In most domains, VR is still experimental, and its usage is not systematic or based on best practices (Radianti et al., 2020). The technologically heavy development of the soft-ware and steep learning curves in the use of VR puts constraints on teachers effectively and flexibly deploying these technologies in their practice and makes educators dependent on solution providers (Mujuru & Lopez, 2021). Therefore CloudClass technology has been developed as a DVR visualisation and presentation

tool aiming to overcome the previously identified problems and to foster teachers in creating and customizing the virtual environment that they can use at rather low cost. Having been developed for the broadcasting industry, it evolved as a low-cost cloud-based solution that can be used in the classroom without big hardware investments and integrated in existing video-conferencing systems. This has potential to enhance the learning experience in the virtual classroom by a possibility to work with virtual spaces (e.g. a room) and 3D models (e.g. solar system), importing and blending pre-recorded video material, images and 3D models with streamed video and other digital objects without the need of using HMDs. What is more, CloudClass is being developed as a low threshold desktop tool that teachers can and flexibly use in their practice without having to go through specialized graphic design or programming training, or being dependent on technology developers.

As previous studies identified numerous challenges and barriers for wider institutional implementation of VR tools in educational context (Merchant et al., 2014; Mikropoulos & Natsis, 2011; Villena-Taranilla et al., 2022; Vogel et al., 2006), this paper aims at identifying the requirements for implementing a DVR tool (CloudClass) for education in the university context to foster efficient, effective and enjoyable learning. Therefore the two research questions are addressed:

1. What are the requirements for implementing and using a DVR tool like CloudClass in university education? (RQ1)
2. What is the feasibility and the importance of the identified implementation requirements for the use of a DVR tool like CloudClass in higher education? (RQ2)

We applied the Group Concept Mapping (GCM) research methodology (Kane & Rosas, 2018; Trochim & McLinden, 2017) to collect, objectively aggregate and analyse the opinions of core stakeholder groups – teachers, educational media experts and managers – to depict their shared vision on the potential of implementation of a tool like CloudClass in higher education in the long term.

2. Method

2.1. Group Concept Mapping

Group Concept Mapping (GCM) is a participatory mixed-methods research methodology that identifies a shared understanding of a particular issue or topic that a group of individuals have (Kane & Rosas, 2018; Trochim & McLinden, 2017). It differs from traditional data collection methods by placing the power of idea generation and organization in the hands of the participants, rather than researchers. GCM involves several stages, including brainstorming, sorting, and rating, and uses advanced statistical techniques such as Multidimensional Scaling (MDS) and Hierarchical Cluster Analy-sis (HCA) to detect patterns and connections within the data, which offer valuable insights into the factors affecting the topic under investigation. Results are presented visually through a concept map, pattern matches and go-zone charts, among others, making them easy to understand and apply (Kane & Rosas, 2018; Trochim & McLinden, 2017). By utilizing the GCM

methodology, educational research can gain valuable insights into the factors that impact technology adoption and educational policies.

2.2. Procedure

Employees across two European universities were approached – a distance learning university in the Netherlands – the Open Universiteit (OU) and a traditional Spanish face-to-face-learning university – the University of Santiago de Compo-stela (USC). The study was reviewed and approved by the Research Ethics Com-mittee of the OU (under the reference number A1234567). Data collection and main statistical analyses were performed in GroupWisdom™ software. Participants were invited to take part in the GCM institution-wide with a post on the intranet, via email, as well as during faculty and department meeting presentations and ongoing events. The information letter outlining the aim of the research and procedure was included in the email or distribution materials together with a link to a 6-minute infomercial describing the functionality and affordances of the tool CloudClass. Participants had to give their informed consent in GroupWisdom before starting each stage of the GCM. Anonymous demographic questions about the role in the institution and faculty of affiliation were mandatory to answer for each stage.

Brainstorming. The purpose of this phase was to generate and collect ideas of the three stakeholder groups across the two universities – OU and USC. Having watched a video introducing the affordances of CloudClass, participants were asked to complete the following focus prompt: "*To use/implement CloudClass in education it is required/ needed that...*". For the USC, the GroupWisdom environment was set to Spanish as the interface language, and the focus prompt was translated as: "Para utilizar/implementar CloudClass en la educación se requiere/se necesita...". Participants were encouraged to add as many ideas as they wished, while keeping each statement limited to one thought and formulating it as if they were completing the focus prompt. Each participant was working independently from others, but could see all the previous contributions under the input field. Participants from the USC were asked to complete the focus prompt in Spanish, while in OU instructions were given in English, but participants could respond in English or Dutch. There was no time limit for completing the brainstorming activity and participants could leave GroupWisdom and return at a later point.

Idea synthesis. Upon the completion of the brainstorming phase the generated statements from both universities were combined and edited with the purpose of unifying the format of the data set to be used in the following stages of GCM process. Idea synthesis was an iterative group process that involved researchers from both OU and USC. Because of the different languages, some sentences had to be back-translated from Spanish and Dutch into English for analysis and editing.

While editing, the following criteria were used: each statement represents one idea, so entries having several ideas were split; each statement is unique, so ideas close in meaning were combined without the loss of meaning; each statement is relevant to the focus prompt, so grammatical formulations were adjusted to fit the focus prompt if needed, and ideas out of the scope were weeded out. The value,

popularity or priority of ideas was not considered. After the idea synthesis was complete, the unique statements were fed back into the GroupWisdom so that participants could sort them into meaningful groups and rate for feasibility and importance.

Sorting and rating. Participants from OU representing three stakeholder groups were contacted again via email, faculty and department meetings and other ongoing events and invited to participate in sorting and rating. During the sorting activity participants were asked to categorize statements into piles according to their view of the meaning and give each pile a name that describes its theme or contents. A statement could be put alone in its own category, and participants were discouraged to create piles according to priority or value. Although there was no time limit for the activity and participants could leave and get back to GroupWisdom if they wanted, it took on average between 30 and 50 minutes to complete.

After the sorting activity, participants were asked to rate the same set of statements for importance and feasibility on a 5-point scale, from 1 as least important to 5 as most important, and from 1 as least feasible to 5 as most feasible respectively. Participants were encouraged to spread out their ratings using all 5 given options. With higher values in importance scale participants articulated their values, while feasibility displayed the understanding of opportunities and challenges in practical implementation of the CloudClass tool.

2.3. Analysis

The rating activity collected the data that can be analysed with multidimensional scaling and hierarchical cluster analysis of the aggregated coding data.

Multidimensional Scaling (MDS). Participant grouping of statements was analyzed with MDS to identify the position of each idea relative to others in a 2-dimensional space resulting in a point map. The points that are closer together on a point map indicate a closer relationship in meaning, reflecting the way participants had grouped them together during the sorting activity. This mathematical model was evaluated for accuracy with a routinely-generated stress value index, which for GCM studies typically ranges between 0.20 and 0.35 (Rosas & Kane, 2012).

The output of the MDS analysis provided information on the anchoring and bridging values of each statement. Statements with low bridging values have been grouped together with statements in close proximity, while those with higher bridging values have been grouped together with some statements further apart from either side. These values are valuable in understanding the point map (Kane & Rosas, 2018). By knowing which ideas serve as anchors or bridges, the researchers were able to make more informed judgments about the content. This knowledge also guided their decisions regarding cluster formation before the cluster map was fully completed. Once the cluster array had been decided upon, the average anchoring and bridging values for each cluster were calculated.

Hierarchical Cluster Analysis (HCA). To organize content into meaningful clusters of statements that aggregate to reflect similar concepts, HCA was applied (Anderberg, 1973; Everitt, 1980). Based on the established GCM research and

practice (Kane & Rosas, 2018; Kane & Trochim, 2007), the 15-to-4 heuristics was applied, where HCA started with a 15-cluster solution and at each step proposed merging two of the clusters until the 4-cluster solution was reached. A group of four researchers considered the generated cluster solutions individually and discussed the suitability of each cluster solution keeping in mind the purposes of the project.

3. Results

3.1. Participants

Brainstorming. During the brainstorming phase participants of the Dutch Open Universiteit (OU) and the Spanish University of Santiago de Compostela (USC) were approached, reaching out to all the university faculties and service media departments of both institutions (see Appendix A, figures 1-4). Three stake-holder groups were included in this study – teachers/lecturers, educational media experts and university managers (deans of faculties and management board), which was reflected in demographic questions that participants had to complete before each activity. Out of 121 participants who opened GroupWisdom envi-ronment at OU, 59 participants across all the six faculties answered the demo-graphic questions and were able to start the brainstorming. In USC out of 50 par-ticipants 22 answered the questions, representing 8 out of 28 faculties.

Brainstorming phase was conducted in both universities, and idea synthesis resulted in a single list of final statements. Responses about participants' role in their university are summarized in Table 1 below.

Table 1

Participant numbers for GCM activities

Activity	univers ity	teachers		media experts		managers		total, 100%
		N	%	N	%	N	%	N
Brainstorming	OU	35	59	9	15	15	25	59
	USC	13	59	3	14	6	27	22
Sorting	OU	49	89	6	11	0	0	55
Rating	OU	66	83	9	11	5	6	80

Sorting and rating phases involved participants from OU across all the faculties. USC participants were not included in the sorting and rating due to organizational factors. The demographic data for each GCM activity collected through participant questions in GroupWisdom is given in Table 2 below.

Table 2

Participation in sorting and rating activities by faculty

	Sorting		Rating	
Faculty/division	N	%	N	%
Science	1	1.82	10	12.5
Humanities	1	1.82	1	1.25
Management Sciences	1	1.82	3	3.75
Educational Sciences	40	72,73	42	52.5
Psychology	4	7.27	7	8.75
Law	0	0.00	3	3.75
Expertise Centre Education	8	14.55	14	17.50
Total	**55**	**100**	**80**	**100**

3.2. CloudClass implementation requirements

As the result of the brainstorming activity 236 ideas were collected (57 at USC and 179 at OU) in response to a focus prompt: *To use/implement CloudClass in education it is required/ needed that....* After the idea synthesis this number was reduced to a list of 95 single unique statements that complete the focus prompt (see Appendix A, table 1).

Sorting activity and MDS resulted in a graphical representation of a point map (see Appendix A, figure 5) with all the 95 statements. The stress value index for this study is 0.27 indicating that the map quite accurately reflects the participants' original sorting. Bridging values for each statement are also displayed on the point map (figure 5 in Appendix A).

Based on the results of the HCA, the group of researchers chose upon the 5-cluster solution as the one reflecting the core themes of the project. The following themes were identified, which are reflected in the cluster names: *Evaluation*, *Institutional Requirements*, *Maintenance and Training*, *Student Requirements*, *Affordances and Infrastructure*. These are displayed in the cluster map in figure 1 together with the average bridging values for each cluster. The description of each cluster summarizing main themes is given below and the statements within each cluster are presented in Appendix A.

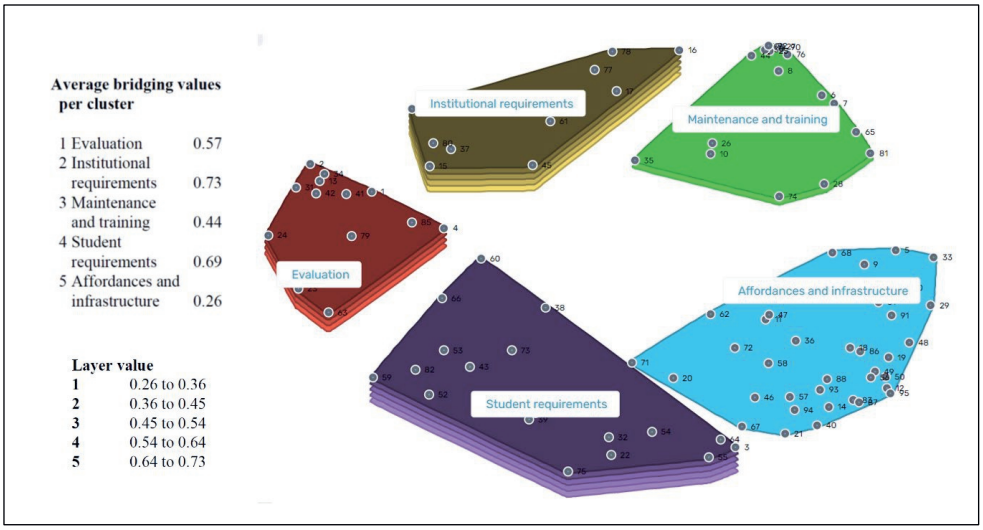
Affordances and Infrastructure. Within this cluster with the lowest bridging value of 0.26 participants seem to agree on the coherence of this theme, having grouped the statements with the ones close to them on the point map. The theme connects the expectations of the CloudClass system affordances with the requirements for the infrastructure and hardware, both for students and teachers.

Maintenance and Training. This cluster features two closely related sub-themes. The first embraces teacher training in various formats – from self-study resources like instruction manuals and videos, to in-person training sessions, workshops (e.g. script-writing, using a green screen, lighting) and availability of support by an expert. The second sub-theme reflects the need of awareness of how CloudClass should

be used in specific contexts, which pedagogical scenarios are suitable and how they can be translated in technical design.

Figure 1

5-cluster solution with average bridging values for each cluster



Evaluation. This cluster embraces statements around the evaluation of CloudClass in various forms. The array of coherent sub-themes includes the need for structured research and evaluation approaches to explore efficiency and effectiveness of the tool in multiple contexts with different target groups (e.g. learners with disabilities); investigating short- and long-term effects on learning, as well as comparison with other similar tools; involvement of all the stakeholder groups in implementation and evaluation processes; and finally, the expediency (reasonableness) of the tool use in relation to its cost.

Student Requirements. This cluster covers sub-themes ranging from technical affordances available to students (e.g. manipulating 3D objects, collaboration, usability), their privacy (e.g. data processing, anonymity), agency in shaping the usage of the software (participative design) to the skills' requirements of students themselves and the effect of using the software on learning (e.g. increase student engagement).

Institutional requirements. This cluster has the highest average bridging value of 0.73, meaning least agreement among the participants on the groupings of the statements which were often sorted with statements that were not in their vicinity. Within this cluster there is also a range of sub-themes that participants attribute to the institutional organization. These include the strategic vision of the reason for using CloudClass, accompanied by a clear plan and communication of these widely within the organization. There is a need to define the institutional support in the use of the tool, both in the form of extra working hours, and teach-ing/academic recognition for educators. Finally, instructional objectives for the use of CloudClass

should be clear, transparent, and should be reflected in the recommended instructional design.

3.3. Importance and feasibility ratings of the identified requirements

Rating data brings another dimension to the analysis making not only numerical, but also visual comparisons possible in the form of pattern matches and go-zones.

Average cluster ratings that were calculated based on individual statement ratings for importance and feasibility were quite high, spanning from 3.69 to 4.17 for importance and from 3.38 to 3.66 for feasibility on a 5-point Likert scale.

The absolute pattern match presented in Figure 2 illustrates the average rating comparison of importance and feasibility for each cluster with a correlation of r=0.66 between the two ratings. Here the higher ratings for importance for all the thematic clusters are apparent.

T-tests were produced for each cluster rating. A statistically significant difference was found between the importance and feasibility rating for the following clusters: *Evaluation* (T-Value=4.28, $p<0.001$) and *Maintenance and Training* (T-Value=4.99, $p<0.001$); moderately significant difference is seen in clusters *Institutional Requirements* (T-Value=2.45, $p<0.05$) and *Affordances and Infrastructure* (T-Value=2.03, $p<0.05$); and no significant difference was identified in the cluster *Student Requirements* (T-Value=1.68, $p>0.05$). More detail on the T-tests is given in Appendix A.

Go-zones. To take a closer look at the rating differences within each cluster, go-zones were produced for each cluster. Each go-zone shows the entire content of a particular cluster allocating each statement on the two-dimensional x/y scale according to its rated importance (horizontal axis) and feasibility (vertical axis). All the charts are provided in Appendix A (in figures 6-10 and tables 2-6), and an example of two go-zones for cluster *Evaluation* and *Maintenance and Training* is given in Figure 5 below.

Based on the means of rating values, go-zone charts divide the scatter plot into quadrants that can be analysed further. In the context of the CloudClass project, statements located in the upper right quadrant represent immediate or first-priority action points based on participants' shared vision of highest importance and feasibility. Ideas in the yellow quadrant with high importance rating but low-er feasibility (if located at the top of the quadrant) are seen as strategic goals for the project. Finally, statements in the right part of the orange quadrant can be considered as further steps in the workflow of technology implementation, or sub-actions within the major tasks.

Figure 2

Absolute pattern match for Importance vs. Feasibility

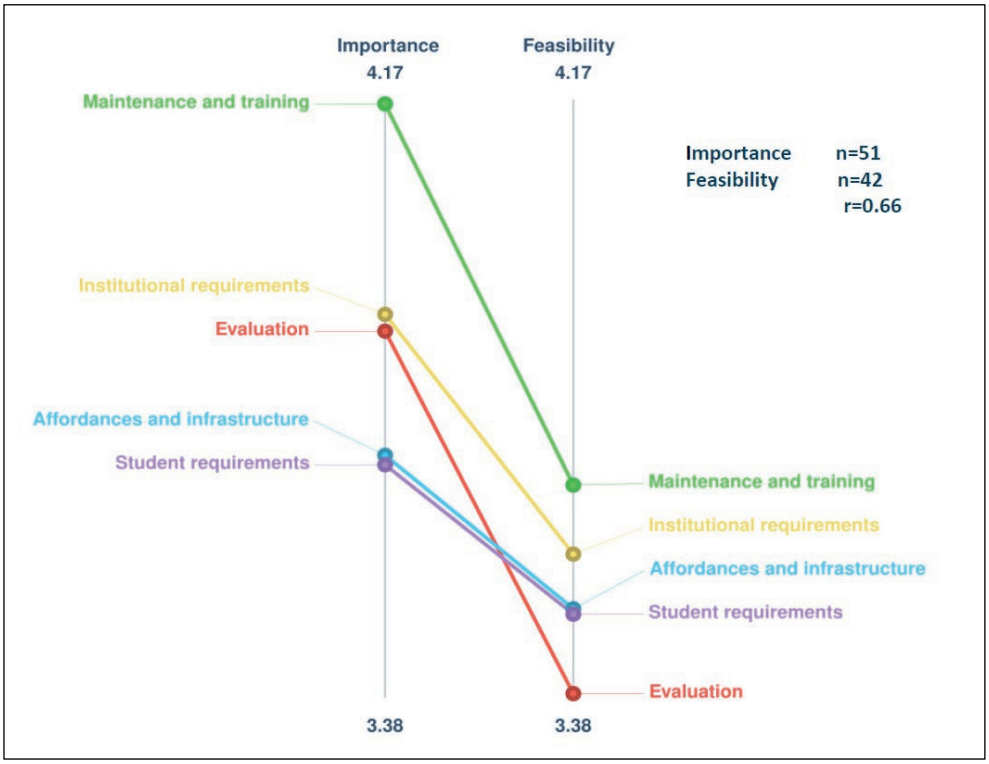
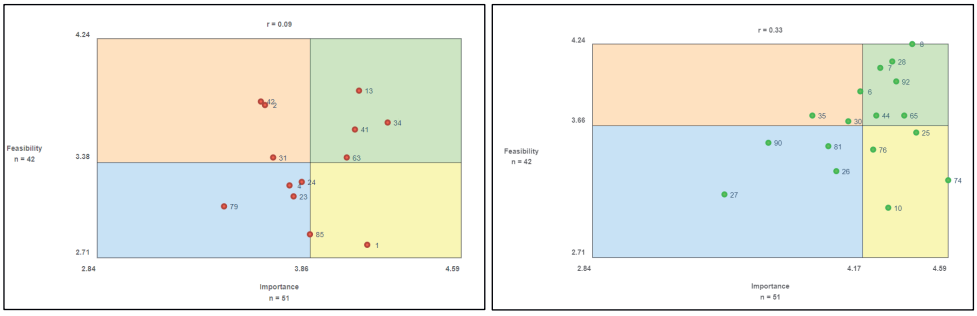


Figure 5

Examples of go-zone for clusters Evaluation (left) and Maintenance and Training (right)



4. Discussion

The present study aimed at identifying the requirements for implementing a DVR tool like CloudClass for education in the university context to foster efficient, effective and enjoyable learning. Therefore the two research questions were ad-dressed.

RQ1: What are the requirements for implementing and using a DVR tool like CloudClass in university education?

The list of 95 individual unique statements with requirements was produced based on the input from the participants across two universities. The requirements were statistically sorted in five core thematic clusters representing the major requirements that need to be considered for the implementation of CloudClass within an institution: *Maintenance and Training*, *Institutional Requirements*, *Evaluation*, *Affordances and Infrastructure*, *Student Requirements*.

RQ2: What is the feasibility and the importance of the identified implementation requirements for the use of the VR tool like CloudClass in higher education?

Feasibility and importance rating of each individual requirement, as well as thematic cluster was identified and presented in different graphical and statistical ways to inform the implementation process – in the cluster map (figure 1), pattern match (figure 2), and go-zones (see figures 6-10 and tables 2-6 in Appendix A).

Using the GCM methodology, the present study collected and statistically aggregated the views of three stakeholder groups (teachers, educational media experts and managers) within two European universities from different countries – a distance learning university and a face-to-face one, thus depicting the diversity of contexts in the ideas generated within the brainstorming phase. The numbers of participants involved in sorting and rating activities were sufficient to draw robust conclusions for the further analyses.

The requirements for implementation and use of VR technology in education identified in this study go in line with the factors reported in the literature. Financial cost (Merchant et al., 2014; Mujuru & Lopez, 2021), complexity and accessibility of software and hardware (Mujuru & Lopez, 2021; Mulders et al., 2020), the need for evidence-based didactic frameworks (Dalgarno & Lee, 2010a; Makransky & Petersen, 2021; Mulders et al., 2020; Smetana & Bell, 2012) and teaching practices that can support teacher training (Merchant et al., 2014; Radianti et al., 2020), have been mentioned as factors affecting technology adoption as well as effective and widespread implementation of VR tools outside specialized domains like engineering and computer science (Radianti et al., 2020).

This study also took a systematic approach to prioritize the identified implementation requirements according to their importance and feasibility ratings within an institution. The importance cluster ratings on a scale from 1 to 5, ranging from 3.69 (*Student Requirements*) to 4.17 (*Maintenance and Training)*, and feasibility ratings from 3.38 (*Evaluation*) to 3.66 (*Maintenance and Training*) highlighted that all the major factors identified through clustering are of significant importance and high feasibility with a strong correlation between the two. It is worth noting that the order of priority for all the clusters except for *Evaluation* is the same, emphasizing that all

the indicated factors need to be considered early on in the project development. Although it is quite typical to have higher importance ratings in GCM projects as a way for participants to voice their values, the statistically significant difference between importance and feasibility ratings for the clusters *Maintenance and Training* and *Evaluation* emphasizes their first-line importance that should be part of technology implementation policy. The former cluster also scored highest on average ratings, bringing about the importance of the identified themes that can be taken as action points in the implementation process. Although cluster *Evaluation* scored lowest on feasibility, the significantly high importance rating values underscore the urgency to address the research needs early on within the project.

One of the major findings of this study is the result of go-zones which list the action points for each thematic cluster with a specific level of priority. This way, the present study is addressing a previously-identified absence of systematic approach in the field of VR use for educational purposes (Radianti et al., 2020). Based on go-zone charts, the statements in the three quadrants of interest were further analyzed qualitatively to inform the CloudClass project. The outcomes of each thematic category are summarized for each cluster in order of average importance and feasibility ratings.

Maintenance and Training. Statements in this cluster prioritise the ease of meaningful use by teachers and smooth operation for students. Teacher training should include knowledge on why when and how to use CloudClass, in other words, which didactic strategies should be used in specific learning situations. For this purpose instructional materials need to be developed, including instruction hands on workshops, lectures, and in further stages of the project teachers can be well supported by developed pedagogical scenarios, best practice examples. A helpdesk or a CloudClass expert is required to assist teachers with the use of the tool, and after the end of the project continuous maintenance is required.

Institutional requirements. Within this cluster the need is voiced to have clear goals for the use of CloudClass that teachers will know about (why when and how to use CloudClass). More specifically, instructional objectives for the use of CloudClass should be defined in specific contexts and supported institutionally by developing teaching practices and suitable instructional design. As a further step, information about CloudClass should be disseminated widely throughout the university.

Evaluation. Research should be conducted on the effectiveness of CloudClass including short- and long-term effects, comparison with other tools and effects on different target groups (students with disabilities). Further steps suggest forming a working group to evaluate and discuss the added value of CloudClass. It should be mentioned that participants found important that added value of CloudClass would outweighs its costs, but this item scored low on feasibility (2.80 out of 5.00, cluster mean 3.38).

Affordances and infrastructure. Within this cluster, interaction support between students and teachers takes primary importance, as well as the possibility of operation with a large group of students. User-friendliness and short learning curve for using the technology are seen as core features, together with the flexibility of use

on the available equipment that students and teachers have, including sufficient connection speed. Apart from that, making CloudClass templates for the use of 3D objects is seen as immediate action point, later including libraries available for teachers' use.

Strategic goals include integration of CloudClass in the university eco-system on all levels: hardware and software facilities, as well as appropriate design of learning materials (both instructional and media design).

Student requirements. Based on the go-zone analysis of this cluster, participants see the need for CloudClass environment to be easy to use and engaging/appealing (know what) as opposed to distracting. Knowing how to balance effectiveness, efficiency and enjoyability within the environment for students is a strategic goal, as well as students being able to opt for a plain background. Technology acceptance and learners' data protection need to be considered as goals of primary importance.

The study has some limitations with respect to generalization of the findings. Because participants involved in the sorting and rating phases represented one institution (OU), the results drawn from the analyses can reliably inform the workflow of the specific project set in that country in a distance-learning university. It would be interesting to compare these findings with those of other institutions, countries and/or developed for other tools. What is more, the majority of participants for the sorting and rating phases were represented by teachers (89,09% and 82,50% respectively), and it would be interesting to compare this data with other stakeholder groups, potentially including students and representatives of companies developing the tools.

Another limitation derives from the fact that the study was based on evaluating the possible application of DVR tools based on an example of CloudClass. Despite the fact that participants' responses were triggered by the technical affordances of one tool, we consider the generated output informative and transferable to a range of similar DVR tools that have relatively low technical threshold and do not require extensive training in graphic design or programming.

The results of this GCM study make a solid starting point in addressing technology implementation and integration projects within universities in a holistic and systematic way to ensure effective, efficient and sustainable use and further development of these technologies. Such approach gives voice to the core stakeholder groups and end users and can foster the development of the VR tool by informing the involved partners of the factors that need to be considered for the successful implementation of similar projects.

5. Conclusions

The present study focused on identifying the requirements for implementing a DVR tool like CloudClass in a university setting. The results of the study provide valuable insights into the priorities and challenges associated with the wide-scale adoption of VR technology in educational institutions.

The findings of this GCM study revealed that the requirements identified across the two European universities (OU, USC) that have been grouped into five thematic clusters: *Evaluation*, *Institutional Requirements*, *Maintenance and Training*, *Student Requirements*, and *Affordances and Infrastructure*. Go-zones generated from the importance and feasibility ratings for each cluster provide an informative overview of implementation steps to ensure the holistic implementation of a DVR tool like CloudClass that considers a balance between the pedagogical needs and technological affordances of a given tool.

The findings of this study offer insights to the scientific community, addressing the pressing issue of integrating DVR tools into mainstream education beyond experimental endeavours. By shedding light on the perspectives and challenges faced by the core stakeholders, the study not only facilitates a better understanding of their needs but also empowers them to articulate their struggles. Moreover, it strives to bridge the gap between technology developers and educators/practitioners, fostering collaboration, and provides guidance to other similar implementation projects by acknowledging the current experimental phase of VR tool adoption in educational institutions.

In conclusion, the findings of this study emphasise the importance of considering the identified requirements when implementing DVR tools like CloudClass in educational institutions and offer valuable insights into the priorities and challenges associated with DVR adoption in universities.

Chapter 2

Enabling the Integration of Desktop Virtual Reality in a Distance University: An Educational Stakeholder Perspective

As desktop virtual reality (VR) technologies become more accessible, universities face the challenge not of adoption, but of achieving meaningful and scalable integration. While prior research has examined the pedagogical affordances of VR, little is known about how these tools can be embedded within institutional structures and practices over time. This qualitative interview study investigates the factors that enable the integration of desktop VR in a European distance-learning university. Drawing on in-depth interviews with teachers, media designers, and institutional managers, the study identifies five interdependent themes: *Context*, *Values*, *Technology*, *Pedagogy*, and *Management*, that shape integration processes. Findings indicate that integration is achieved not through isolated initiatives, but through coordinated alignment between the themes. Two key mechanisms are proposed: a three-point audit (hardware, software, staff expertise) to assess organisational readiness, and a value-aligned design workflow that links VR affordances to instructional goals while anticipating risks such as cognitive overload and accessibility gaps. This paper contributes empirical stakeholder evidence on conditions for integrating desktop VR in distance higher education, introduces two actionable mechanisms to operationalise sustainable, value-sensitive integration, and offers practical recommendations to align implementation with pedagogical aims and institutional priorities.

The study offers an institutional-level perspective on VR integration within a single distance university and provides context-sensitive insights into how desktop VR can be integrated in pedagogically grounded, ethically informed, and organisationally sustainable ways.

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1. Introduction

As societies move from the efficiency-focused Fourth Industrial Revolution (Schwab, 2017) toward the more human-centric vision of the Fifth Industrial Revolution (European Commission. Directorate General for Research and Innovation., 2021), educational institutions face increasing pressure to adapt to rapid technological change and to prepare future generations for unpredictable realities. Within this context,Virtual Reality (VR) has attracted growing attention as a technology capable of enhancing learning through immersion and presence (Allcoat & von Mühlenen, 2018b; Fowler, 2015; Levin et al., 2015; Luo et al., 2021; Radianti et al., 2020; Rojas-Sánchez et al., 2023). VR enables interactive three-dimensional environments that can support motivation and spatial understanding (Dalgarno & Lee, 2010a; Radianti et al., 2020; Villena-Taranilla et al., 2022), and recent advances in artificial intelligence further amplify these affordances by enabling more adaptive, responsive, and interactive VR experiences (Zawacki-Richter et al., 2019). Historically, however, each emerging technology – from recorded audio and film to the internet, MOOCs, and more recently, Large Language Models (LLMs) – has been hailed as transformative for education (Cuban, 2001; Hall, 2024; Jonassen, 1996; Kozma, 1991; Laurillard, 2016; Reiser, 2001a). Yet educational benefits do not follow automatically from technological innovation; instead, they depend on pedagogically grounded integration into teaching and learning practices (Bice & Tang, 2022; Fawns, 2022; Fowler, 2015; R. E. Mayer & Fiorella, 2021). This raises a central problem: how can VR technologies be integrated in ways that enhance learning without distracting from educational objectives (Makransky, Terkildsen, et al., 2019)? Addressing this challenge, the present study investigates how desktop VR can be meaningfully and sustainably embedded in higher education by analysing stakeholder perspectives in a single-institution case study.

Virtual Reality (VR) can be defined as a collection of technologies that facilitate the development of synthetic, highly interactive three-dimensional (3D) spatial environments, which can simulate both real and imagined scenarios (Mikropoulos & Natsis, 2011). High-immersion VR (iVR) generally involves a head-mounted display that offers stereoscopic vision, head and position tracking, and a wide field of view, thereby fully immersing the learner in the virtual environment. By contrast, low-immersion or desktop VR presents the environment on a standard computer screen and relies on conventional input devices such as a mouse and keyboard without the use of head-mounted displays (E. A.-L. Lee & Wong, 2014; Limniou et al., 2008; Makransky, Terkildsen, et al., 2019; Makransky & Petersen, 2019a; Mikropoulos & Natsis, 2011). Previous research demonstrates that VR offers substantial immersion and presence, engaging learners through high-quality visualizations (Allcoat & von Mühlenen, 2018b; Fowler, 2015; E. A.-L. Lee & Wong, 2014; Levin et al., 2015; Luo et al., 2021; Radianti et al., 2020; Rojas-Sánchez et al., 2023; Villena-Taranilla et al., 2022). Research has shown that VR-based interventions lead to moderate positive effects on students' learning performance, particularly in domains such as basic science, social science, and health education, where abstract concepts, procedural knowledge, or authentic problem-solving are central to the learning goals (Luo et al.,

2021). Several meta-analyses have shown that VR instruction, whether implemented through immersive simulations, desktop-based virtual environments, or game-based platforms, can have greater learning gains than conventional teaching approaches. Effectiveness is typically operationalised as improvements in post-intervention performance on standardized or researcher-developed cognitive assessments targeting conceptual and procedural knowledge (Merchant et al., 2014; Mikropoulos & Natsis, 2011; Villena-Taranilla et al., 2022; Vogel et al., 2006).

Along with the growing interest in VR, substantial work has been done to incorporate pedagogical theories into technology-enhanced classrooms, resulting in a range of frameworks and models for integrating VR into learning environments. Dalgarno and Lee (2010) explored the affordances of 3D virtual environments for learning, particularly focusing on spatial knowledge representation and the immersive, interactive qualities of these environments. Fowler (2015) expanded this understanding by addressing the pedagogical aspects of VR, particularly through the concept of "pedagogical immersion," and emphasized the need for clear learning objectives and pedagogical frameworks when designing VR-based learning experiences. Mulders et al. (2020) integrated recent developments in instructional design, applying the Cognitive Theory of Multimedia Learning (CTML) (R. E. Mayer, 2005) to VR, and proposed guidelines for designing immersive VR environments that minimize cognitive load (Kalyuga, 2011; R. E. Mayer & Moreno, 2003; Sweller, 2010) and promote active learning. Additionally, Makransky and Petersen (2021) introduced the Cognitive Affective Model of Immersive Learning (CAMIL), which synthesizes existing research to describe how immersive VR experiences enhance learning through cognitive and affective factors, such as motivation, self-efficacy, and presence (Makransky & Petersen, 2021).

Despite VR's potential to enhance learning, most evaluations have been confined to experimental settings focused on user experience and interaction, which offered valuable insights and established a strong foundation for understanding the potential of VR in teaching and learning (Merchant et al., 2014; Mikropoulos & Natsis, 2011; Radianti et al., 2020). However, as the field matures, attention is increasingly turning to the question of how to support meaningful and scalable integration within institutional contexts. To date, relatively few studies have examined how VR can be embedded into regular teaching practices or aligned with broader curricular and organisational structures over time (Radianti et al., 2020; Rojas-Sánchez et al., 2023). Addressing this gap, the present qualitative interview study explores distance university stakeholders’ perspectives on what is needed to achieve meaningful and sustainable integration of desktop VR at the institutional level.

Previous research has identified several barriers to the institutional adoption of educational technologies. These barriers include the need for teachers’ digital competence(Cattaneo et al., 2021), the integration of technology within pedagogical frameworks that account for specific context, stakeholder values, and priorities (Fawns, 2022), and the design of learning environments that effectively blend physical and digital spaces (Tondeur et al., 2024). Cattaneo (2025) emphasizes that successful technology implementation requires alignment among individual factors such as teachers' digital skills, institutional support, leadership, and school culture,

all of which must work together to create a supportive environment for integration (Cattaneo et al., 2025). These studies largely focus on theoretical aspects of technology integration or do not specifically address Virtual Reality (VR), particularly in higher education contexts. A group concept mapping study explored the challenges of integrating desktop VR technology at scale in university settings, aiming to improve learning processes rather than merely adopting new technology (Holubinka et al., 2023). While that study provided a valuable initial exploration of the requirements for VR implementation in universities, it did not address how these requirements translate into the core factors that enable meaningful, scalable technology integration that enhances learning. This underscores the need for further research to explore these factors in greater depth and understand how they interact in real-world university settings.

This study aims to provide more insight into the factors that enable the integration of VR technology into the classroom by conducting an interview study within a European distance-learning university. Through in-depth interviews with teachers, media design experts, and institutional managers, we aim to identify and analyse the key factors that enable the mainstream integration of desktop VR technology in higher education at a distance. The guiding research questions for this study are:

RQ 1: Which factors enable meaningful scalable (desktop) VR technology integration in a distance university setting?

RQ 2 How should a specific VR tool be best integrated within the institutional setting to maximize its educational impact?

This paper contributes in three ways. First, it identifies institutional and pedagogical factors that enable the integration of desktop VR, using evidence from 20 cross-role interviews. Second, it proposes two integration mechanisms: the three-point audit and the value-aligned design workflow. Third, it distils decision-support recommendations to align scalable implementation with pedagogical and institutional priorities.

2. Methods

2.1. Research design

An interview-based qualitative design was selected to address the research questions, as this approach facilitated a detailed examination of stakeholder perspectives on the complex and interdependent factors influencing the meaningful and scalable integration of desktop VR technology. Guided by Creswell and Creswell's strategy-of-inquiry framing and Maxwell's interactive model, we conceptualized the study as a qualitative single-case design situated in one distance-learning university, aligning goals, conceptual framework, research questions, methods, and validity considerations (Creswell & Creswell, 2017; Maxwell, 2013).The focus on a single institutional setting enabled a context-sensitive analysis of how these factors are manifested and negotiated in practice. Rather than focusing solely on the adoption of VR technology, this study emphasizes the "how" - examining how a specific tool can and should be best integrated within the

institutional setting to maximize its educational impact. By shifting the focus from mere adoption (the fact of use of technology) to meaningful pedagogical and organizational integration, in the present study we aim to uncover the conditions necessary for sustainable implementation at scale. The study incorporates the perspectives of several stakeholder groups through maximum variation sampling (Creswell & Creswell, 2017; Creswell & Poth, 2016; Patton, 2014), selecting participants across disciplines (six faculties), roles (teachers, educational researchers, media design experts, and institutional managers and coordinators), and years of teaching experience. We also varied prior VR exposure, ranging from none or limited exposure to course-level use and, for a small subset, experience developing VR-based materials. Because this was a pre-implementation, problem-exploration study, participants had not used the specific desktop VR tool (Edison) in sustained teaching; to provide a common frame of reference, all participants viewed the same short video demonstration and read a brief description of Edison before the interview. This ensured that the sample captured diversity in professional background and technology familiarity, thereby strengthening the credibility and transferability of findings (Maxwell, 2013). Such a multi-perspective approach facilitates a comprehensive understanding of the factors influencing the mainstream adoption of VR technology in a higher education institution and offers insights into how these factors operate within a real-world academic environment (Miles & Huberman, 1994; Patton, 2014; Tracy, 2019).

To explore how desktop VR technology can be meaningfully integrated into distance higher education, a distance-learning Open University in The Netherlands (OU) was selected as the research setting, implicating that the participants were not only accustomed to using digital media as part of their instructional practices, but that they had most likely experienced transitions from older to newer technologies over time as well. Furthermore, the chosen university houses a well-established educational science department with a long-standing tradition of research on learning technologies. Many university lecturers are also researchers who engage with novel educational tools in their own teaching practices, positioning them to critically evaluate the potential benefits and challenges of integrating VR into mainstream higher education. At OU, this combination of pedagogical expertise and institutional experience with educational technology provides a rich context for this study.

By gathering qualitative data from a range of stakeholders with diverse roles including teaching staff, media designers, and institutional managers, this study aims to generate insights that, while grounded in a single institutional setting, may offer a useful perspective for institutions facing similar challenges in educational technology integration.

2.2. Procedure

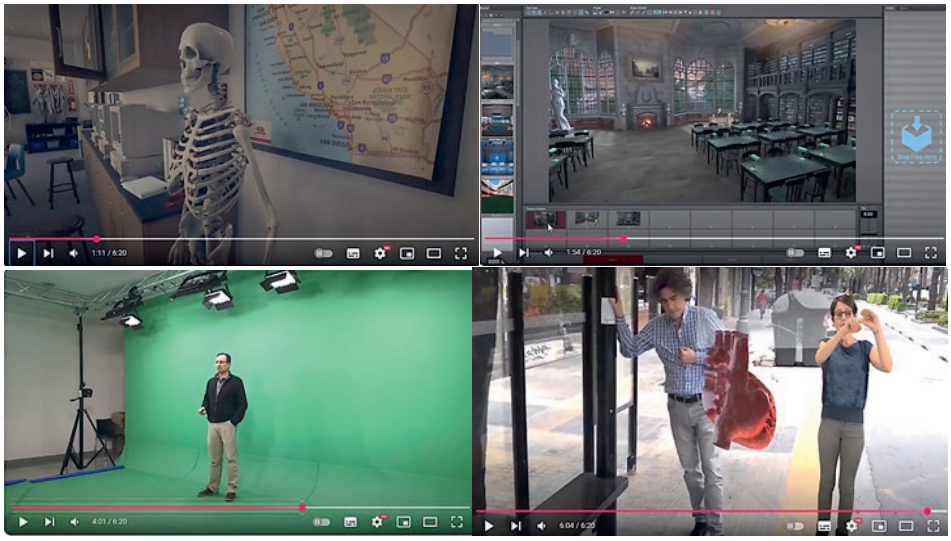
The study had been reviewed and approved by the Research Ethics Committee of OU (under the reference number U202200762), and all participants received an information letter about the study. They provided active informed consent to participate in the in-depth interviews.

In total, 28 participants from 6 faculties and the teacher training and media support division were approached via email. Individual interviews were scheduled with those who agreed to participate, and two interviewers conducted the sessions. A total of 20 semi-structured interviews were conducted online via video conferencing on MS Teams. Data collection proceeded in two batches: after the first 12 interviews, preliminary coding and memoing indicated recurring patterns; a second batch of 8 interviews was conducted to confirm and elaborate these themes. Following the twentieth interview, no new codes or themes emerged, indicating that thematic saturation had been reached (Creswell & Creswell, 2017; Maxwell, 2013; Tracy, 2019). Saturation thus provided the rationale for concluding data collection and supported the adequacy of the sample size.

The interview protocol (see Appendix B) was designed and piloted with a group of four researchers, and subsequently revised. To elicit participants' opinions and insights on the factors enabling successful integration of a VR tool in their institution, an authentic situation needed to be under consideration. For that, a short video was created, showcasing technical features and educational possibilities of the VR tool Edison [2]. Several screenshots from the video are given in the Figure 1 below.

Figure 1

Screenshots from the video presentation of the desktop VR tool Edison



Note. (1) 3D model of a human skeleton in a virtual environment; (2) a virtual classroom layout; (3) the presenter in front of a green screen; and (4) a dynamic 3D heart model integrated into the video feed.

Overall, the tool offers visualisation possibilities for VR environments that can be augmented with other types of multimedia – presenter's video, the display that can feature any content, and integration of 3D models. Originally designed for the

[2] The demonstration video can be accessed following this link: https://shorturl.at/N7sgb

broadcasting industry, Edison was adapted into an accessible classroom version that requires minimal hardware investment and no graphic design or programming expertise, and without reliance on technology developers. It can be used for recording content or integrated with existing video conferencing systems, enabling live-streamed content delivery without the need for head-mounted displays (HMDs). The video was sent to participants prior to the interviews together with the research question “How would you see this tool implemented in the context of [your university]?”.

Individual interviews were conducted in February 2022, each lasting approximately 60 minutes, totalling around 1200 minutes. With participants' consent, the interviews were recorded and transcribed verbatim for analysis by two research assistants. To ensure confidentiality, all identifying information was removed during transcription. Participants were assigned anonymised identifiers ranging from P1 to P20, which are used throughout the results section to attribute quoted interview excerpts.

2.3. Participants

Given the study’s focus on mainstream tool integration, participants were approached with maximum variation criterion in mind. They represented five of the six faculties as well as the teacher training and media support division and performed a range of roles from teaching assistants to education coordinators. Notably, 40% of the participants were affiliated with the Faculty of Educational Sciences and were involved in both teaching and research topics related to educational technology. Participants from the *Expertise Center* division were involved in both practical and administrative aspects of technology adoption and management within the university. The working and teaching experience ranged from several years (N=3) to “several decades” (N=11) , with the remainder (N = 6) representing mid-career staff. The representation of participants’ affiliation within the university is presented in Figure 2. Within this group, 50% of participants were involved in educational science and/or educational technology research activities; 20% had managerial roles (e.g. education coordinator); 20% were involved in technical and administrative processes or project management of educational processes. The participant sample reflected an equal distribution between male and female respondents.

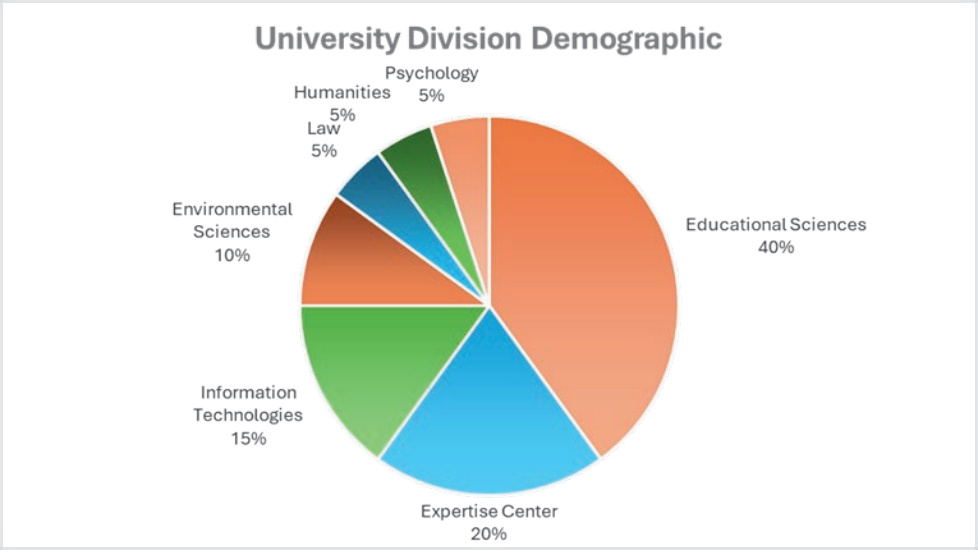
2.4. Data analysis

The analysis was conducted from a critical realism perspective(Archer et al., 2013). This approach combines a realist ontology – acknowledging that reality exists independently of human perception – with a constructivist epistemology, recognizing that our understanding of this reality is shaped and constrained by our positionality within it. This perspective was well-suited to the research questions, which sought to identify not only *which factors* enable the integration of desktop VR in higher education, but also *how* these factors interact within a broader institutional context. Critical realism allowed the analysis to move beyond surface-level descriptions to uncover deeper mechanisms and systemic alignments, while remaining reflexive

about how researcher interpretation is always situated. To ensure the trustworthiness of the analysis, credibility was supported through triangulation across stakeholder groups and iterative coding with extended team involvement; transferability was enabled by providing thick descriptions of institutional context; and confirmability was addressed through peer debriefing and analytic memoing. These strategies were used to enhance the transparency and analytical rigour of the study, ensuring that interpretations were grounded in the data while open to critical scrutiny (Archer et al., 2013; King & Brooks, 2017).

Figure 2

Participants' affiliation within the Open University, The Netherlands



*Note***.** Total N=20

The data was analyzed using the template version of thematic analysis with two independent coders to enhance credibility and reliability (King & Brooks, 2017). This approach enabled a structured yet flexible analysis of the interdependent factors identified in the research questions, while allowing for theoretical sensitisation based on the critical realist stance. In practice, we first organised participants' accounts and examined which conditions plausibly underlay these experiences in our setting—such as policies, resource allocation, or workload norms (Archer et al., 2013; Maxwell, 2013). Within Template Analysis, we progressed from initial descriptive codes to higher-order themes that specify candidate mechanisms and their contextual contingencies, refining these across cases and roles (King & Brooks, 2017). We evaluated each proposed explanation against disconfirming instances and across stakeholder groups to avoid remaining at the level of description (Maxwell, 2013). The first coder was the main researcher of the study, familiar with the aims of the study, and having background in educational sciences and technology-enhanced learning (first author). The second coder was a researcher in educational sciences independent of the project but experienced in qualitative research (second author). This combination of proximity to the study and external

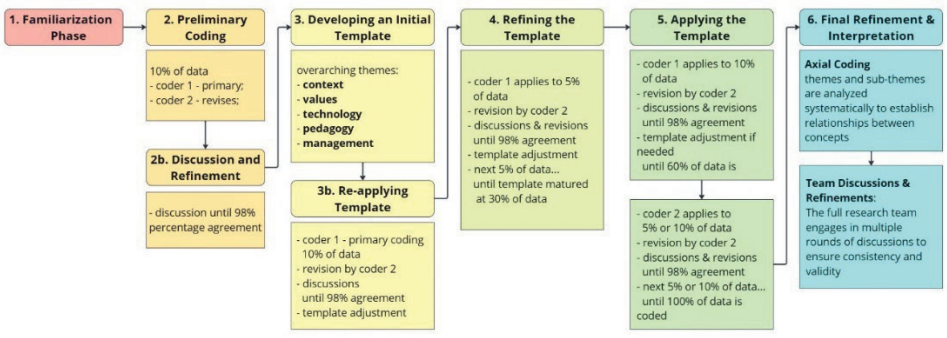
perspective strengthened the interpretive process. The coders brought complementary viewpoints: one theoretically sensitised, the other open to inductive insights. Both shared institutional familiarity as university staff, which enabled empathetic engagement with participants' accounts while remaining reflexive about how their roles and assumptions might shape interpretation. All authors were involved in reviewing and discussing the developing coding structure and thematic synthesis, enhancing reflexivity and analytical rigour.

The data was initially coded by one coder inductively with both semantic and latent codes, and then revised by another coder, using the Dedoose application (*Dedoose (Version 9.2)*, 2025). The process of data analysis is outlined in the flow chart in Figure 3 below. In cases of disagreement on coding, discussions were held to reach agreement on the points of divergence.

Following the *familiarization phase (1)*, *preliminary coding (2)* was conducted on 10% of the data by both coders in succession, after which discussions were held between coders to refine interpretations. The *initial template was developed (3)* by organizing and grouping codes into a hierarchical structure based on recurring patterns identified across the first two interviews. The initial template emerged through inductive coding and was iteratively refined through team discussions. Broad themes were developed by clustering related codes into higher-order categories based on conceptual similarity and salience across interviews, following the iterative logic of template analysis (King & Brooks, 2017). These themes were then refined into a hierarchical structure and interpreted through relevant theoretical lenses that aligned with the patterns observed in the coded data: *context* (Fawns, 2022), *values* (Fawns, 2022), *technology* (Dalgarno & Lee, 2010a; Fawns, 2022; Fowler, 2015), *pedagogy*, (Dalgarno & Lee, 2010; Fawns, 2022; Fowler, 2015), and *management* (Holubinka et al., 2023). Following initial theme development, these higher-order categories were further refined through recursive engagement with the data, leading to the specification of subthemes and the reorganisation of underlying codes within the evolving template structure (King & Brooks, 2017).

Figure 3

Flow chart of data analysis.



After that, the coding template was re-applied to the initial 10% of the data. The template was then *refined* (4) by iterative application to each subsequent interview, with codes and subthemes adjusted as new data required, and regular discussions held between coders to ensure consistency and interpretive alignment. This process continued until the coding template matured with 30% of the dataset, ensuring its robustness and applicability to the remaining data. The template was *applied* (5) to the further 30% of the data with the first coder as primary. Each coded transcript was subsequently reviewed by the second coder, with discrepancies discussed and resolved collaboratively. The remaining 40% of the data was coded by the second coder as primary, again followed by review and confirmation by the first coder to ensure consistency and analytical alignment. Any discrepancies in coding were resolved through discussion and consultation until agreement was reached. At the end of the coding process, there were 140 codes across 743 excerpts, with 1,280 code applications in total. To calculate the reliability between the coders, the formula “Reliability = Consensus / (Agreement + Disagreement) × 100%, recommended by Miles and Huberman (1994), was applied. The resulting reliability percentage was found to be 92%.

After the coding was completed, *final refinement and interpretation* (6) was conducted focused on reviewing the internal coherence of each theme, clarifying distinctions between themes and subthemes, and identifying meaningful relationships across the thematic structure. Finally, the themes were discussed with the entire research team of six researchers and adjusted through consensus to ensure robustness and alignment with the study’s objectives. Multiple rounds of team discussions were conducted to facilitate reflexivity and sharpen thematic interpretations.

3. Results

3.1. Factors for Meaningful and Scalable Integration: Thematic Analysis

As a result of the template thematic analysis, five core themes were identified, providing an answer to the RQ1: *Which factors enable meaningful and scalable (desktop) VR technology integration in a distance university setting?* These themes – *Context*, *Values*, *Technology*, *Pedagogy*, and *Management* – embrace the groups of factors influencing the meaningful integration of VR technology in the university setting.

(1) Context explores the institutional setting, addressing the question "*Where*" the technology should be integrated. Theme *(2) Values* deals with the "Why" of the tool integration, while theme *(3) Technology* focuses on the technical affordances needed, addressing "What" should be integrated in the learning process. Theme *(4) Pedagogy* embraces “How” the technology should be used in a given educational setting. Finally, theme *(5) Management* strives to address the question "What is the strategy for integration?"

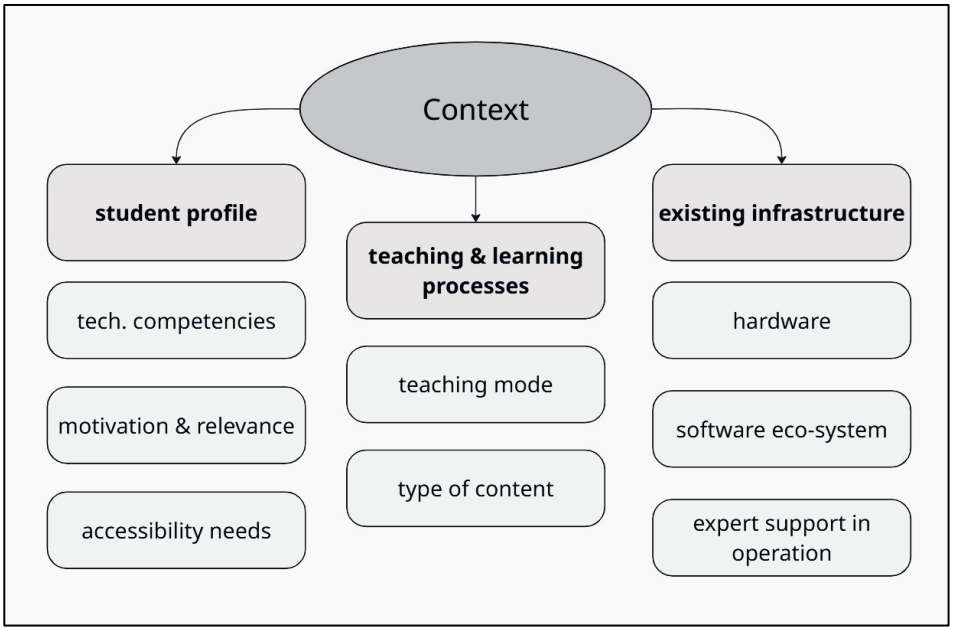
The following sections outline each theme in detail, supported by participants' quotes and references to specific data items.

3.1.1. Context

The theme *Context* focuses on the setting where the desktop VR tool Edison should be integrated, answering the question "Where?" It embraces factors within the institutional environment that interact dynamically at the time of investigation. In this study, these factors include the student profile, teaching and learning processes, and the existing institutional infrastructure, and are listed in figure 4 below.

Figure 4

Factors for VR integration within the theme 1.Context.



Student Profile. As an online distance university, OU serves a uniquely diverse student population whose characteristics may influence how technology is implemented and adopted within the institution. Participants observed varying degrees of digital competence among the student population, highlighting the need for intuitive design and tailored support. Younger students were often comfortable with immersive tools and "gaming-like" interfaces, with one participant noting, *"They like it, and if I can show them in the class, this 3D virtual environment... it's a language they understand"* (P5). Some even expected technology integration as a norm: *"The 18-19s might wonder, 'Why doesn't the teacher use it?'"* (P17), unlike more mature learners: *"For older students, it might be overwhelming"* (P19). However, adult learners were also seen as highly motivated by career-related goals, influencing their engagement with technology: *"They're typically between 25 and 45... They also want to go up the ranks"* (P8). Additionally, a large portion of students are geographically dispersed, making online access essential: *"It's easier to join*

online" (P7). Participants also highlighted the importance of balancing the mode of delivery of online resources, as some learners may have autism spectrum conditions or attention-related challenges: *"We have a lot of students who have, for example, Asperger... if there's too much going on, they can't concentrate"* (P7). Given the diversity in digital literacy, accessibility needs, and learning preferences, instructors stressed the importance of usability, emphasizing that *"you have to assume that students are not very tech savvy... it has to work really effortlessly"* (P11).

Teaching and learning processes. The teaching mode as well as the educational model as a whole emerged as an important consideration in discussions about integrating new technology as it can both constrain and open up new possibilities. OU primarily operates primarily online, with occasional hybrid or face-to-face sessions from multiple study centres to accommodate the working students, and many classes take place in the evening when lectures teaching from home. Some participants described their own "hybrid formulas," combining *"blended ... asynchronous teaching, synchronous online teaching, and face-to-face meetings"* (P3), highlighting the need for adaptability based on course objectives. The fact that teachers were delivering education from home by default could potentially corroborate wide-scale implementation of the VR tool, as not only is the access to the university facilities limited in the evening hours, but it is hardly feasible to equip a mini-studio in teachers' homes: *"we mostly teach from home... but the study centres are not places where you would have green screens"* (P7). However, the online format also presents opportunities, enabling the use of virtual environments that would otherwise be inaccessible to both students and teachers. In addition, the type of content being taught to students was discussed as a factor defining relevance of the VR tools, e.g. some participants mentioned that their courses "rely heavily on text". So, harmonisation would need to happen if these tools were used at scale.

Infrastructure. Many participants (7/20) emphasized that new technologies should work in concert with existing hardware and software facilities of the university. The learning management system (LMS) and video-conference system, which offer features like breakout rooms, polling, and screen sharing, are widely-used for teaching and together create an eco-system of virtual tools with a single access: *"as a teacher, when I enter my course, I'm also automatically signed in to [video-conferencing tool], and then I'll also be automatically signed into your system. I don't have to again put my credentials to access the system*" (P15). At the same time, challenges of using unauthorized third-party tools were noted: "*If teachers use third-party applications, they do so as employees of the university... anything that goes wrong could lead to serious institutional issues*" (P15). Any software should be integrated into the existing ecosystem to ensure safe use and compliance with institutional standards. Implementing this integration could potentially require substantial technical investment before the new tool can be deployed at scale.

The OU's primarily online distance mode of operation results in quite basic hardware requirements and minimal technical setups, both on campus and in the study centres where students attend in-person sessions. Participants highlighted that the lack of necessary facilities, such as equipped studios, could hinder the broader integration of Edison. However, they also saw some opportunities: "*Study*

centres could be technological hubs if their hours were extended and access improved" (P12).

When creating multimedia instructional materials, many teachers noted that they required structured institutional support, particularly in areas like recording, lighting, and editing videos. As one participant stated, *"It took a lot of time and money to make these videos, but the experience for students was worth it."* (P14). With such support, teachers can effectively use advanced tools without significant additional effort, though this requires resource investment from the university. Several participants pointed out to constraints related to institutional funds and staffing: *"Money is a problem, time is a problem, and staff is a problem to really develop... advanced state of the art tools"* (P10). Thus, the more complex and advanced the technology, the greater the support teachers will require across various aspects. Professional tasks may need to be delegated to experts, rather than expecting teachers to independently manage the tools and face a steep learning curve. What is more, participants also mentioned the challenges that the university was already facing: "*We don't have the resources,… technology is moving fast. People can't keep up. That's also … not specifically at our institution, but everywhere"* (P10). On the whole, barriers to widespread adoption stem from limited budgets, the availability of facilities, and the need for technical or specialised expertise.

To sum up, the theme *Context* captures the unique institutional factors that must be taken into account for the harmonious, meaningful, and feasible integration of the new VR tool. A clear understanding of student profile, teaching and learning processes and institutional infrastructure is the first step in identifying the best fit for technology integration, as each of these areas may present both constraints and opportunities.

3.1.2. Values

Participants in this study brought up ethical considerations and reflections on societal, institutional, and individual values in the context of technology adoption, which crystalised as a theme *Values* that embraces the "*Why*" for technology integration and is schematically presented in figure 5 below.

Societal values. Societal values emerged in various aspects discussed by participants. Specifically, participants' comments reflect a changing worldview in education, from behaviourist models of instruction to constructivist and connectivist paradigms, which, as Anderson and Dron (2011) note, corresponds with broader societal transformations toward participatory, learner-driven models. One participant noted, "*I was not very satisfied with the educational system in [country] because I thought the education at the time was too teacher-led*" (P6). This shift is mirrored in the use of new technologies, as another participant emphasized: "*Learning is a personal interaction, so you should know who's on the other side*" (P8), revealing the focus on the learner and personal interaction, rather than content-driven learning, and the farther can be facilitated by new VR tools in distance education.

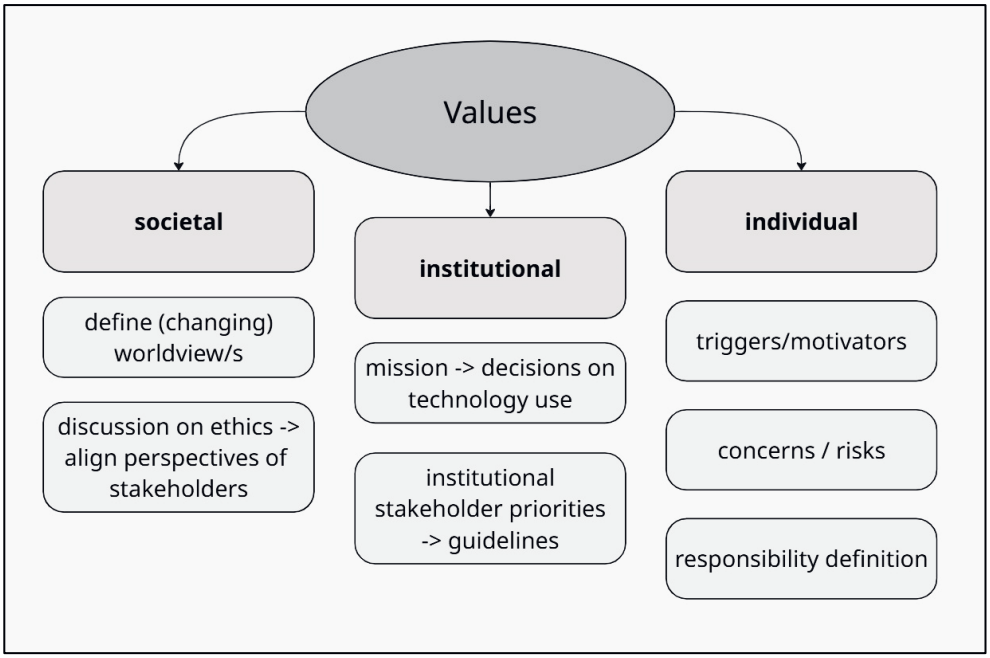
Another key point raised was the need "*to have a good ethical discussion*" (P1) regarding the safe use of emerging VR technologies as with new opportunities come

new questions and potential risks that need to be addressed. One participant discussed concerns related to the policy of recording online sessions:

"*I find it a really hard discussion still… if you were in a normal classroom then you wouldn't even think about people recognizing you. So, what's the issue really? Is it that people can see you, or is it that the information is stored somewhere, or is that it's not just a moment but that it's there forever?*" (P1).

Figure 5

Factors for VR integration within the theme 2.Values.



As learners may feel exposed or vulnerable in a digital space, there is a need to discuss and agree on the appropriate balance of the benefits of emerging technologies like VR with the ethical considerations of their use. Overall, participants' reflections suggest that shifting societal values are influencing evolving educational worldviews, which in turn shape teaching models and the integration of new learning tools such as VR (Anderson & Dron, 2011). In this dynamic landscape, explicitly defining the values for each component is crucial to maintaining a balance between safety and impact, as well as ensuring alignment across the different components of the educational ecosystem.

Institutional values. Participants' accounts revealed that values were also articulated at the institutional level, particularly in decision-making processes concerning appropriate learning methods and tools. As one participant explained, "*it starts from the tagline, the mission [OU] has, which is the part-time study offering personalized and activating online education. …"* (P2). Technologies considered for the learning process must first align with the university's principles of "*freedom of play, space/place and tempo*" before further instructional design decisions and

course integration are made (P2). This highlights how the university's mission serves as a cornerstone for decision-making in instructional development for the VR tools that need to be integrated.

Participants also emphasized equity as a strong institutional value, discussing how technology could exacerbate disadvantages for certain student populations. One participant stated, "*It should be accessible for all kinds of students and not just those who can afford the technology*" (P13). Many teachers also stressed the need to make technology accessible to neurodiverse students, with one suggesting, *"…put in some opportunities for those students to make it easier for them to follow the class*" (P7). These perspectives align with the university's values of ensuring higher education is accessible to all, particularly to disadvantaged populations.

Individual values. In addition to societal and institutional values, participants shared personal beliefs, attitudes, and concerns that influenced their decisions regarding the implementation of the VR tool in their teaching practices, which shaped the range of individual values. For many teachers, seeing students succeed served as a strong motivator, as noted by one participant: *"It's very motivating to help students... especially if some start in really nice jobs"* (P8). This desire for student success can lead to a greater willingness to adopt tools that positively impact the learning process, e.g.: *"If my students are more engaged… I will have the feeling it [using the new tool] pays off"* (P5). Inspiring students was also a motivating factor for teachers to incorporate VR tools like Edison into their practices. As one participant put it, *"We can inspire students to think of interactive, active and actually almost authentic activities with young children... it's something I can already use in my education."* (P20). Overall, positive learning outcomes for students emerged as a key factor in teachers' perceived benefit of technology use: *"Teachers will adopt tools if they think it's better for their students or saves them time"* (P3). However, some participants expressed concerns about the potential negative effects that new technologies might bring and their responsibility for the safe use, with one teacher advising, *"Be careful not to use extreme things... you always have to be aware... it has a lot of potential but think about what you're going to show your students."* (P18). Overall, while participants are motivated by the potential for positive learning outcomes, they also feel a sense of responsibility in ensuring that new technologies are used thoughtfully, weighing their benefits against any potential risks.

Overall, values underpin the educational worldviews that inform both pedagogical models and the design of technological tools, shaping the ways in which emerging technologies like VR are taken up in higher education. These values are often implicitly embedded in the educational tools themselves, influencing how VR technologies are perceived and used by teachers and students. However, for these tools to be effectively integrated into educational practice, it is crucial that the values driving their use – whether societal, institutional, or individual – are made explicit and aligned across all components of the educational ecosystem. This alignment ensures that the VR tools do not operate in isolation but work synergistically with pedagogical goals, institutional priorities, and societal needs. In this context, values are not just foundational; they serve as the "glue" that holds the various elements of the educational system together, shaping decision-making processes, instructional

methods, and the long-term impact of VR technology on learning. Thus, being aware of and clearly articulating these values is essential for maximizing the benefits of VR tools and ensuring their meaningful and responsible integration into educational practices.

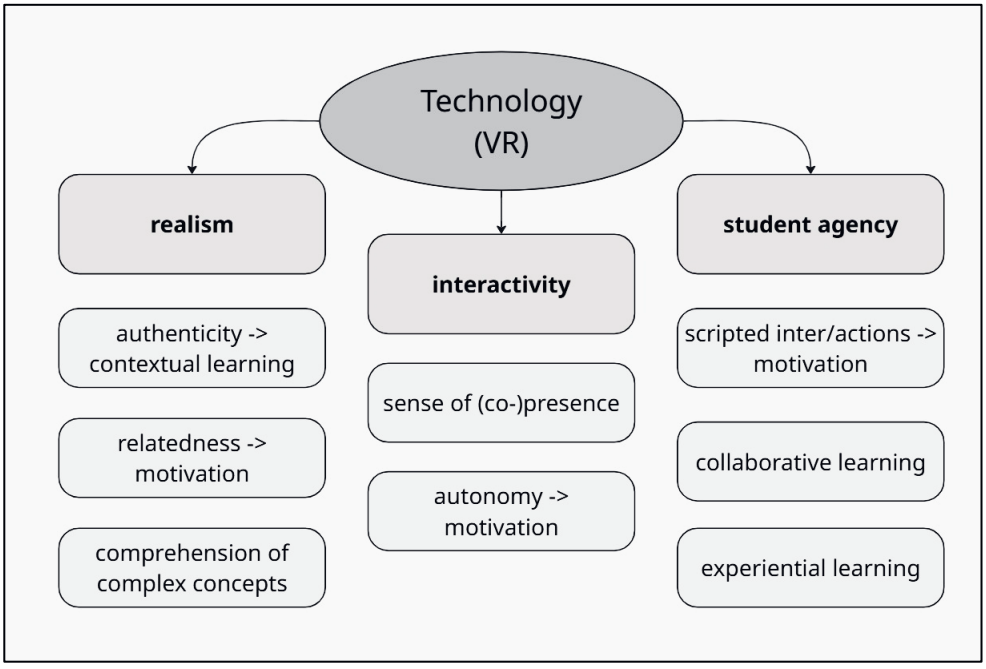
3.1.3. Technology

Theme *Tecnology* embraces a range of affordances that participants would like to have while using a tool like Edison, as expressed by one participant: *"Can I do things I always wanted to do but wasn't able to do with [Edison] technology?"* (P3). Participants stressed the need to understand the capabilities and limitations of the VR tool as the first step in the integration process:

"You have to have a very clear understanding of the functionality you can expect of it and what it can't offer. ... If you know what it can do for you, you can still do something no one has done before" (P6).

Figure 6

Factors for VR integration within the theme 3.Technology.



This theme includes both the potential learning benefits that a VR tool like Edison has to offer and the risks posed for the learning process. It addresses the question "*What*?" in relation to the affordances needed by teachers and students for effective learning. The factors within the theme Technology are schematically presented in Figure 6 below.

Realism. Participants highlighted that realistic 3-dimensional environments can be useful in the learning process for several reasons. Firstly, context-relevant backgrounds can foster a sense of relatedness(Ryan & Deci, 2000a) in distance

education by helping students feel as though they are in "*the same classroom they [students] are used to*" (P5). Backgrounds aligned with the teaching topic or scenario, such as "*a restaurant as your background*" or presenting objects "*as if you are in a real situation,*" further enhance the authenticity of the learning experience, e.g.: *"You can recreate a courtroom with a suspect, a defendant, a lawyer, and a judge"* (P10). Additionally, learning in a virtual 3D environment can improve attention and focus or simulate real-world experiences: *"Are you more focused because it's 3D all around you? That could be an added value of such a virtual world"* (P8). Participants highlighted that 3D models (e.g., solar system, engines) can help clarify complex concepts, allowing learners to "*see how ... everything is connected together*" (P7). As one participant explained, "*You can go inside the model, you can turn it around and you can zoom into some parts and that's wonderful if I want to show them, for example, how the heart works*" (P5).

Contextualized virtual environments, when meaningfully integrated, can replicate real-life situations, such as virtual museums or outdoor settings, helping bridge the gap between theoretical learning and practical applications, also facilitating access to disadvantaged groups, e.g.: "*Sometimes students can't come to the museum... if you can add those extra things to the study environment, it can be very useful*" (P9). In this way, VR tools like Edison enable contextual learning, fostering deeper comprehension and preparing students for real-world challenges by grounding learning in relevant contexts.

Interactivity. In the context of distance education, affordances that foster a sense of presence and reduce feelings of isolation during online interactions were identified as essential. One participant explained, *"having your avatar in the virtual environment... I have the feeling that [users] have more social presence … of the others compared to [students in traditional online settings]"* (P5). Another participant highlighted the value of seeing peers "*sit at a table and see each other's face,"* which leads to "*much more realistic"* interactions (P14), thereby supporting presence through immersion. Additionally, the ability to express realistic non-verbal cues was seen as a key factor in enhancing communication during learning. One participant noted, *"If [Edison tool] could facilitate... two students, for instance, facing each other in a room... with more of a feeling of their non-verbal behaviour... that would give a better simulation of a real conversation"* (P11). Overall, effective user representation through avatars, shared spaces, and non-verbal cues was seen as essential for enhancing immersion and presence during online communication in the learning environment.

Participants recognised the importance of interactivity of the virtual environment for students, e.g.: "*the inability for students to move independently within the environment could restrict their engagement and interaction*" (P18), while the possibility to "*walk through the environment," "turn around," "zoom into some parts"* of models, and "*manoeuvre around the environment*" can facilitate a more interactive and immersive learning experience (P18; P6). These realistic and interactive features *"give students this idea that they're really present... you get this idea of being in a classroom or another area [together]"* (P18). While advanced technologies like haptics are ideal, intermediate solutions, such as using a mouse to manipulate

objects, were also considered beneficial compared to merely observing the models (P13).

Student agency. Participants emphasized that certain features, when embedded into the design of the desktop VR tool such as Edison, can play a crucial role in fostering student agency. In particular, scripting student inter-/actions, which involves embedding structured roles, tasks, and progression mechanisms within virtual environments, can foster collaboration and enhance intrinsic motivation through experiential learning. Participants gave examples of specific applications, such as train drivers learning by exploring the environment where they can "*map the entire train system*" and interact with various passenger scenarios (P10), or students can travel to Paris or explore the solar system (P11). The role of design in creating effective experiential learning environments was emphasized, with one participant describing the complexity of designing such experiences and the challenges teachers face in achieving "*high-quality design*" (P2). Apart from interactivity, a range of other features were mentioned as desirable to support active learning, e.g.: "*The ability for students to independently navigate the environment or a presentation without interrupting the flow of the lecture*" was also seen as valuable (P8), as well as an option to "*make immediate annotations*", e.g. collaboratively (P8). Furthermore, "*enabling students to create their own presentations using 3D environments*" was identified as a way to promote student agency and deepen learning (P4).

In sum, theme *Technology* captures participants' reflections on the role and potential of VR tools like Edison in enhancing distance education. Rather than treating VR as a generic upgrade to existing platforms, participants emphasised the importance of understanding its specific capabilities and constraints as a necessary starting point for meaningful use. Throughout the interviews, technology was positioned not as an end in itself but as a means to enable new forms of interaction, representation and participation. Participants described how immersive 3D environments could simulate authentic settings, support focused attention, and provide alternative ways of explaining complex content. They also stressed that effective integration requires a level of interactivity and learner control not typically available in standard video-conferencing tools. Ultimately, the pedagogical value of VR was seen to depend on how well its technical affordances could be aligned with teaching goals and adapted to real-world learning needs in online distance higher education.

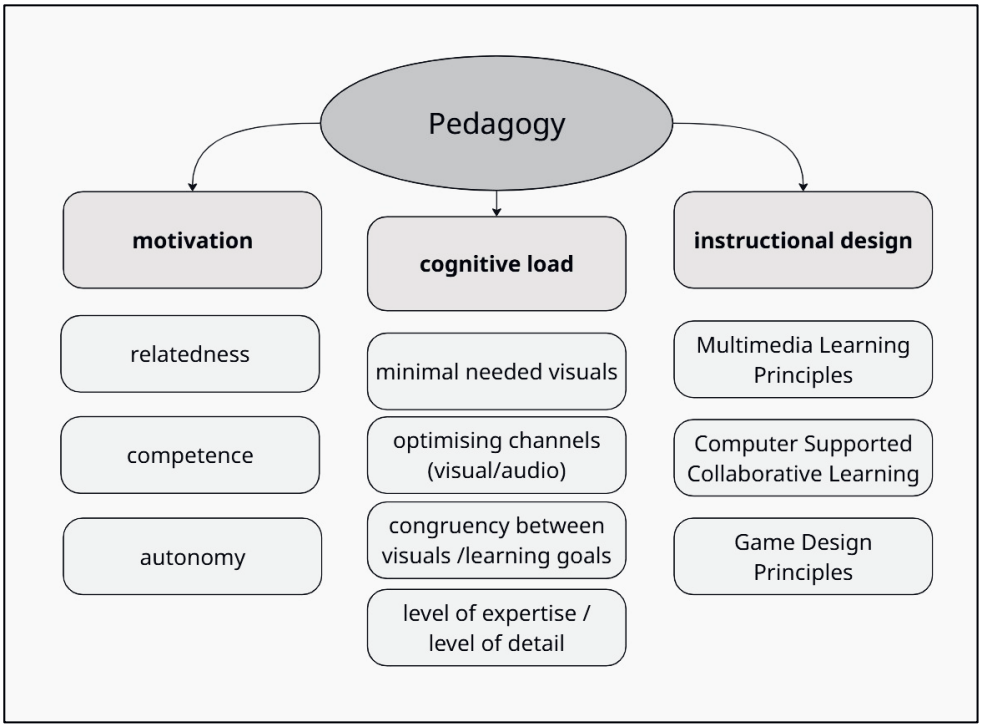
3.1.4. Pedagogy

The theme *Pedagogy* addresses the methods and principles guiding the meaningful use of VR technologies in education. As one participant put it, *"People need to understand… this is a new way of using technology, not just doing old stuff with a new tool"* (P4), emphasizing the need to align the tool and the method. Thus, this theme addresses the "*How?*" of using VR technologies in educational settings. The theme brings together three interrelated aspects considered important for the meaningful use of VR tools: affective factors, specifically intrinsic motivation and cognitive load, and the role of instructional design in structuring learning activities in

technology-mediated classroom settings. The factors featured in this theme are summarised in figure 7 below.

Figure 7

Factors for VR integration within the theme 4.Pedagogy.



Intrinsic motivation. Participants discussed intrinsic motivation as a key factor in designing effective learning experiences with Edison, particularly in relation to the psychological needs outlined in self-determination theory (Ryan & Deci, 2000a). Several interviewees explicitly referred to the theory's three components: relatedness, competence, and autonomy, essential conditions for fostering intrinsic motivation in the context of using the tool like Edison, e.g.: "…*if you're looking at motivation, I think it's always very helpful if you look at those three components of [self-determination] theory – relatedness, competence and autonomy – whether these are supported by the learning scenario that has been designed*" (P6).

In the context of online distance learning, like in OU, *relatedness* or the sense of connection among and between students and teachers (Ryan & Deci, 2000a) may often be lacking because of the loss of informal interactions and the "*hallway chats*" that usually foster rapport in face-to-face settings (P5, P8). Informal networking spaces that mirror real-life interactions can enable peer collaboration and casual socialization: "…*you can come into some kind of meeting place... where you could approach someone for a one-to-one chat*" (P8); Exchanging reactions or emotional responses like laughing or "*getting bored together*" (P16) can promote bonding and sense of belonging. The possibility to "*see*" others provides opportunities to build

community and reduce feelings of loneliness (P4, P2, P6), thus restoring the sense of presence and closeness (P5, P14, P16). However, there is also recognition that technical or design complexities might impede these affective factors if not well-implemented (e.g. P6, P2).

When it comes to *competence* (Ryan & Deci, 2000a), supportive feedback and clear guidance can help, like in the example that one of the participants gives from his experience with VR-based serious games: *"In serious games and simulations, providing feedback is key. Students can make mistakes and get instant feedback, which helps them feel more competent and supports their learning"* (P6). And on the contrary, if students struggle to use the platform or if it introduces unnecessary complexity, their sense of competence (and thereby their motivation) may diminish (P4).

The ability to choose roles, navigate independently, or engage with materials at their own pace, or *autonomy* (Ryan & Deci, 2000a), fosters a sense of control and self-determination (P8), thus positively affecting intrinsic motivation: *"giving them [students] autonomy to work on tasks the way they prefer can boost their motivation"* (P6). However, the challenge lies in balancing autonomy with guidance. If the environment is too open-ended or complicated, it may distract or overwhelm learners, thereby reducing motivation (P18, P8).

Cognitive load. Balance is also important when it comes to realistic complexity of the virtual environment and learners' processing capacities. Specifically, references were made to extraneous cognitive load (Mayer, 2005; Plass et al., 2010) – unnecessary information or overly complex stimuli that burden working memory – and the need to optimize instructional design to support rather than hinder learning. While adding multiple elements (e.g., 3D models, animations, complex detailed backgrounds) can seem tempting, it may also lead to *"information overload ... teachers are tempted to make it so fancy ... it is too much for the learners"* (P1). Similarly, another participant stated, *"I try to keep my environment as "clean" as possible ... if you add information with a lot of details ... it might distract the students ... might be an overload of information and sensory stimuli"* (P19). At the same time, appropriate use of multimedia channels and alignment of modalities can optimise cognitive load. For example, embedding the teacher's explanation within the same environment as the presented content was viewed as potentially beneficial: *"If you use the teacher as voiceover ... guide the process of explaining the model ... that could be an advantage. But if ... not aligned, then it does increase the cognitive load"* (P6).

Congruency between the environment and the learning content was also seen as important, as one participant pointed out: *"If you have that space virtually available and it's congruent with your topic ... it might improve the learning experience"* (P10). Conversely, off-topic elements were seen as potentially harmful, serving only to distract rather than support understanding, thus increasing extraneous cognitive load.

Another point that was raised is tailoring the level of detail of VR representation to the learner's level of expertise. Particularly concerns were raised for novice

learners, older students, or learners with special needs (such as autistic spectrum conditions) who may struggle with too many details, resulting in distractions and reduced focus on key learning materials, e.g.: *"…their brain may be overloaded… If the teacher has also a 3D model and it moves around… it may take the attention away or overload them"* (P5). Beginners might benefit from simplified, less detailed representations, while more advanced learners could handle additional complexity, e.g.: *"For a novice it should be very clear ... you should diminish extrinsic cognitive load as much as possible ... as the student gets more experienced, then you probably can add more distracting features"* (P12). In other words, the complexity and representational fidelity of the virtual environment should be progressively aligned with learners' growing expertise. Expert guidance emerged as another way to support learners in visually rich virtual environments. Teachers should be able to pause demonstrations, highlight expert decision-making, and provide additional information at critical moments. One participant imagined: *"You can pause what the expert does…give additional information in a specific source"* (P12), ensuring learners remain focused and not cognitively overloaded.

Instructional design. Instructional design was identified as a foundational component in the development of educational practices involving new tools. As one participant put it, "*we're talking about this like the chicken and egg problem. And usually, you would want it to start with instructional design, rather than with the tool perspective, getting to this media debate*" (P6), referencing the Kozma and Clark debate (R. E. Clark, 1983, 1994; Kozma, 1991, 1994). In this context, Richard Mayer's multimedia learning principles (Mayer, 2005; Mayer & Fiorella, 2021) are relevant as VR tools operate within different modalities and thus evidence-based cognitive psychology principles for designing effective learning scenarios apply well, as was pointed out by many participants (P5, P6, P7, P12, P20).

Authenticity and presence afforded by the tools like Edison also align well with the principles of computer-supported collaborative learning, as noted by several participants (P6, P14, P19), who envisioned realistic scenarios such as a museum, classroom, or even a train environment to situate group tasks meaningfully, e.g. *"Context is everything…if you get a group experience inside a location where learning can happen…that would help"* (P10). Here, the participant refers to context in the sense of immersive situational environments, rather than the institutional context discussed as a distinct analytical theme. Game design principles have also been mentioned as useful in using tools like Edison in educational settings, with examples ranging from chemical bonding and classroom management to environmental problem-solving where learners could interact with elements and roles to construct knowledge collaboratively (P16, P2, P15). However, the consensus was that such approaches must be integrated thoughtfully and aligned with learning goals.

"It's an excellent tool but only works if connected directly to the learning outcomes and instructional strategies" (P16); "*it's critical to ensure that the tools align with the curriculum and the instructional goals, so the gamification does not feel like a gimmick"* (P15).

Finally, within the desktop VR learning environment it is important to also facilitate immediate feedback and continuous assessment to help students understand their performance and areas of improvement promptly. Gamified feedback elements, such as evolving avatars (P16) or scoring systems were mentioned, e.g.: *"We try to map game activities on the learning goals…to have a dashboard…How much points did you earn?"* (P2).

In sum, the theme *Pedagogy* highlights participants' shared understanding that the educational value of VR lies not in its novelty, but in how it reshapes the relationship between method, medium, and learner. Rather than replicating traditional practices in virtual space, participants stressed the need for intentional instructional design that aligns technological possibilities with meaningful learning experiences. Motivation, presence, and cognitive load were recurring concerns, not as abstract constructs, but as practical challenges that must be addressed through thoughtful scenario design, appropriate complexity, and supportive feedback. Importantly, the pedagogical potential of VR was seen to depend on maintaining a delicate balance: between immersion and distraction, autonomy and guidance, innovation and curricular alignment. Across participant interviews, effective integration was seen to require a shift in mindset – from using tools to deliver content more efficiently, to designing immersive, goal-oriented experiences that actively engage learners in meaningful, context-rich activities.

3.1.5. Management

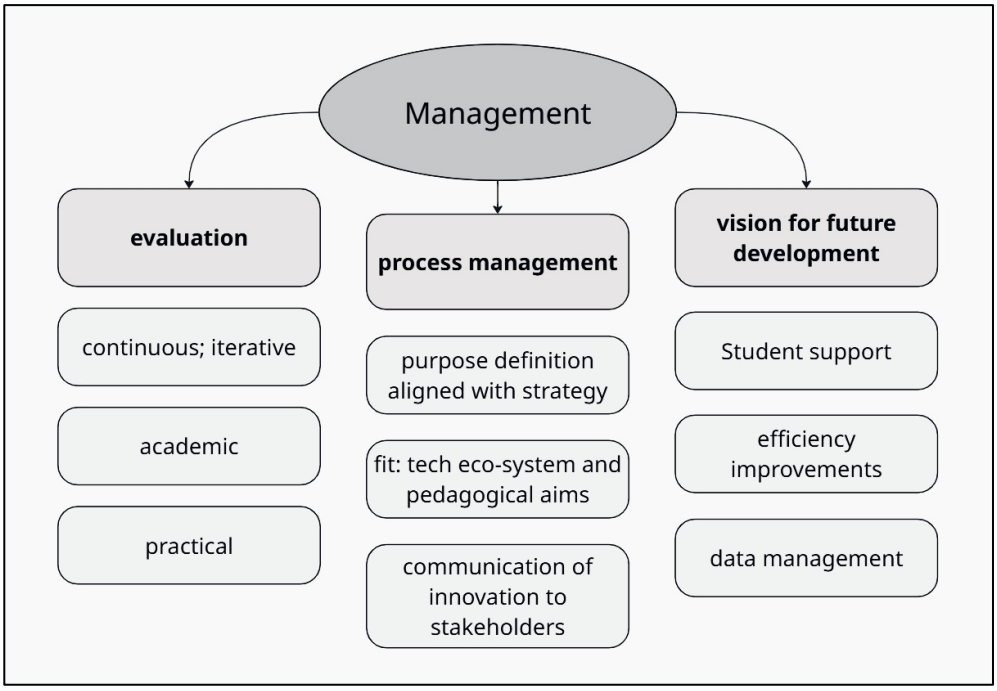
Management emerged as another theme consistently highlighted by participants, which pointed out the critical role of the university in facilitating alignment of all the previously-identified factors through a clear processes for integrating the new technology. Without this support, the implementation of new technologies risks becoming fragmented or ineffective, e.g.: *"It's a huge task for people to integrate this into their curriculum without institutional support"* (P4). This theme embraces three aspects – evaluation, process management and vision for further development which were visualised in figure 8 below.

Evaluation emerged as a sub-theme, underscoring the dual imperative to rigorously assess the tools both prior to and during their implementation. Participants highlighted the importance of ensuring not only pedagogical effectiveness but also efficiency of the tools, e.g.: "… *to me it's very important to not only develop, but also to research [the tools]. And in that case, you have an iterative cycle of improving*." (P2). This process involves two complementary dimensions: academic evaluation of effectiveness of the learning process, ensuring that using the tool improves learning, e.g.:

"*Well, you are talking to someone doing experimental psychology most of the time, it's like, yeah, just there you would need to run like the same class with this fancy setup and same class with the standard setup, and then do a test afterwards and see whether students remember more after one or the other*." (P13), and practical evaluation, which focuses on the technology usability in real-world settings, institutional processes, and user satisfaction.

Figure 8

Factors for VR integration within the theme 5.Management.



Efficiency evaluation of a VR tool like Edison was deemed crucial by participants. As one noted, *"If it's a lot more effort, a lot more hours to put this together, then I won't use it. I'll take my pencil again and just draw"* (P5). Usability was also highlighted as an important factor, with the user interface needing to be intuitive and user-friendly. As one participant pointed out, *"If it's really difficult to use and you need a long instruction to use the software, then people will probably fall back on default methods"* (P13). Training materials were seen as a way for improving the ease of use, e.g.: *"Create YouTube-style videos for training, … this is critical for adoption"* (P12). Furthermore, participants emphasized that the technology must be robust. As one stated, *"I don't have a lot of technology knowledge, so if I have to spend a lot of time on troubleshooting, I won't use it"* (P5). Evaluating and ensuring compatibility with existing infrastructure and user devices – as mapped in the *Context* theme – was also considered essential for broader adoption. As one participant noted, *"Can it run in a browser? Can students use it on a tablet? Those are concerns"* (P13); "*It has to work really effortlessly without any problems... Even one extra click can be a barrier"* (P11).

Effective implementation requires efficiency evaluation or balancing the tool's added value with its demands: *"You have to have that balance between the value it brings and the time it takes"* (P8). As a red thread, it was highlighted that added value needs to be evaluated and well-defined to prevent simple substitution of already existing tools at hand: *"what we see is a lot of substitution and a little of innovation and even less real transformation going on in education… we are still not really using*

the added value of the new technologies" (P2). Cost emerged as a significant factor influencing the tool's viability. One participant explained, *"If it's only applicable in a limited number of courses, then the discussion shifts to the business case… What does it mean for our IT infrastructure?"* (P15). Another expressed concerns about affordability, stating, *"You don't want to pay thousands of euros for just added functionality" (P13).* The need for context-specific evaluations to determine the tool's relevance across disciplines was highlighted by: *"I didn't see immediately what I could do with it as a … teacher"* (P9).

Finally, participants stressed the importance of studying long-term impact, warning of initial enthusiasm due to novelty fading over time: "*The tricky thing is that, with any of these technologies… at the beginning students are very enthusiastic only because it's new and different. So, I think it's important to see what the long-term effects are*." (P1). Some participants warned of the novelty not per se translating into improved learning outcomes: "*Anything that's new and fancy they might like better, but that doesn't necessarily improve learning outcomes*" (P13). These insights suggest that evaluations should extend beyond initial adoption to monitor ongoing effectiveness.

Overall, evaluation embraces iterative cycles of assessment and improvement , beginning before and continuing throughout implementation. When brought together, academic evaluation (learning effectiveness, novelty versus long-term effects, discipline-specific considerations) and practical evaluation (usability in practice, efficiency evaluation of time, effort, and resources, user satisfaction, and financial evaluation) build a single evidence base on the technology's overall integration potential. Combining data from these strands in one continuous feedback loop supports an informed decision-making and facilitation process, enabling management to align the previously identified enabling factors with the institutional priorities of every stakeholder group and to steer desktop-VR integration process toward impactful and scalable use.

Process management. The successful implementation of a tool like Edison, according to participants, depends on clearly defining its purpose and aligning its use with broader institutional strategy. Participants stressed that Edison should enable innovative educational opportunities rather than simply replicate existing practices in a different format, e.g.: *"You should always think about what Edison can do in this case, what can I do in Edison that I can't do at the moment?"* (P6). This shift should also be reflected in a suitable pedagogical approach: *"This is now a new way of thinking and a new way of using technology to teach, not just doing old stuff with the new tool"* (P4). Strategic alignment was also highlighted as essential for ensuring that Edison fits seamlessly both into the institution's existing technological infrastructure and teaching objectives. There is a reported need for compatibility with current systems and clarity about how the tool could advance institutional goals: *"It should be compatible with what we use at [the institution] … It should be easy to use within the system that we have"* (P17). Such alignment ensures that the adoption of the tool contributes to a broader educational vision.

Another element of process management that should be taken into account according to the participants is communicating the benefits of a given VR tool to

stakeholders to support its adoption. This way added value could be showcased through concrete examples relevant to specific disciplines: *"It's also important that you show teachers good examples of Edison use in their field… to make the transfer easy to establish"* (P12). Providing relatable, discipline-specific scenarios helps teachers understand how the tool can address unique challenges in their teaching contexts.

The successful integration of VR tools like Edison into educational settings requires robust infrastructure, both in terms of hardware and software. Participants identified several critical hardware requirements for implementing the technology like Edison effectively, emphasizing the need for green screens, cameras, audio and lighting equipment to enable teaching quality. Green screens were seen as a practical investment, as they are "*not necessarily really expensive*" (P18), but access remains limited, with some institutions having only one, requiring careful scheduling (P7). Cameras were highlighted as essential, with participants suggesting dynamic options such as "*a camera that follows the lecturer*" (P13), while sufficient lighting was also deemed important for professional presentations (P10). Audio quality was another priority, with participants noting the necessity of headphones and microphones to ensure clarity, as "*sometimes it's not easy for students to follow*" without them (P7). The need for dedicated spaces equipped with the necessary infrastructure was also emphasized, e.g.: *"Study centres could host spaces with the necessary equipment for hybrid and Edison sessions"* (P12).

Apart from that, software compatibility and ease of use were frequently mentioned as critical requirements. Teachers stressed that the tool must work seamlessly on existing university-provided devices, e.g. "*It's very important... it should be working on our laptops we have from [the university] without too much additional programming*" (P12). Smooth functionality and minimal technical issues were identified as key to adoption: "*It should feel smooth, without technical hiccups, otherwise people will stop using it*" (P3). A recurring point was the need for seamless integration with existing Learning Management Systems (LMS) to ensure a smooth user experience, as one participant noted: *"It should be completely transparent. Students should never have to re-enter their username and password"* (P15). The ability to support collaborative work and integrate external tools, was also emphasized: *"We ask students to work collaboratively on Miro, and if it could be integrated into Edison, that would be great"* (P14).

A recurring challenge highlighted in the interviews was the time and effort required to adopt and integrate a tool like Edison into teaching practices: *"You need time to learn how to use the technology…incorporate it in your lesson…redesign your lessons..."* (P5). This adjustment disrupts well-established routines, as teachers often operate on *"automatic pilot"*, and transitioning to a new approach requires deliberate effort and focus (P5). Participants also noted that recognition of teachers' efforts is important, otherwise they might resort to superficial usage: *"if we're not receiving allocated time to learn how to do this and also compensation … That is maybe even worse than not using it at all." (P4).* Hence, to enable technology integration, institutions should allocate dedicated time and resources for lesson redesign and technology training as part of professional development.

Structured teacher training programs tailored to meet teachers' needs in adopting and integrating a tool like Edison in their practice have been suggested, facilitating clear, accessible instructional materials and tutorials, e.g.: *"There should be good training materials, manuals, and examples. Teachers or even self-instruction guides should make the software easy to operate"* (P12). Training should follow a scaffolding approach, offering comprehensive support initially and gradually reducing it as teachers gain confidence:

"My primary concern would be how much time I have for the initial training and what [kind of] support, which has to be … scaffolding: maximum at first, then minimal" (P20); *"Teachers need to master teaching knowledge, pedagogical knowledge, and technological knowledge… Training is very important"* (P6).

Participants also suggested having continuous training to maintain skills, especially when tools are not used regularly, e.g.: *"I don't work with [virtual classes] all the time, and I forget how it works because it doesn't stick. For me, it needs a lot of experience and ongoing working with it to remember"* (P19).

According to participants, instructional design should go beyond replicating traditional methods in digital environments, e.g.:

"You have to change how you deliver education instead of just saying, 'I'm going to give a lecture, but on Edison" (P4); *"It should not be a substitution of your current situation, but something that really enriches your educational offerings"* (P6).

As a way of overcoming the complexities of new technologies on the way to their adoption, the need for co-creation processes emerged, where instructional designers can help teachers in developing meaningful content: *"Ideally, teachers would have support during creation. A person very familiar with the technology should work alongside the teacher, helping with instructional design"* (P6). Such collaborative approaches can mitigate the challenges associated with instructional design and have potential to ensure high-quality outcomes.

The need for to take responsibility for developing guidelines for protecting student and teacher data, ensuring ethical practices, and maintaining a safe learning environment was highlighted (P3, P10, P11, P12, P14, P15, P18). As an example, the potential risks of sensitive data exposure were identified due to the visual nature of the virtual environment: *"You see real faces in this environment…characteristics like race or wearing glasses could be registered, so you have to be very careful"* (P3). As new technological affordances introduce novel challenges around data visibility, use, and interpretation, the findings suggest a need for facilitated institutional dialogue to anticipate and address these developments in ways that reflect diverse stakeholder interests and priorities. As one participant cautioned, *"If this data is used also in analytics or even in an assessment... we must really be very careful. Then we address a very ethical issue."* (P1) underscoring the high stakes of unregulated data practices in digitally mediated education. Collectively, the findings point to a growing institutional imperative to articulate clear, ethically grounded data governance frameworks that attend to privacy, informed consent, and the mitigation of risks associated with the potential misuse of student and teacher data in virtual learning environments.

Vision for further tool development. Vision for further development of Edison emerged as an aspect that should be considered by the university in the context of continuous improvement cycle, embracing points like supporting students, improving efficiency and data analysis.

Throughout the interviews participants mentioned the need for real-time tools that would allow teachers to better respond to students' emotional and cognitive needs during lectures and practical sessions. Participants consistently mentioned a desire for features that simulate or replicate the real-world cues usually gleaned from face-to-face contexts, e.g. *"If I'm in a real classroom, I'd see who raises their hand. Here [in the current system] I can't. I want something more natural."* (P16). Similarly, the importance of student agency was voiced – opportunities for learners to manipulate parameters, view content individually, and signal confusion or approval more seamlessly. These features, participants argued, would not only benefit teachers but also promote peer awareness in collaborative settings.

Efficiency improvement suggestions addressed streamlining workflows that reduce teachers' preparation time while maintaining a high level of pedagogical quality through template-based approaches, reusable libraries, and easily searchable 3D assets, e.g.: *"It would be great if there was something that was ready made and that you can easily adapt to your wishes… I'd be willing to spend about 10 minutes per lesson on this"* (P18). The notion of resource sharing among colleagues also recurred, with one participant suggesting a *"project library where one teacher's environment could be re-used by another"* (P9), or where "*projects or resources from previous classes"* (P17) could be reused. Collaborative mechanisms were viewed as critical for improving workflows, with suggestions that tools should enable teachers to work together on shared resources: *"The teachers would be possibly using [stored resources], or you can have a team of teachers working collaboratively"* (P9). Such features were perceived as particularly important for integrating AR/VR tools into existing teaching practices without excessive preparation time.

Data management and analysis suggestions addressed how recordings, analytics, and other data streams should be handled. The need for tools to manage recordings, annotations, and learning analytics securely and effectively was voiced. Participants highlighted the importance of safe, easily retrievable session data that would allow students to revisit recorded sessions and shared resources: *"Storing resources in the classroom for students to review later would enhance continuity"* (P17). Yet, the privacy should remain a paramount concern: *"Recordings should be easily deletable if a student is not comfortable, and these concerns should be addressed with the legal officer"* (P12). Beyond privacy, some interviewees saw value in advanced analytics, including *"post-processing video… analysing non-verbal cues, intonation, speed of talking"* (P6).

3.2. Integrative Analysis: Linking the Themes

In this section, we turn from presenting each theme in isolation to an integrated synthesis of the findings. This bridging section traces how the five analytically

derived themes are linked to address RQ2, namely *how a specific VR tool should be integrated within the institutional setting to maximize its educational impact*. This way we clarify the conditions under which VR can become a meaningful part of teaching and learning practice. By following the recurring patterns emphasized by participants, the systemic interactions emerge among *Context*, *Values*, *Technology*, *Pedagogy* and *Management*.

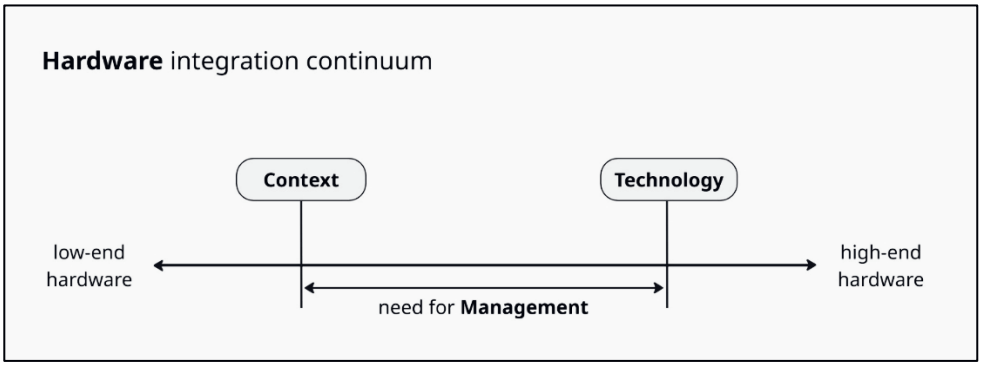
3.2.1. Technical Assessment and Facilitation: Aligning Context and Technology through Management

One of the key conditions for moving from piloting to institution-wide adoption of a desktop VR tool like Edison lies in the alignment between the characteristics of the *Context*, or what the university *has,* and the demands of the *Technology*, or what the tool *needs,* achieved through active institutional *Management*, each plotted in Figure 9 below. To visualise this relationship, the analysis introduces a three-point audit that locates both the institutional *Context* and the tool's *Technology* on continuums ranging from *low* to *high* for (i) hardware facilities, (ii) software integration and (iii) staff expertise in operation. Any mismatch signals a capacity gap that *Management* should address before scaling can proceed.

Hardware continuum. Teaching at OU often takes place from home or from campus and regional study centres where green screens, cameras, and studio lighting are not standard. As one participant noted, *"We mostly teach from home... but the study centres are not places where you would have green screens"* (P7), while another pointed out that *"Green screens are not necessarily really expensive, but you do need them"* (P18). By contrast, Edison presupposes at least mid-level recording facilities to be used effectively. In response, several suggested the creation of *"central facilit[ies]"* (P15) and provision of essential recording infrastructure (P18). These needs imply that, where the existing hardware baseline falls short, *Management* could intervene through loan schemes, mobile recording kits, or upgrades to local study centres.

Figure 9

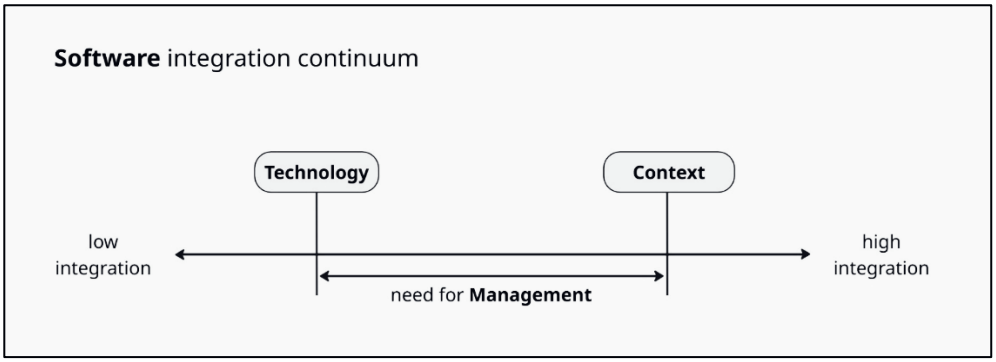
Technical assessment and facilitation through alignment of Context, Technology and Management.



Software-integration continuum. The digital ecosystem of OU sits toward the *high-integration* end of the spectrum: every new application must plug into the LMS, support single sign-on and satisfy strict data-protection rules. As one participant explained, *"It should be completely transparent. Students should never have to re-enter their username and password"* (P15), while another added, *"As a teacher, when I enter my course, I'm also automatically signed in to [video-conferencing tool], and then I'll also be automatically signed into your system"* (P15), highlighting expectations for seamless authentication across systems. A desktop-VR tool such as Edison can therefore progress beyond pilot use only if its APIs, authentication flows and data practices align with institutional standards.

Figure 10

Software integration continuum and alignment of Context and Technology through Management.



Where alignment is lacking, *Management* faces a choice: (i) fund bridging work to facilitate integration or (ii) pivot to a tool "that works on our laptops without too much additional programming" (P12). As one participant noted, "If teachers use third-party applications, they do so as employees of the university… anything that goes wrong could lead to serious institutional issues" (P15). In sum, software interoperability, secure authentication and device compatibility are non-negotiable pre-conditions for scaling Edison within this tightly governed Context.

Expertise (in operation) continuum. While the average lecturer at OU reports proficiency with routine LMS tasks and videoconferencing, Edison presupposes skills in VR scene design, audiovisual production and live troubleshooting, revealing a marked expertise gap, as reported by participants. One of them emphasized, *"You need time to learn how to use the technology… incorporate it in your lesson… redesign your lessons…"* (P5), highlighting the cognitive and logistical burden of integrating complex tools into teaching routines. *Management* can address this gap along two intertwined tracks. On one hand, participants called for capacity building through institutional support structures. As one put it, *"It's also important that you show teachers good examples of Edison use in their field… to make the transfer easy to establish"* (P12), referring to structured peer mentoring, modelling, and accessible training. On the other hand, participants emphasised the need to reduce the technical threshold of the tool itself. *"If we had a team who could help us with the*

setup... maybe some templates... it would be easier to experiment with it" (P3), one participant suggested, while another argued that *"There should be simplified paths for teachers who are not media experts"* (P7). Overall, selecting or combining these two strategies – raising institutional capacity and lowering technological complexity – was seen as essential to align everyday teaching expertise with the operational demands of Edison technology. If left unaddressed, participants warned, adoption would likely remain confined to *"the enthusiasts"* (P7), thereby limiting the tool's pedagogical promise.

3.2.2. Mediating Technology and Pedagogy through Institutional Values

Moving the VR tool like Edison beyond the pilot stage depends not only on what the technology can do, but on *why* and *how* it should be used in practice. Across participant accounts, it became clear that meaningful integration requires a triadic alignment: the tool's technical affordances must support instructional designs valued by lecturers, and those designs, in turn, must embody the university's declared educational priorities. In other words, Values serve as the normative bridge that links *Technology* and *Pedagogy* within the broader institutional *Context*. Based on participants' accounts, we synthesise an integrated value-driven workflow for evaluating aspects of technology integration against Values.

Stage 1. Articulating Values. The starting point in this sequence could be the shared articulation of values. Participants referred to the university's mission of "*personalised and activating online education*" as the compass for evaluating whether and how a tool like Edison should be integrated (P2). Core principles such as equity, flexibility, accessibility, and personalisation were frequently cited as guiding criteria for pedagogical and technological decisions. For example, a participant emphasized, *"It should be accessible for all kinds of students and not just those who can afford the technology"* (P13), while another pointed out that designers should *"put in some opportunities for those students [with Asperger's/autism] to make it easier for them to follow the class"* (P7). These commitments were not framed as abstract ideals, but as active design constraints shaping how tools are evaluated and used.

Stage 2 Linking Technology to Pedagogy. Participants described the process of mapping the tool's afforded learning benefits (*Technology*) such as contextualisation, interactive visualisation, and social presence, onto specific instructional goals (*Pedagogy*). As one participant explained, *"I'm very interested if it [Edison] can somehow help the students to collaborate better… maybe being able to see each other better helps them to regulate their emotions a little better"* (P5). The emphasis, however, was not on technological novelty, but on pedagogical appropriateness. Several participants explicitly questioned whether technical possibility alone justified use. As one put it, *"It's not the old wine in new vessels, it's about how can we offer learning experiences that are appropriate to this environment"* (P2). Another added, *"It might be technically possible, but that doesn't mean it fits into my education"* (P5). This way, the choice of tool was described as following from instructional purpose, rather than determining it. As one participant noted, "*when it's really hard to imagine what it would look like and there's only*

drawings or maybe some pictures... then this [VR-enhanced environment] could help in seeing the space. So I think that would be a nice added value" (P18).

Stage 3. Values-Aligned Risk Evaluation. Once the tool's affordances have been linked to defined instructional goals through suitable pedagogical methods, participants highlighted the importance of evaluating potential risks before implementation. This includes not only reviewing equity, inclusivity and accessibility, already grounded in institutional Values, but also anticipating cognitive, affective and ethical implications of immersive learning. Several participants noted that if visual or interactive elements are poorly aligned with content, especially for novice or neurodiverse learners, they may increase extraneous cognitive load and disrupt learning, e.g. as one participant noted, "w*ith a 3D model, it can be really helpful, but it can also be distracting. Especially if it's too detailed or if students don't know where to focus"* (P1). Ethical concerns were also raised, particularly around privacy, persistent recordings, and the sense of being constantly visible in virtual spaces, *"if they [students] have a recording of me they might use it against me not in a legal way, or I don't know, in a way that I'm not aware of"* (P5). These issues were not framed as secondary, but as integral to assessing whether a scenario supports or undermines the university's educational priorities.

Across these considerations, the institutional *Context* was not seen as a passive setting, but as a normative framework that defines what learning should enable and for whom. Scenarios that align with institutional Values while meeting pedagogical goals may be advanced for broader implementation; others may require further iteration. In this way, risk evaluation becomes a practical expression of the university's educational mission ensuring that innovations in teaching with VR remain not only effective, but inclusive and ethically sound.

4. Discussion and conclusions

This study aimed to identify the key factors that enable the meaningful and scalable integration of VR technology in higher education at a distance, drawing on in-depth interviews with teachers, media design experts, and institutional managers at a European distance-learning university. It makes three main contributions. First, the study provides empirical evidence from 20 stakeholder interviews across six faculties on the institutional and pedagogical conditions that enable or hinder the integration of desktop VR. Second, it introduces two integration mechanisms: the three-point audit and the value-aligned design workflow, which translate stakeholder insights into actionable design strategies. Third, the study outlines practical recommendations for aligning VR implementation with pedagogical aims and institutional priorities, thereby supporting sustainable integration and scale-up.

Two research questions guided the investigation. To explore the first research question, namely identifying the factors that enable meaningful and scalable integration of desktop VR technology in a distance university context, the analysis drew in-depth interviews with teachers, media design experts, and institutional managers at a European distance learning university, yielding five themes: *Context*, *Technology*, *Pedagogy*, *Values*, and *Management*.

Context concerns the specific setting in which the VR tool is to be used and addresses the question of *where* integration should take place. Participants described how meaningful integration depends on a clear understanding of the institutional environment, including the *student profile* (e.g., digital skills and accessibility needs), *teaching and learning processes* (e.g., asynchronous delivery formats, home-based instruction), and *infrastructure* (e.g., hardware availability, LMS, and the role of study centres). These contextual conditions define both the opportunities for and the constraints on integration.

Values provide the underlying rationale—the *why*—for adopting new technologies like VR. Across interviews, participants articulated *societal, institutional,* and *individual* values that influence adoption decisions. Equity, accessibility, and personalisation were consistently framed as *"active design constraints"* rather than aspirational ideals, operating as practical filters for both pedagogical and technical decisions. These values were seen not only as foundational but as essential to determining whether and how integration aligns with the university's mission.

Technology represents the *what* of integration. Rather than seeing the tool as a generic upgrade, participants focused on its specific affordances. Key among these were *realism*, *interactivity*, and *student agency*, which together enable contextual learning, social presence, and learner control. Technology was thus framed as a means to support new forms of interaction and representation, not as an end in itself.

Pedagogy concerns the *how*—the instructional methods and learning designs that guide the meaningful use of VR. Participants emphasised that effective integration requires aligning VR capabilities with sound instructional principles. Three pedagogical factors emerged as central: *intrinsic motivation* (especially relatedness, autonomy, and competence), *cognitive load management*, and *instructional alignment*. Integration was viewed as pedagogically valuable only when immersive experiences were designed to support learning goals without overwhelming or distracting learners.

Finally, **Management** addresses the strategic question of *what the process* for implementation should entail. Participants highlighted the importance of institutional *evaluation* (including both pedagogical and practical assessment), *process management* (alignment with infrastructure, communication, training), and a forward-looking *vision for further development*. Management was not framed merely as logistical coordination, but as a mechanism for aligning all other factors through policy, infrastructure investment, and stakeholder engagement. Without such facilitation, participants suggested, integration would remain fragmented and unlikely to scale.

Taken together, these five themes do not represent standalone enablers but operate as a system. Participants consistently emphasised that meaningful and scalable integration of desktop VR cannot be reduced to technological or pedagogical conditions alone; rather, it is achieved when all five themes are actively coordinated.

To address the second research question, namely, how a specific VR tool should be integrated within the institutional setting to maximise its educational impact, the analysis focused on the dynamic interplay between the five themes. Two key integrative mechanisms emerged. First, aligning the institutional *Context* and the demands of the *Technology* through proactive *Management* was seen as essential to identify and resolve capacity gaps in hardware, software, and staff expertise. Second, educational impact was maximised when the affordances of the VR tool were deliberately linked to pedagogical purposes that embody institutional *Values*.

To support the first mechanism, the study introduced a three-point audit across hardware, software, and staff expertise. Where gaps were identified, for example, the lack of studio facilities, limited software compatibility, or insufficient technical skill, *Management* was seen as responsible for resolving misalignments through infrastructure investment, integration planning, or capacity building. This process framed technology integration not as a matter of individual initiative, but of system-wide readiness and facilitation.

The second mechanism centred on a value-driven design workflow. Integration was seen as pedagogically meaningful only when the tool's affordances such as realism, interactivity, and student agency were clearly linked to defined instructional goals and reviewed through a *Values-Aligned Risk Evaluation.* Participants stressed that scenarios must be assessed not only for their intended learning benefits, but also for their potential to introduce risks related to equity, cognitive load, accessibility, and privacy. The institutional *Context* was therefore not a neutral setting, but a normative framework that shapes what is acceptable and desirable in educational practice.

Together, these findings point to integration as a negotiated process involving multiple stakeholders and operating across interdependent domains. Rather than adopting VR as a novel delivery tool, participants envisioned a strategic, mission-aligned process in which technology serves instructional purpose, values guide design, and management structures enable continuity and scale. The focused institutional setting of this interview study enabled a fine-grained analysis of these dynamics. By anchoring the analysis around a single VR tool as an example, participants were able to assess its integration potential in relation to their pedagogical goals, organisational conditions, and institutional commitments. The inclusion of diverse stakeholder perspectives across teaching, design, and management roles further enriched the analysis, offering a system-level account of the practical, strategic, and normative dimensions involved in VR technology integration.

These findings are conceptually consistent with, and extend, several strands of literature on educational technology integration. Initial models of VR implementation in education, such as those proposed by Dalgarno and Lee (2010), Fowler (2015), and Mulders et al. (2020), highlight the importance of aligning a tool's representational and interactive features with clearly defined instructional goals (Dalgarno & Lee, 2010a; Fowler, 2015; Mulders et al., 2020). These frameworks underline that learning benefits only emerge when technological affordances are activated through pedagogical purpose and instructional design. The current study

reinforces this principle, with participants repeatedly insisting that desktop VR tools must not replicate existing content delivery methods, but instead support forms of learning, such as collaborative, experiential, authentic learning scenarios that are pedagogically distinct and purposefully chosen.

Beyond pedagogical considerations, the findings of this study align with institutional models of technology acceptance, particularly extended versions of the Unified Theory of Acceptance and Use of Technology (UTAUT) (Neves et al., 2025; Venkatesh et al., 2003, 2016). These models highlight the importance of facilitating conditions, social influence, and organisational support – factors which map closely onto the themes of *Management* and *Context* identified in this study. The emphasis placed by participants on institutional readiness, professional development, and interdepartmental coordination reflects the enabling conditions described in UTAUT-based frameworks, while adding detail about the elements of organisational infrastructure and support mechanisms needed in distance learning contexts.

Finally, the thematic structure and interdependencies identified in this study strongly resonate with the concept of entangled pedagogy (Fawns, 2022). Rather than treating *Technology*, *Pedagogy*, or *Context* as discrete variables, Fawns proposes that educational practices emerge through the mutual shaping of methods, technologies, values, and purposes within particular settings. The present findings support this view, particularly in the way participants described institutional *Values* not as constraints or add-ons, but as mediators of technological decisions and pedagogical design. In this light, meaningful integration of VR technology is less a matter of adopting new tools, and more a process of negotiating their use in relation to educational commitments and infrastructural realities.

Together, these theoretical models provide a multidimensional lens through which the findings of this study can be understood. They affirm that successful integration of desktop VR in higher education is not a singular technical challenge, but a systemic coordination problem that involves aligning instructional purpose, technological affordances, institutional values and readiness with the organisational capacity.

Given the exploratory nature of this research, several directions for further study are warranted. First, quantitative or mixed-methods studies could test and refine the thematic model presented here across multiple institutional contexts, helping to assess the relative influence of each factor and their interdependencies. Second, practice-oriented research is needed to translate these insights into actionable frameworks for institutional decision-makers. This may include design-based studies focused on piloting integration strategies, professional development interventions, or tools for scenario evaluation and values alignment. Taken together, such future work can contribute to building a more robust, evidence-informed approach to VR technology integration in higher education.

Limitations

This study offers an exploratory in-depth account of the factors shaping the integration of desktop VR technology within a single European distance university. While the focused institutional context enabled a multifaceted analysis, it also limits

the generalisability of the findings. The geographical location, institutional culture, and policy environment of a European publicly funded distance-learning university may shape stakeholder views in ways that differ from other regional or educational contexts. Moreover, the study was limited to three stakeholder groups internal to the university – teachers, media design experts, and institutional managers, whose perspectives may not fully capture the broader ecosystem of VR integration. In particular, the sample did not include students, technology developers, policy-makers, or societal actors, all of whom play important roles in the institutional uptake and broader acceptance of emerging educational technologies. Future research should involve these additional stakeholder groups to build a more comprehensive understanding.

Although most participants had not used the specific desktop VR tool in sustained instructional practice, this represents a limitation in terms of drawing on concrete classroom experience. Their insights were therefore shaped by anticipated use, prior experience with comparable technologies, and professional judgment, rather than by direct engagement with the tool itself. However, this limitation is partially offset by the study's design focus: participants were invited to reflect strategically on the conditions under which a tool *like* Edison could be meaningfully and scalably integrated within their institutional context. As such, the findings should be understood as capturing informed expectations and perceived requirements for integration, rather than evaluations of post-adoption outcomes. Future work may complement these findings by investigating how such anticipatory judgments correspond with implementation experiences in practice.

Further research should also examine whether similar thematic patterns and alignment dynamics emerge in other types of institutions, including campus-based, hybrid, and cross-institutional settings, as well as in relation to other emerging educational technologies beyond VR.





Part II
Design and Construction

Chapter 3

Developing Technology-Specific Instructional Templates for the Scalable Use of Desktop VR in Distance Higher Education

Distance universities face enduring challenges of sustaining learner motivation, social presence, and conceptual understanding in large and diverse cohorts. While desktop virtual reality (DVR) offers new possibilities for enhancing spatial explanation and teacher presence, its meaningful and sustainable integration in higher education remains underexplored. This study investigates how DVR can be scalably embedded within synchronous distance teaching and what instructional principles should guide the design of VR-enhanced presentation formats. Using a design-based research (DBR) approach, four iterative cycles were conducted at a European distance-learning university: Study 1 developed and internally evaluated pedagogical scenarios for desktop VR; Study 2 refined these scenarios through expert focus groups with media designers and instructional developers; Study 3 validated the redesigned scenarios through surveys and focus groups with teachers, engineers, and institutional stakeholders; and Study 4 synthesized cross-cycle findings into design guidelines for DVR-enhanced presentations. The project introduced and empirically validated the concept of Technology-Specific Instructional (TSI) templates – structured, context-sensitive design products that connect pedagogical purposes, instructional techniques, and technical configurations. Three TSI templates were developed: the Slide Presentation, 3D Model Presentation, and Virtual Environment Presentation templates. The final stage yielded design principles for effective DVR use, underscoring the importance of cognitive-load management (cueing, segmentation, coherence), purpose-aligned teacher presence, and institutional embedding through teacher training and support in achieving sustainable integration. TSI templates provide scalable, pedagogically grounded formats for integrating VR-enhanced presentation technologies within institutional practice and hold promising potential for informing other technology-specific applications in higher education.

This chapter is based on:

Holubinka, K., Urlings, C., Van Lankveld, G., Klemke, R., & De Groot, R. Developing Technology-Specific Instructional Templates for the Scalable Use of Desktop VR in Distance Higher Education.

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1. Introduction

Distance education has long served as a proving ground for educational technologies, as instruction and interaction are mediated by tools rather than shared physical presence (Bates, 2005; T. Clark, 2001; Garrison, 2011; Reiser, 2001a; Tait, 2018; Zawacki-Richter & Naidu, 2016). From early correspondence models to contemporary video-conferencing systems, distance universities have consistently experimented with digital innovations to enhance scalability, access, and instructional quality (Cuban, 2001; Kozma, 1991; Laurillard, 2016; Richardson et al., 2017). Such contexts provide fertile conditions for testing new presentation formats because instructors and students already depend on mediated resources for both synchronous and asynchronous learning. Yet despite advances in connectivity and delivery platforms, distance higher education continues to face persistent challenges of sustaining learner motivation, social presence, and conceptual understanding in large and diverse cohorts (Bağrıacık Yılmaz & Karataş, 2022; Hartnett, 2018; Richardson et al., 2017). Addressing these challenges requires solutions that are not only pedagogically effective, but also technically feasible and scalable within institutional infrastructures. To this end, the present study investigates how desktop virtual reality (DVR), , understood as a three-dimensional virtual environment displayed on a standard monitor and navigated with conventional input devices (E. A.-L. Lee & Wong, 2014; Makransky & Petersen, 2019a), can be meaningfully integrated into higher education. Specifically, it explores how DVR can support synchronous online lectures in a distance university context and what instructional principles should guide the design of VR-enhanced presentation formats.

Virtual reality (VR) has been widely investigated as a technology that can enrich higher education through immersive experiences, enhanced spatial visualization, and increased learner motivation (Merchant et al., 2014; Mikropoulos & Natsis, 2011; Radianti et al., 2020). VR generally refers to computer-generated, interactive three-dimensional environments that simulate real or imaginary settings and allow users to explore and manipulate digital content in real time (Mikropoulos & Natsis, 2011; Wilkinson et al., 2021). VR simulations can be implemented with different technological setups and degrees of immersion, ranging from head-mounted display systems to screen-based configurations, often referred to as desktop VR or DVR (Bowman & McMahan, 2007; Cummings & and Bailenson, 2016; Luo et al., 2021; Radianti et al., 2020; Stracke et al., 2025). DVR can be defined as a 3-D virtual environment generated on a computer monitor, which can be explored interactively by using computer equipment such as keyboard, mouse, joystick or touch screen, and headphones (E. A.-L. Lee & Wong, 2014; Makransky & Petersen, 2019a; Mikropoulos & Natsis, 2011). Because it relies on widely available hardware yet preserves key affordances such as three-dimensional visualization, spatial orientation, and instructional control, DVR offers a particularly promising pathway for scalable integration in higher education (E. A.-L. Lee & Wong, 2014; Limniou et al., 2008; Stracke et al., 2025). These affordances are especially relevant in domains where abstract or complex content must be spatially represented, such as teacher

education (Liu & Lin, 2025), engineering and structural sciences (Hu et al., 2023), or natural sciences (Martarelli et al., 2024; Smetana & Bell, 2012). Beyond visualization, DVR formats have also been shown to foster learner motivation and situational interest by providing enriched environments without the physical discomforts or costs associated with immersive systems (Makransky & Petersen, 2019; Mujuru & Lopez, 2021). Importantly, DVR can be designed to guide learner attention and support cognitive processing through established multimedia principles, such as signalling, cueing, and spatial-temporal contiguity (Mayer, 2021; Decker & Merkt, 2025; Makransky & Mayer, 2022). These characteristics position DVR as a suitable modality for presentation-based instruction in distance higher education, where scalability and pedagogical alignment are equally critical.

Across reviews and meta-analyses, the most promising results with virtual environments in higher education are consistently associated with how technology is instructionally designed and enacted rather than with the technology per se (Dalgarno & Lee, 2010; Fowler, 2015; Merchant et al., 2014; Mikropoulos & Natsis, 2011; Radianti et al., 2020; Villena-Taranilla et al., 2022). In DVR, studies show that 3D spatial visualization, instructor-controlled navigation, and attention guidance (e.g., signalling/cueing) can support learning and motivation, especially when aligned with learners' needs and task demands (Glaser, Aberle, & Schwan, 2023; Lee & Wong, 2014; Makransky & Petersen, 2019). Yet, despite these indications, empirical work seldom articulates didactic scenarios that explicitly pair DVR's technical features (e.g., slide/scene orchestration, 3D object handling, presenter-driven camera control) with established multimedia design principles such as signalling, spatial–temporal contiguity, redundancy management, and segmentation (Castro-Alonso, Fiorella, & Paas, 2021; Mayer, 2021). Design-based research studies demonstrate that iteratively coupling technical affordances with instructional sequences before, during, and after learning can produce robust and shareable design knowledge; however, comparable presentation-oriented DVR scenarios in higher education remain under-specified (Geriş & Özdener, 2024; Hirumi et al., 2016a, 2016b). Stakeholder-focused work likewise highlights the need to translate institutional and pedagogical requirements into concrete scenarios that align DVR capabilities with teaching aims (blinded reference). Accordingly, the paper contributes design knowledge on how DVR affordances can be coupled with pedagogical scenarios for scalable use in higher education.

The potential of VR-enhanced presentation formats can be better understood through established theories of learning and design. Cognitive Load Theory (Sweller, 2010; Sweller, Ayres, & Kalyuga, 2011) and the Cognitive Theory of Multimedia Learning (Mayer, 2021) emphasize the need to manage intrinsic and extraneous load by means of signalling, segmentation, and modality, thereby freeing cognitive resources for meaningful processing. Theories of spatial learning and embodied cognition further highlight how three-dimensional visualization can facilitate comprehension of structural and dynamic relationships (Castro-Alonso, Fiorella, & Paas, 2021; Fiorella & Mayer, 2016). Presence theory underscores the role of spatial and social cues in fostering engagement and perceived immediacy in mediated environments (Makransky & Petersen, 2021; Lombard & Ditton, 1997). In addition,

Self-Determination Theory frames intrinsic motivation as a central driver of sustained learning, pointing to the importance of supporting learners' experience of enjoyment, usefulness, and relatedness (Ryan & Deci, 2000; Hartnett, 2018). Together, these theories suggest that when DVR affordances such as visualization, signalling, and instructor-controlled navigation are deliberately aligned with pedagogical goals, VR-enhanced presentation formats can support knowledge gain, intrinsic motivation, and a heightened sense of presence.

Building on these perspectives, the investigation addresses how DVR can be meaningfully integrated into higher education by aligning its affordances with established instructional principles and pedagogical goals. The research is situated within the context of the Open University in The Netherlands (OU), where synchronous online lectures form a central mode of instruction and scalable solutions are required. To this end, the study focuses on Edison, a DVR presentation tool designed to integrate with existing videoconferencing systems. Edison enables instructors to combine slides, 3D models, and virtual environments within a real-time lecture, while retaining centralized control over navigation and visualization. Originating from professional broadcasting contexts, the platform now supports relatively simple operation and offers basic spatial interactivity, such as positioning, movement, and pointing gestures, allowing teachers to convey visual emphasis during live instruction. In this study, we refer to this instructional format as a *VR-enhanced presentation*. This functionality provides opportunities for enhancing spatial explanation, guiding learner attention, and fostering presence in distance education. Within this context, the following research questions were examined:

RQ1. Which pedagogical scenarios can be effectively supported by the DVR tool Edison to enable didactically grounded and scalable integration within the OU context?

RQ2. What instructional principles should guide the design and use of VR-enhanced presentation formats in higher education?

2. Research design

To address the research questions, we employed a design-based research (DBR) approach, characterized by iterative cycles of design, evaluation, and reflection in authentic educational settings (McKenney & Reeves, 2019). DBR was selected because it enables researchers and practitioners to collaboratively develop interventions that are pedagogically grounded, ecologically valid, and theoretically informative. The project was structured into four embedded sub-studies, each aligned with a stage of the DBR cycle. These sub-studies moved from the initial design of pedagogical scenarios for the DVR tool Edison (anonymised), through iterative expert evaluation and refinement, to validation and cross-cycle reflection that yielded design principles for VR-enhanced presentation formats. Ethical approval was granted by the OU Ethical Review Board (reference U202302314), and all procedures were carried out in accordance with institutional ethical standards and data protection protocols. Table 1 provides an overview of how the sub-studies correspond to the DBR stages (McKenney & Reeves, 2019).

Table 1

Overview of Embedded Sub-Studies within the DBR Cycle

DBR Stage	Embedded Sub-Study	Aim	Data Collection Methods	Participants
Design & Construction	**Study 1:** Scenario Development and Internal Evaluation	To design pedagogical scenarios for DVR with Edison tool and evaluate their feasibility	Structured internal review meetings (informal notes; no recordings specified)	4 educational technology researchers (core team)
Evaluation & Reflection (Cycle 1)	**Study 2:** Expert Review and Refinement	To refine pedagogical scenarios based on expert perspectives on appropriateness, clarity, and technical feasibility	3 focus groups (90 minutes each), semi-structured protocol, recorded with facilitator notes	16 educational media designers, instructional developers, and researchers (OU)
Evaluation & Reflection (Cycle 2)	**Study 3:** Validation of Redesigned Scenarios	To evaluate and validate the pedagogical appropriateness, clarity, and usability of redesigned pedagogical scenarios	Open-ended online survey (N = 24); 2 follow-up focus groups (N = 21), recorded with facilitator notes	24 participants in total: – 18 university teachers (OU, 3 departments) – 2 university teachers (European partner university) – 2 engineers (technology company) – 2 business stakeholders
Cross-Cycle Reflection	**Study 4:** Design Guidelines and Lessons Learned	To synthesize findings across cycles into design guidelines for meaningful VR-enhanced integration	Reflexive thematic synthesis of data collected across studies	Consolidated input from participants in Studies 1–3

3. Study 1: Design & Construction – Scenario Development and Internal Evaluation

3.1. Methods

3.1.1. Inputs and Design Rationale

In the first study, we developed initial pedagogical scenarios for integrating the DVR tool Edison into teaching at OU. This design phase translated earlier project findings into preliminary prototypes appraised for conceptual robustness and feasibility within a DBR cycle (McKenney & Reeves, 2019).

Design requirements and propositions

The design activity was grounded in prior stakeholder input from a group concept mapping study and an interview study with institutional stakeholders (Holubinka et al., 2023). These investigations identified pedagogical priorities, contextual constraints, and institutional conditions for VR-enhanced teaching. Building on these findings, the research team systematically derived a set of *design requirements* (criteria the scenarios had to meet, e.g., accessibility, feasibility, pedagogical alignment) and *design propositions* (principled conjectures linking design features to mechanisms and outcomes). This process ensured that scenario development was evidence-informed and theoretically grounded in cognitive load theory (Sweller,

1988, 1994, 1994; Sweller et al., 1998a; Sweller, 2010), multimedia learning principles (R. E. Mayer, 2020; R. E. Mayer & Fiorella, 2021), and self-determination theory (Deci et al., 1994; Deci & Ryan, 1985; Ryan & Deci, 2000b). The design requirements and propositions are documented in Appendix C. These served both as guiding principles for prototype development and as criteria in the internal expert appraisal.

A further guiding criterion was scalability: pedagogical scenarios had to be flexible enough to support diverse courses and contexts, while specific enough to guide pedagogical and design decisions. This reflects DBR's ambition to create solutions that are both pedagogically sound and institutionally viable (McKenney & Reeves, 2019).

Choice of Pedagogical Scenarios

Three scenarios were selected for development: (1) slide presentation, (2) 3D model presentation, and (3) virtual environment presentation. This selection was guided by the design requirements and propositions, as well as by the institutional teaching model of OU and the affordances of the VR tool:

1. Slide presentation: Chosen because slides are the primary teaching format at OU, used extensively in both synchronous virtual classes and pre-recorded video lectures. Much course content is text-based, and slide presentations constitute the mainstream, scalable pedagogical scenario.

2. 3D model presentation: Selected because of the VR tool's capacity to display complex spatial or abstract concepts through manipulable 3D models. This scenario addressed stakeholder calls (from the interview and group concept mapping studies) to leverage VR for enhancing visualisation of difficult subject matter.

3. Virtual environment presentation: Included for its potential to situate teaching in authentic or otherwise inaccessible contexts, thereby expanding opportunities for presence and contextual learning. Previous stakeholder input highlighted this as a promising use case for enhancing authenticity and motivation.

By combining institutional teaching practices with stakeholder-identified opportunities, the design team narrowed the broad range of potential scenarios to these three, ensuring they were both pedagogically relevant and aligned with the affordances of Edison.

3.1.2. Procedure: Prototype Development and Internal Appraisal

Based on the requirements, propositions, and the three chosen scenarios, the prototype demonstration videos were designed by the first author. These prototypes illustrated how Edison could be used to support different instructional purposes in line with the identified requirements. They were designed not as subject-specific examples but as generalised instructional solutions that could later be refined in subsequent cycles.

Consistent with DBR methodology, the prototypes underwent an internal expert appraisal (developer screening) before broader stakeholder review (McKenney & Reeves, 2019). This appraisal examined alignment between the prototypes and the design requirements/propositions. The appraisal was conducted in two structured

meetings (each ~60 minutes) with four research team members, whose expertise covered technology-enhanced learning, cognitive psychology, and media design. These researchers served as evaluators, reviewing the prototype templates using a guided discussion format and referring to the predefined design requirements and propositions. The appraisal focused on: (1) pedagogical coherence (consistency with learning goals and instructional design principles), (2) design feasibility (technical and organisational practicality within OU), and (3) alignment with stakeholder-informed requirements (traceability to the prior evidence base) (McKenney & Reeves, 2019). During the discussions, feedback was provided collaboratively by all four evaluators and documented by the first author in structured meeting notes, which were subsequently synthesised into a set of refinement recommendations that are reported in the Results section below. This procedure concluded the first DBR design cycle of scenario development.

3.2. Results

3.2.1. Technology-Specific Instructional (TSI) Templates

The first design stage resulted in the development of the concept of Technology-Specific Instructional (TSI) templates. A TSI template is a structured, context-sensitive design product that connects pedagogical intent with the technical affordances of a specific educational tool, in this case, the VR-enhanced presentation technology Edison. The purpose of the templates is to provide teachers with reusable, evidence-informed formats that are pedagogically sound, technically feasible, and institutionally appropriate, thereby facilitating the meaningful integration of VR-enhanced presentations in higher education.

The novelty of the concept lies in making explicit links between pedagogical purposes, instructional techniques, and technical configurations, with accompanying guidance for teachers. Each template integrates four components:

1. **Pedagogical purpose** – the broader learning goal (e.g., explaining concepts, demonstrating procedures, contextualising knowledge, fostering relatedness).
2. **Instructional techniques** – evidence-informed methods aligned with that purpose (e.g., signalling, segmentation, coherence, worked examples, instructor presence).
3. **Technical configuration** – concrete use of VR affordances (e.g., slides, 3D models, environment presets, camera movements) to enact the techniques.
4. **Practical guidance** – teacher-facing tips on enactment and institutional embedding (e.g., setup, do's and don'ts, scalability).

Together, these components ensure that TSI templates function as reusable, domain-independent design solutions. Once the pedagogical purpose aligns, a template can be applied across subjects, provided teachers are guided in selecting and enacting it effectively.

To instantiate the concept, three demonstration videos (approximately five minutes each) were produced by the first author. Situated in the thematic context of Egyptology, they illustrated potential uses of Edison without being tied to a specific subject. The videos were recorded in OU's studio, where the presenter was filmed

seated at a virtual desk and operated the setup independently using a mouse and streamdeck keyboard. This arrangement limited gestural expressiveness but allowed realistic exploration of the tool's affordances under typical teaching conditions.

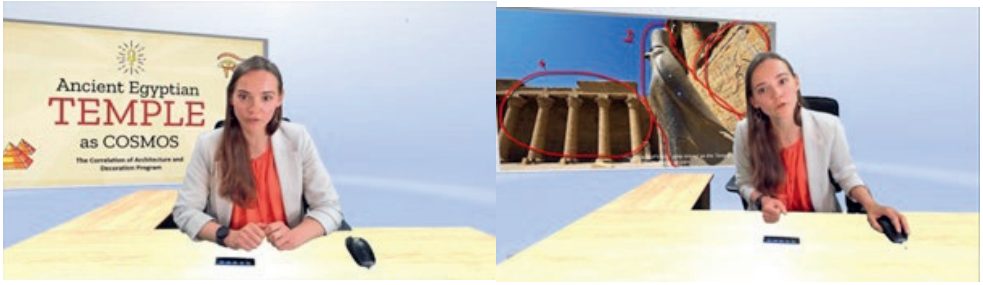
Within these parameters, the videos instantiated three templates, each reflecting a distinct pedagogical purpose: (1) slide presentation, (2) 3D model presentation, and (3) virtual environment presentation. Screenshots of the demo videos are shown in Figures 1–3.

3.2.2. TSI Template 1: Slide Presentation

The Slide Presentation Template was designed to support teacher-led explanation in a lecture-style format, where the pedagogical purpose was to introduce concepts, present declarative knowledge, or demonstrate stepwise processes in a familiar setting. Among the three templates, it also required the least preparation effort from teachers and the least technical knowledge, making it suitable for rapid uptake and routine use. To achieve its pedagogical purpose, instructional techniques such as signalling and cueing to highlight key elements, segmentation to structure content into short phases, and coherence to avoid extraneous detail were embedded. These techniques were instantiated through the technical configuration of the VR tool, which integrated slides with pre-set camera positions and zooms, a slide-only display mode, and annotation tools for highlighting or drawing attention to focal information. Layout flexibility allowed switching between teacher-only, slides-only, or combined views, enabling variation in the degree of teacher presence. Finally, the template included practical guidance recommending the sparing use of annotations to reinforce main points, the strategic application of zooms and slide-only views to direct attention, and alternating layouts to balance content delivery with social presence.

Figure 1

Screenshots of the prototype video for slide presentation



3.2.3. TSI Template 2: 3D Model Presentation

The 3D Model Presentation Template was designed to support teacher-led explanation of spatial and structural features of three-dimensional objects, with the pedagogical purpose of enhancing students' understanding of form, function, and relationships between components. To achieve this, instructional techniques such as signalling to draw attention to critical parts, segmentation to pace the exploration of

complex structures, and gestural or verbal cues to reinforce spatial relations were integrated. These were instantiated through the technical configuration of the VR tool, which enabled the display and manipulation of a 3D model—in this case, an obelisk—placed alongside the teacher in a neutral background. The presenter could rotate, zoom, and enlarge the model, while switching between views that alternated the focus between the teacher and the artefact, thus combining explanatory narration with visual demonstration. Practical guidance recommended introducing the model gradually, highlighting only one feature at a time, and using zoom and rotation deliberately to reduce cognitive load while maximising spatial clarity.

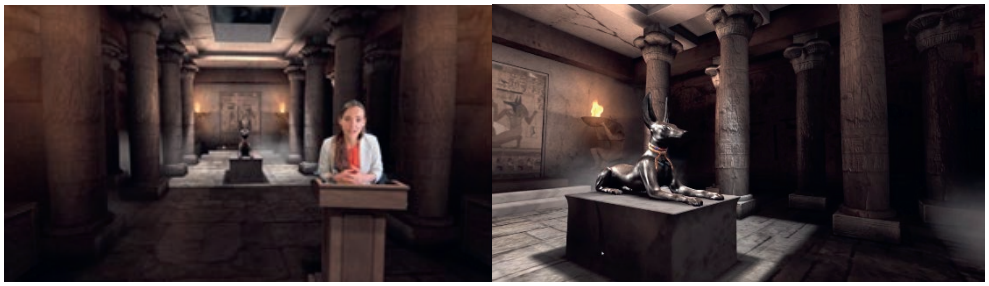
Figure 2

Screenshots of the prototype video for 3D model presentation



Figure 3

Screenshots of the prototype video for 3D environment demonstration



3.2.4. TSI Template 3: Virtual Environment Presentation

The Virtual Environment Presentation Template was designed to support the teaching of content situated within or represented by a 3D setting, with pedagogical purposes ranging from contextualising knowledge to presenting the environment itself as central subject matter. This makes it applicable for illustrating reconstructions of historical sites, demonstrating spaces that are normally inaccessible, or visualising hazardous or large-scale structures. To realise these purposes, instructional techniques such as advance organisation of the setting, cueing of salient features, and application of coherence by removing unnecessary detail were integrated. These were instantiated through the technical configuration of the VR tool, which combined camera presets and transitions to move between the teacher and different parts of the environment. In the demo video, the teacher appeared beside a virtual lectern, with the presentation alternating between teacher-

focused shots, wide overviews, and close-ups of architectural features to illustrate their relevance. Practical guidance recommended aligning environment changes with clear verbal transitions, limiting the number of shifts to avoid overload, and using the teacher's presence as a stable reference point to anchor attention.

Improvement Recommendations

The internal appraisal generated several recommendations for refinement before advancing to the next design stage. First, the visual calibration of 3D models and environments required improvement, as distortions in scale, surfaces, or textures distracted from the intended explanations. Second, the absence of graphic design expertise within the team highlighted the need for media design consultation and system presets to optimise visual and spatial configurations without relying on specialist skills from teachers. Third, reviewers stressed the importance of balancing teacher presence with slide visibility, ensuring that the presenter does not obscure critical visual elements. Finally, for the 3D Model Presentation Template, a minimalist setting was recommended, replacing themed backgrounds with a simple lectern and semi-transparent slide display to reduce distraction and focus attention on the model.

These recommendations were incorporated into the subsequent design stage and guided the refinements reported in Study 2.

4. Study 2: Evaluation & Reflection (Cycle 1) — Expert Review and Refinement

4.1. Methods

4.1.1. Inputs and Refinements

The aim of this study was to refine the pedagogical scenarios developed in Study 1 through structured expert evaluation. The inputs were three demo videos of TSI templates (Slide Presentation, 3D Model Presentation, Virtual Environment Presentation) updated per the Study 1 internal appraisal. Refinements included recalibrated model/environment scale and surface settings to reduce visual distortion; simplified visuals—for the 3D Model template, a minimalist lectern with a semi-transparent slide panel—to limit distraction; revised layout logic and camera presets to balance teacher presence with slide/asset visibility and avoid occlusion; and standardised visual presets to support consistent configuration. Figure 4 presents screenshots from the adjusted Slide and 3D Model templates.

4.1.2. Procedure: Expert Appraisal

Three focus groups (~90 minutes) were conducted in June–July 2023 with 16 participants (educational media designers, instructional developers, educational researchers) affiliated with OU but not otherwise involved in the project. Using a semi-structured protocol (Annex B), participants appraised pedagogical coherence, technological feasibility, usability, and integration potential of the three templates. Sessions were facilitated by a team member, video-recorded with consent, and supplemented by facilitator notes.

Figure 4

Screenshots of adjusted demo videos of TSI templates (Slide and 3D Model Presentation)



4.1.3. Data Analysis

Focus group transcripts were analysed using reflexive thematic analysis (Braun & Clarke, 2013; Clarke & Braun, 2017). Analysis followed a semantic, inductive orientation and was conducted in Dedoose (Version 9.2). Coding was performed by the first author, with iterative refinement of themes with critical review by the research team. The analysis focused on identifying design strengths and areas for improvement in the three TSI templates.

4.2. Results

The expert focus groups generated recommendations for refining the three TSI templates. Feedback addressed pedagogical coherence, technical feasibility, and attentional guidance, and these insights informed the redesign reported in Study 3.

4.2.1. Cross-cutting Recommendations

Experts emphasised several refinements relevant to all templates. First, they recommended moving from a seated to a standing presenter view to enhance dynamism, motivation, and gestural expressiveness. Standing positioning was seen as more compatible with the affordances of virtual sets and with effective cueing practices (Mayer, 2021; Sweller, 2010). Second, participants highlighted the need for operational support. Managing slides, camera moves, environment features and instruction – all by the teacher – was judged distracting; instead, these tasks should be delegated to a trained operator or supported by presets, freeing the teacher to maintain natural eye contact and gestures. Third, experts advised that camera movements should be limited to clear didactic purposes such as segmentation or

signalling (Castro-Alonso et al., 2021). Finally, teachers should be positioned so as not to occlude key visuals, with adjustable size and placement depending on whether motivational or knowledge-focused goals were prioritised.

4.2.2. TSI Template 1: Slide Presentation

For the slide-based scenario, experts recommended using a slide-out mode during content-dense segments, reducing teacher visibility to minimise extraneous cognitive load (Mayer, 2021). The presenter's role was judged particularly valuable for motivation and engagement at the start and end of lectures, while content delivery benefited from full-screen slides and attentional cueing. Experts also recommended a more visible pointer and highlighting tools, including the ability to toggle these on or off to avoid distraction.

4.2.3. TSI Template 2: 3D Model Presentation

For the 3D Model scenario, experts recommended situating the presenter next to the object to provide a human scale reference and to strengthen attentional guidance through gestures. They highlighted the importance of clearly articulating the purpose of model use—whether to provide contextual information (e.g., object size, perspective) or to demonstrate dynamic processes. Experts also suggested simplifying the visual environment, replacing podiums or chairs with a minimalist lectern and semi-transparent slide display to reduce distractions. Camera moves and pointer use were to be kept purposeful and limited, and some participants expressed longer-term interest in student-controlled views of models for exploration.

4.2.4. TSI Template 3: Virtual Environment Presentation

In relation to the Virtual Environment scenario, experts considered it the most immersive format but stressed the importance of representation fidelity (e.g., scale, placement, textures) to avoid cognitive dissonance. They recommended pairing camera transitions with explicit verbal guidance to reinforce the didactic purpose of movements. As with the other templates, experts advised that technical operation should be supported by an operator or robust presets, especially in live sessions, to avoid overburdening teachers. Finally, immersion could be enhanced by subtle audio or animation elements, but only when these directly supported the learning goals.

Overall, across all three templates, experts consistently highlighted the need to balance teacher presence, attentional guidance, and cognitive load management (Mayer, 2021; Castro-Alonso et al., 2021). The recommendations pointed towards clearer differentiation between motivational/engagement functions (where teacher visibility is emphasised) and knowledge-focused delivery (where visual content dominates). These recommendations formed the design rationale for the refinements implemented in Study 3.

5. Study 3: Evaluation & Reflection (Cycle 2) — Validation of Redesigned Templates

5.1. Methods

5.1.1. Inputs and Refinements

The third study aimed to validate the redesigned TSI templates, focusing on instructional robustness, clarity, contextual applicability, and potential for meaningful integration in university teaching. In the DBR cycle, this stage corresponds to iterative evaluation following expert appraisal (McKenney & Reeves, 2019).

The inputs were refined demo videos based on Study 2 recommendations. Adjustments included:

- shifting the presenter from seated to standing to enhance dynamism and gesture use,
- delegating slide and camera operation to a facilitator or presets to reduce presentational load, and
- systematically incorporating attention-guiding features (cueing, highlighting, scaling, reduction of distractors).

These refinements ensured that the prototypes in Study 3 integrated most improvements identified in the preceding stage. Figures 5–7 present screenshots of the demo videos for each template (Slide Presentation, 3D Model Presentation, Virtual Environment Presentation).

Figure 5

Screenshots of reworked demo videos of TSI template (for slide presentation)

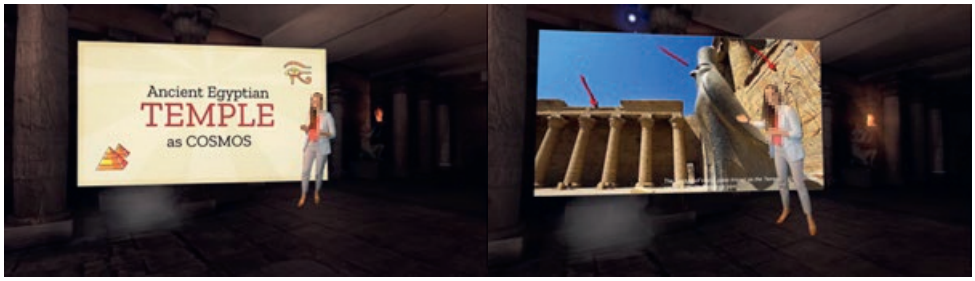


Figure 6

Screenshots of reworked demo videos of TSI template (for 3D model presentation)



Figure 7

Screenshots of reworked demo videos of TSI template (for virtual environment presentation)



5.1.2. Procedure: Validation of TSI Templates

Twenty-four stakeholders contributed: 18 teachers from OU (three departments), 2 teachers from two European partner universities, 2 engineers from the technology provider, and 2 business stakeholders involved in institutional change processes. This heterogeneity enabled triangulation across pedagogical, technological, and organisational domains, consistent with DBR's emphasis on ecological validity and multi-stakeholder perspectives.

Two complementary instruments were employed. An open-ended online survey (N = 24) collected reflections on the templates' usefulness, clarity, and pedagogical applicability. Two follow-up focus groups (N = 21) explored didactic possibilities, implementation scenarios, technical constraints, and cross-context relevance. The same semi-structured protocol as in Study 2 (Annex B) ensured continuity of evaluation criteria. All sessions were video-recorded with consent and supported by facilitator notes.

5.1.3. Data Analysis

Survey and focus group data were analysed using reflexive thematic analysis (Braun & Clarke, 2006, 2021), consistent with the pragmatic–interpretivist stance of DBR (McKenney & Reeves, 2012, 2019). Coding followed a semantic, inductive orientation, with emphasis on identifying refinements, technical adjustments, or confirmation of adequacy. Survey and focus group data were analysed separately before integration for cross-validation across stakeholder roles and template formats.

Analysis was conducted in Dedoose v9.2 across two cycles, supported by analytic memos and team discussions. At this stage, the emphasis was pragmatic rather than theoretical: the goal was to establish whether further adjustments were necessary, not to generate final themes. In DBR terms, the evaluation was semi-summative (McKenney, 2001), balancing formative identification of refinements with summative appraisal of robustness for broader institutional integration.

5.2. Results

The validation study examined whether the three refined TSI template demo videos required further adjustment or were sufficiently robust for broader use with DVR presentation technology Edison. Analysis of survey responses and focus group

discussions indicated broad consensus that the templates were pedagogically appropriate, usable in authentic teaching contexts, and technically feasible within typical institutional conditions. Participants valued the clarity of presentation, the effectiveness of attentional guidance features (e.g., slide-out mode, pointer and annotation tools), and the added value of scale and spatial visualisation in the 3D Model and Virtual Environment templates.

5.2.1. Cross-Cutting Recommendations

Suggested refinements concerned production quality rather than instructional design. Recommendations included moderating background contrast and lighting, ensuring the presenter did not occlude slide content, improving pointer visibility and eye-line alignment, eliminating minor visual distractors (e.g., floor reflections), smoothing camera motion, and stabilising audio. Participants also suggested adding captions/subtitles for accessibility. These were judged routine adjustments that did not require conceptual redesign.

5.2.2. Template-Specific Recommendations

The Slide Presentation Template was valued for visually rich introductions and short knowledge clips. The 3D Model Template was considered particularly effective for content requiring interpretation of structure and scale (e.g., artefacts, anatomy, engineering). The Virtual Environment Template was highlighted for guided tours of spaces and contexts not otherwise accessible (e.g., labs, galleries, field sites). Across templates, participants noted that the formats added the most value for visually or spatially rich content and were less relevant for highly textual or abstract material.

In summary, Study 3 yielded no new design-level refinements beyond those identified in Study 2. The three TSI templates were validated as instructionally robust and contextually feasible for broader institutional use. Remaining adjustments relate to operational embedding, including basic production standards (lighting, contrast, audio, captions) and practice-oriented support (e.g., operator or preset checklists, guidance on when and how to deploy templates).

6. Study 4: Cross-Cycle Reflection – Design Guidelines

6.1. Methods

6.1.1. Inputs and Data Corpus

Study 4 consolidated qualitative datasets from Study 2 (expert focus groups) and Study 3 (cross-stakeholder focus groups and open-ended survey responses) to produce a cross-stage synthesis of stakeholder perspectives on TSI templates and translate these into actionable design guidelines, consistent with DBR's focus on triangulation and ecological validity.

6.1.2. Procedure

Thematic analysis followed a semantic, inductive approach within a reflexive framework (Braun & Clarke, 2006, 2021), informed by a pragmatic–interpretivist stance consistent with design-based research (McKenney & Reeves, 2012). Reflexivity here refers to the recognition that the researchers' disciplinary backgrounds and positionalities inevitably shape the coding process and theme development, with transparency and critical self-awareness applied throughout the analytic cycle. The first author led the analysis, beginning with data revision and analytic memoing, whereby reflective notes were systematically kept to capture emerging insights, coding decisions, and the researcher's own positional influences on interpretation. Given the multi-stage structure of the study, the datasets from Stage 2 (focus groups) and Stage 3 (survey and focus groups) were first analysed separately to allow for within-stage meaning-making prior to triangulation.

6.1.3. Data Analysis

Initial coding was conducted in Dedoose (Version 9.2), with semantic codes generated through close engagement with the transcripts and open-ended survey responses. These codes were iteratively refined over multiple analytic cycles to capture patterned meaning relevant to the research questions. The analytic workflow followed Braun and Clarke's six-phase process. After familiarisation and initial coding, codes were collated into preliminary thematic clusters. Candidate themes were then reviewed by checking internal coherence (i.e., consistency of codes within themes) and external distinction (i.e., separation between themes), which resulted in several rounds of refinement, merging, or splitting. This iterative theme review process was conducted first within each dataset and then again after merging Stage 2 and Stage 3 data.

Following this, both datasets were integrated and subjected to another round of thematic review, enabling cross-validation across institutional roles, template formats, and stakeholder types. To enhance transparency and analytic clarity (O'Connor & Joffe, 2020; Nowell et al., 2017), a second researcher independently applied the codebook to a 25% sample of the data. Cohen's Kappa was calculated across coding instances and yielded $\kappa = 0.93$, indicating good agreement (Landis & Koch, 1977). In line with the assumptions of reflexive thematic analysis (Braun & Clarke, 2021), theme generation remained the interpretive responsibility of the first author. Final themes were then defined and named, with attention to conceptual clarity and alignment with the research questions of the study. Themes were presented to the broader research team for critical discussion, supporting both internal coherence and design relevance.

The final set of themes presented in the Results section reflects this layered and reflexive analysis process, integrating insights from both phases of stakeholder engagement. The inclusion of multiple data types and iterative interpretation across stages supports convergence, elaboration, and complementarity (Fusch et al., 2018), consistent with the objectives of design-based research.

6.2. Results

6.2.1. Pedagogical Purpose

Across the focus groups and survey responses, participants stressed that the VR-enhanced presentation format must begin with a clear articulation of the pedagogical purpose. Two types of goals were consistently distinguished: affective goals (stimulating situational interest, establishing presence, fostering relatedness) and knowledge goals (supporting conceptual and procedural understanding). This differentiation was viewed as critical because it shaped design decisions, such as whether to include the teacher on screen, how to stage visuals, and when to simplify presentation elements. As one participant noted, "*you should have a clear distinction between the two: 'okay, so now I'm going for motivation… and now I'm going for knowledge*" (Study 2 focus group). Several also highlighted the importance of sequencing, for instance, starting with teacher presence to motivate learners, and then minimising distraction during content-heavy segments.

6.2.2. Affective Goals

Participants described how VR-enhanced presentations could serve as an "*appetiser*" to capture attention and spark situational interest, particularly for younger learners or in the opening phases of a session. Visual effects such as zoom-ins or dynamic camera moves were valued for their ability to "*hook*" learners (Study 2 focus group), even if such features alone did not ensure retention: "*if you really want… that something remains there [is remembered], more focused instructional support is necessary*" (Study 2 focus group).

Beyond initial attention, participants pointed to the potential for creating enjoyable, atmospheric experiences through playful visuals or subtle audio ("*I liked the fire behind the presenter*"; Study 2 focus group). Such elements were seen as contributing to a positive climate rather than replacing substantive instruction.

Immersive qualities were also linked to a sense of presence - "*very nice to actually BE in the place that you were talking about!*" (Study 3 survey) – and to contextual atmosphere that made the content more engaging. When combined with visible teacher presence, these features were perceived to support social connection in distance learning, addressing the "*super important*" need for relatedness (Study 2 focus group). From a Self-Determination Theory perspective (Ryan & Deci, 2020), these affordances may help satisfy learners' need for relatedness, thereby enhancing motivation and persistence.

6.2.3. Knowledge Goals

Participants emphasised that VR-enhanced presentations were most valuable for advancing conceptual and procedural understanding when their affordances aligned with the representational needs of the content. This selective use was captured in the principle: "*low tech as possible and high tech as necessary*" (Study 2 focus group). When material could be effectively conveyed through static media, VR was not considered an added value; but for phenomena difficult to represent statically – such as engines, musical instruments, or fluid systems – dynamic 3D visualisation was seen as "*super easy*" and effective (Study 2 focus group).

Specific affordances were valued for clarifying structural and spatial relationships. Camera moves and object manipulation (rotation, zoom, slicing) allowed learners to see internal mechanisms, while proportional cues and overlays clarified size ("*giving the meters or centimetres"*; Study 3 focus group). These functions were judged particularly useful for interpreting artefacts, anatomy, or engineering structures.

VR was also valued for enabling learners to access otherwise inaccessible phenomena – from reconstructions of historical sites to hazardous or future scenarios (Study 2 focus group). Interactivity was highlighted as essential: allowing learners to "*go around [the model]… analyse it by themselves*" (Study 2 focus group) was seen as supporting personalisation and deeper engagement (Study 3 focus group).

6.2.4. Cognitive Load Management

Participants frequently discussed how cueing strategies in the VR-enhanced presentation format could either support or hinder learning. Overall, they emphasised that cueing must be purposeful, synchronised with narration, and carefully integrated to direct attention without introducing extraneous load.

Pointers and drawing tools were generally valued for guiding attention: "*The 'digital laser'… combines the slideshow and the teacher well*" (Study 3 survey). Smaller, less intrusive markers were preferred, as oversized arrows risked distraction: "*The small light I really liked… not like the arrow of the mouse*" (Study 2 focus group). "*Inconsistent or unclear markings undermined their usefulness*" (Study 3 focus group).

Zooming and slide manipulation were seen as helpful for focusing on critical elements ("*Bringing the slide to the foreground… drawing on slides*"; Study 3 survey) but were considered effective only when deliberate and tied to instructional goals (Study 2 focus group).

Camera movements also functioned as visual cues. When used selectively, they sustained attention and signalled transitions: "*Camera movement… could indicate the end of one part of the lecture*" (Study 2 focus group). Smooth, congruent transitions were emphasised, while overuse or unmotivated shifts risked confusion (Study 2 focus group).

The presenter's gaze and gestures served as natural cueing devices: "*People tend to direct their gazes at the same point that other people are gazing*" (Study 2 focus group). Purposeful gestures amplified this effect, though several participants noted that constant presenter visibility could compete with content, leading them to focus on delivery rather than substance (Study 2 focus group).

Finally, background design was recognised as integral to cueing. Neutral or dark backgrounds were recommended for complex visuals, especially 3D models, while thematic settings could enhance atmosphere for general discussion (Study 3 focus group). Overly detailed or moving backgrounds were described as distracting, with reflections and clutter drawing attention away from content (Study 2 focus group; Study 3 survey).

In summary, cueing mechanisms – technological (pointers, zoom, camera moves) or embodied (gaze, gesture) – were most effective when intentional, well-

timed, and harmonised with background design, ensuring that attention was guided toward learning-relevant information rather than dissipated through extraneous stimuli.

6.2.5. Operational and Organisational Issues

Participants stressed that effective use of the VR-enhanced presentation format requires specialised presentational skills adapted to green-screen performance. Unlike classroom teaching, presenters cannot see the background they appear in and must maintain connection with learners through eye contact, gestures, and cueing. Camera awareness was described as critical: "*You don't look in the camera… it's super irritating… normally a teacher looks me in the eyes*" (Study 2 focus group). Expressive delivery and physical dynamism were also emphasised: "*Having that teacher more active… performing would improve it a lot*" (Study 2 focus group). Gestural communication was valued for making explanations more relatable: "*I liked having a person… full scale… using your hands a lot*" (Study 3 focus group).

These demands placed significant cognitive load on teachers, who must simultaneously deliver content, coordinate gestures, monitor positioning, and sometimes operate technical controls. As one noted: "*You have to do a lot of things together [simultaneously]… it's quite difficult… the teacher shouldn't overload themselves*" (Study 2 focus group). Teachers highlighted the challenge of balancing strong delivery with technical operation: "*Very difficult to be a good teacher… and at the same time… do the camera options perfectly*" (Study 2 focus group).

Targeted preparation and training were seen as essential. Participants recommended rehearsal and "*a crash course about giving a video lecture… otherwise you make several mistakes*" (Study 2 focus group). Synchronising verbal explanation, gestures, and camera interactions was described as necessary for instructional clarity while managing personal cognitive load.

Many participants suggested dividing roles between content delivery and technical operation. A second person managing cameras, scene changes, or interaction was viewed as freeing the teacher to focus on teaching: "*Having someone else… operate the system… makes your hands free*" (Study 2 focus group). Others proposed a hybrid approach, with teachers controlling slides while a support person managed cameras, coordinated through a shared script (Study 2 focus group). Technical assistance was considered especially critical during live sessions involving audience interaction, where teachers otherwise risked distraction or disengagement.

Questions also arose regarding the return on investment of producing VR-enhanced lectures. Some considered the added value limited for slide-based formats, given the effort required: "…*producing those pre-recorded lectures takes a lot of time… you have to ask yourself, is a teacher willing… if the added value is small*" (Study 2 focus group; Study 3 survey).

Practical constraints further limited feasibility. The lack of a repository of high-quality 3D models and environments was seen as a barrier, as developing bespoke resources was costly and not always relevant across disciplines (Study 2 focus group; Study 3 focus group). Logistical issues such as access to dedicated studio

space, scheduling, and restrictions on collaborative use also emerged: "…*you have to be here physically… the room is closed at seven*" (Study 2 focus group).

Finally, participants raised inclusivity concerns, cautioning that students with sensory impairments could be excluded if accessible alternatives were not provided: "…*students who have a visual or auditive need… you already exclude them*…" (Study 2 focus group). This highlighted the importance of planning for accessible alternatives or supplementary materials to ensure equitable participation.

7. Discussion

This study was designed to investigate how DVR can support pedagogical practice in a distance university setting (RQ1), and what instructional principles should guide the use of VR affordances in designing VR-enhanced presentation formats (RQ2). Following design-based research conventions, we pursued iterative cycles of design, evaluation, and reflection, progressively developing and refining Technology-Specific Instructional (TSI) templates and consolidating cross-cycle findings into design guidelines.

Addressing RQ1, the research demonstrates that the OU's reliance on presentation-based teaching can be meaningfully supported by three validated TSI templates: slide presentation, 3D model presentation, and virtual environment presentation. These templates extend a familiar lecture culture while introducing the affordances of DVR. Stakeholders confirmed that the templates were pedagogically appropriate, feasible within institutional conditions, and sufficiently domain-independent to be applied across subject areas when aligned with pedagogical purpose.

Addressing RQ2, the iterative cycles identified a set of instructional principles that clarify how DVR affordances should be used in higher education teaching. Findings highlighted the need to distinguish between affective goals (e.g., intrinsic motivation, presence, situational interest) and knowledge goals (e.g., conceptual understanding, procedural knowledge), with teacher visibility, cueing strategies, and background design varying accordingly. Cognitive load management (Sweller, 1994, 2010) emerged as a recurring concern: cueing, segmentation, and coherence principles were judged essential, while overuse of visual effects, camera movements, or presenter presence risked distraction (Paas et al., 2003; Sweller, 1994; Sweller et al., 1998a; Sweller, 2010). Operational embedding was also critical: effective use requires teacher training, rehearsal, and, in many cases, technical support during live delivery. These principles were synthesised in Study 4 as design guidelines that move beyond the local case to inform broader practice.

The study also underscores the reflexive dimension of DBR. The first author's dual role as designer and researcher provided deep contextual understanding but required ongoing reflexive memoing, temporal distancing of coding, and team debriefs to mitigate bias. Beyond this, several limitations qualify the findings. First, all design iterations occurred within a single institutional context, which may limit transferability to institutions with different pedagogical cultures, media infrastructures, or staff workflows. Second, although diverse stakeholder roles were

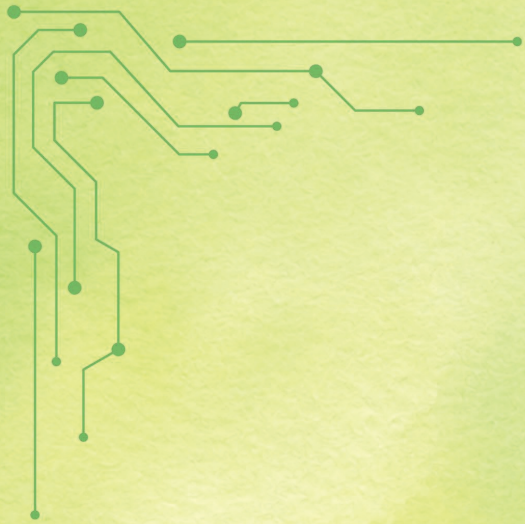
represented, the sample sizes per cycle were relatively small, which constrains generalisability. Third, the study focused on prototype-based appraisal rather than prolonged classroom enactments, leaving long-term instructional effectiveness and student-level learning outcomes for future investigation. At the same time, triangulation across stakeholder roles and cycles enhanced ecological validity. Future research could examine how the concept of Technology-Specific Instructional templates can be applied and further developed in other institutional and disciplinary contexts to support the alignment of technological affordances (Bornstein & Gibson, 1980; Conole & Dyke, 2004a; Salomon, 1997) with established learning theories and instructional design methods.

8. Conclusion

Through four iterative DBR cycles, this project yielded both design solutions and design knowledge. Locally, three TSI templates were developed, refined, and validated as feasible pedagogical scenarios for integrating DVR into higher education. More broadly, the project articulated instructional principles and guidelines for using DVR affordances in VR-enhanced presentations.

For practice, the templates offer educators concrete, reusable formats to integrate VR-enhanced presentations into teaching in ways that are both scalable and pedagogically grounded. For research, the findings contribute to the theoretical base on VR in higher education by clarifying how DVR can be aligned with established frameworks from multimedia learning, cognitive load theory, and self-determination theory. Future work should examine longitudinal classroom implementations in authentic contexts, expand to a wider range of disciplines and institutions, and explore the development of shared repositories of reusable 3D assets.

In sum, by employing a design-based research approach, this study yielded empirically grounded principles and templates to guide meaningful integration of VR-enhanced presentation technologies in higher education.





Part III
Evaluation and Reflection

Chapter 4

Piloting VR-Enhanced Presentations in Synchronous Online Lectures: An Exploratory Study

Virtual reality (VR) is increasingly explored in higher education for its potential to enhance conceptual understanding, spatial reasoning, and learner motivation, particularly in domains requiring dynamic visualization. In distance education, where synchronous lectures often lack visual immediacy and embodied instructor presence, desktop VR offers a promising alternative, yet its pedagogical effectiveness remains under-examined.

This study aims to explore how a pedagogically grounded desktop VR lecture format compares to traditional video-conferencing in terms of knowledge gain, intrinsic motivation, and cognitive load during synchronous online teaching.

An experimental pretest–post-test design was used across three pilots in a distance university, comparing a theory-informed desktop VR lecture format with a traditional video-conferencing condition. University students were randomly assigned to one of the two synchronous lecture formats, with instructional design grounded in cognitive load theory, multimedia learning, and self-determination theory. Data on knowledge gain, motivation, and cognitive load were collected via online surveys and analysed in SPSS.

Across three pilots, no statistically significant differences were found between the desktop VR-enhanced and traditional video-conferencing formats in terms of knowledge gain, intrinsic motivation, or cognitive load. The findings suggest that desktop VR can be integrated into synchronous online lectures without negative effects, providing a foundation for future research into its pedagogical value – particularly in visually demanding domains where spatial or dynamic representations are central to understanding.

This chapter is based on:

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1. Introduction

Virtual reality (VR) technologies are increasingly investigated in higher education for their potential to support spatial reasoning, conceptual understanding, and learner motivation, particularly in disciplines where visualisation and procedural knowledge are critical (Dalgarno & Lee, 2010b; Liu et al., 2025; Makransky & Petersen, 2019b; Mikropoulos & Natsis, 2011; Radianti et al., 2020). In distance education contexts, where even live synchronous lectures may lack visual immediacy and non-verbal cues from the instructor, the possibility of managing students' attention effectively by means of VR is especially promising. However, findings remain mixed: several studies report no significant advantage of VR over traditional formats, highlighting the importance of learner characteristics, task type and complexity, as well as instructional design in moderating outcomes (Jensen & Konradsen, 2018; Marougkas et al., 2023; Meijer & van den Broek, 2010; Radianti et al., 2020). Moreover, the majority of studies prioritize technical performance and usability metrics, while giving limited attention to pedagogical alignment with established principles of multimedia learning and cognitive load theory (Mikropoulos & Natsis, 2011; Radianti et al., 2020). In the present study we will evaluate a theory-informed desktop VR lecture format, comparing it with an equivalent video-conferencing format of a synchronous online lecture to examine effects on knowledge gain, intrinsic motivation, and cognitive load.

1.1. VR in education

Virtual Reality (VR) refers to computer-generated, interactive three-dimensional environments that simulate real or imaginary settings and allow users to explore and manipulate digital content in real time (Mikropoulos & Natsis, 2011; Wilkinson et al., 2021). Definitions vary across fields, but generally converge around the idea of real-time simulation, user interaction, and spatial representation. From a broader mixed-reality perspective, VR applications can be situated on the reality–virtuality continuum, which spans from completely real environments, through mixed reality configurations that combine real and virtual content, to completely virtual environments (Milgram & Kishino, 1994; Skarbez et al., 2021). Building on this continuum, Skarbez et al. (2021) reconceptualise VR as one region within a wider mixed-reality space and propose a three-dimensional taxonomy that characterises systems by the extent of world knowledge (how much of the physical or imagined world is modelled), immersion (a combination of reproduction fidelity and the extent of presence metaphor), and coherence (the degree to which sensory cues and system behaviour form a consistent experience) (Skarbez et al., 2021). Educational technology reviews complement this experiential perspective with more technological classifications that describe VR systems along continua such as immersion, interactivity, and representational fidelity or presence (Dalgarno & Lee, 2010b; Luo et al., 2021; Makransky & Petersen, 2021; Radianti et al., 2020; Stracke et al., 2025). In these classifications, immersion is typically defined as the objective level of sensory fidelity a VR system provides (Bowman & McMahan, 2007), and is

used to distinguish highly immersive systems, such as head-mounted displays or CAVE™ installations, from semi-immersive projection-based systems, and non-immersive or desktop VR (DVR) solutions that rely on standard screens and input devices (Cummings & and Bailenson, 2016; E. A.-L. Lee & Wong, 2014; Limniou et al., 2008; Stracke et al., 2025). A complementary continuum concerns interactivity, distinguishing low-interactivity formats, such as 360° video or guided VR-video segments, from fully interactive simulations and multi-user social VR environments, with empirical work showing that immersion and interactivity jointly shape affective and cognitive processes during VR-based learning (Makransky & Petersen, 2019b, p. 19; Petersen et al., 2022; Won et al., 2023). Immersive VR has demonstrated benefits for learner motivation, conceptual understanding, and presence, but it also presents challenges related to cost, scalability, and physical discomfort (Makransky, Terkildsen, et al., 2019; Mujuru & Lopez, 2021; Radianti et al., 2020). In contrast, DVR offers a scalable and accessible alternative which still retains key affordances such as 3D visualization, simulations and instructional control (E. A.-L. Lee & Wong, 2014; Merchant et al., 2014; Smetana & Bell, 2012; Vogel et al., 2006; Wild et al., 2024).

Recent studies have emphasized that VR design should not solely rely on technical affordances, such as 3D model manipulation, spatial arrangement of visual elements and instructor embodiment, but rather ensure that the chosen level of immersion fits the instructional goals, content domain, and learner context (Dalgarno & Lee, 2010b; Fowler, 2015; Holubinka et al., 2023; Mulders et al., 2020; Skarbez et al., 2021; Stracke et al., 2025). This perspective has particular relevance for online distance education, which, despite its expanding access and flexibility, continues to face challenges as students report lower motivation and social presence, and higher dropout risks in comparison to traditional face-to-face university instruction (Bağrıacık Yılmaz & Karataş, 2022; Rahmani et al., 2024; Richardson et al., 2017). Synchronous online formats are still predominantly limited to videoconferencing featuring static slides and often missing spatial representations, particularly in visually complex subjects (Wild et al., 2024).

In this context, DVR presents itself as a promising modality because of its accessibility and relative affordability. It enables instructors to navigate virtual spaces in real time, offering students enriched visual explanations while maintaining centralized instructional control during the presentation phase of a lecture. As such, DVR may support both affective and cognitive processes underserved by traditional videoconferencing formats. However, empirical findings in learning effects remain mixed. While some studies report higher improvements in learning and motivation when using VR in comparison with traditional classroom instruction (Liu et al., 2025; Makransky & Petersen, 2019b), others caution against overestimating the impact of VR without consideration of cognitive load and learner variability (R. E. Mayer, 2005; Parong & Mayer, 2018). Less immersive VR formats are reported to exceed the learning effects of more immersive ones, as shown by recent meta-analyses (Luo et al., 2021; B. Wu et al., 2020). Apart from technical implementation, a growing body of research points to the importance of considering a task type, learner prior knowledge, content domain, and most importantly instructional embedding as critical

factors shaping the effectiveness of VR-based interventions (Luo et al., 2021; Radianti et al., 2020; B. Wu et al., 2020). Systematic reviews of immersive VR in higher education indicate that many applications are implemented as isolated or experimental scenarios, only partially integrated into regular courses and often not explicitly grounded in learning theories (Radianti et al., 2020; Stracke et al., 2025). These reviews highlight a persistent pedagogical alignment gap, in which the technological possibilities of VR are not systematically connected to coherent instructional designs and curricular structures. Therefore, the present study explores DVR within a controlled instructional setting, using synchronous online lectures across three university courses.

Given previous mixed findings, it is essential to closely examine how DVR influences affective factors like intrinsic motivation in distance education. Intrinsic motivation refers to the drive to engage in an activity for its inherent enjoyment, interest, or personal satisfaction, rather than for external rewards or pressures (Ryan & Deci, 2000b). Within educational settings, intrinsic motivation is often operationalized through enjoyment (the pleasure derived from the learning experience itself), usefulness (the perceived relevance and value of the activity), and relatedness (the feeling of connectedness and meaningful interaction with instructors and peers) (Ryan et al., 1991; Ryan & Deci, 2000b). It is particularly relevant in self-regulated settings like distance education, where motivation has been strongly linked to persistence and learning outcomes (Hartnett, 2018; Richardson et al., 2017). Empirical studies have demonstrated that both immersive and DVR can positively influence intrinsic motivation by fostering greater interactivity, presence, and learner engagement (Jiang & Fryer, 2024; Makransky, Borre-Gude, et al., 2019; M. U. Sattar et al., 2019). However, many existing studies lack robust experimental controls, and observed motivational gains may be partly attributed to novelty effects rather than sustained pedagogical affordances (Richardson et al., 2017). Positive effects have been reported in domains including science (Santos Garduño et al., 2021), medical education (M. Sattar et al., 2020; M. U. Sattar et al., 2019; van Deursen et al., 2021), and engineering (Makransky, Borre-Gude, et al., 2019). Additionally, to our knowledge, no studies have specifically addressed motivational outcomes in synchronous online lectures where students' attention is guided in real time by the instructor-led presentation.

As VR technologies afford dynamic and spatially complex learning experiences, it becomes essential to optimise their design in alignment with human cognitive architecture, particularly the limitations of working memory (Andersen & Makransky, 2021; Makransky, Terkildsen, et al., 2019; Petersen et al., 2022). Cognitive Load Theory (CLT) provides a well-established framework for designing learning environments that account for cognitive processing limitations (Chandler & Sweller, 1991; Paas et al., 2003; Sweller et al., 1998a). CLT differentiates between three types of cognitive load: intrinsic load, determined by the complexity of the material and the learner's prior knowledge; extraneous load, introduced by ineffective or poorly structured instructional design; and germane load, which refers to the cognitive effort invested in meaningful learning processes. In multimedia environments including VR, poor design, such as split attention, excessive visual

detail, or unnecessary interactivity, can increase extrinsic cognitive load, because learners must process information that is not essential for the instructional goal; in complex domains, such design issues can also make the material appear more difficult and thereby increase perceived intrinsic load (Chandler & Sweller, 1991; de Jong, 2010; Skulmowski & Xu, 2022). From a CLT perspective, instructional design should therefore aim to reduce extraneous load, manage intrinsic load, and foster germane load, that is, learners' effort invested in organising information and constructing or refining schemas (Chandler & Sweller, 1991; Leppink et al., 2013; Moreno & Mayer, 2007; Paas et al., 2003; Sweller et al., 1998a). In immersive VR, empirical studies show that these design challenges are non-trivial: learners in head-mounted-display VR lessons often report higher extraneous cognitive load and show lower retention than learners in less immersive or desktop-based formats (Makransky, Terkildsen, et al., 2019; Parong & Mayer, 2018). At the same time, generative learning activities such as summarising or self-explaining can be used to promote germane processing in VR lessons and partially counterbalance the additional sensory and navigational demands (Makransky & Mayer, 2022; Parong & Mayer, 2018). Thus, in the present study we separately examine intrinsic, extraneous, and germane cognitive load in sessions using DVR, in order to better understand how DVR-based instruction relates to students' knowledge gain and to inform instructional design of VR-enhanced presentations.

1.2. Context of this study

This study addresses the acknowledged gap in pedagogical alignment in VR research, understood as the limited attention to aligning VR activities with explicit learning objectives, instructional design, and course context, as reported in several recent reviews (Jiang & Fryer, 2024; Luo et al., 2021; Radianti et al., 2020). To respond to this gap, we applied a previously validated educational template that had been iteratively developed with educational and media design experts as well as university instructors, following a design-based research approach (Amiel & Reeves, 2008; McKenney & Reeves, 2019). This template was created to optimise the instructional use of the DVR tool Edison in the context of synchronous online lectures aimed at the presentation of declarative knowledge to university students. Its design was informed by principles from multimedia learning theory (R. E. Mayer, 2005, 2014), cognitive load theory (Sweller, 1994, 2010) and self-determination theory (Ryan & Deci, 2000b), ensuring a theoretically grounded alignment between technological affordances and instructional goals.

In line with the classifications outlined above, we conceptualise Edison as a non-immersive DVR system positioned on the virtual side of the reality–virtuality continuum. Technically, it implements a mixed reality (Augmented Virtuality) configuration in which a live video stream of the instructor is embedded within a three-dimensional virtual environment and presented within a single display (Milgram & Kishino, 1994; Skarbez et al., 2021). From the perspective of higher education VR taxonomies, this configuration corresponds to non-immersive or DVR: a 3D virtual environment rendered on standard screens that, in other activities, can be navigated and manipulated via conventional input devices (Dalgarno & Lee, 2010; Luo et al.,

2021; Makransky & Petersen, 2019, 2021; Stracke et al., 2025). Within the multidimensional continua of immersion, interactivity, and representational fidelity, the student experience in this study is characterised by low-to-moderate immersion (screen-based access to a coherent 3D scene), low interactivity during the lecture phase (observation rather than direct manipulation), and relatively high representational fidelity and coherence due to broadcast-style compositing and instructor gestures aligned with virtual objects. On this basis, we treat the experimental condition as a DVR–based, VR-enhanced presentation rather than as a conventional video stream, while explicitly acknowledging that students in our pilots did not participate in a fully immersive, multi-user virtual space.

Edison is a DVR tool for synchronous online teaching, designed to enable instructors to co-present alongside slides or 3D models within a virtual space. Originating from professional broadcasting contexts, the platform now supports relatively simple operation and offers basic spatial interactivity, such as positioning, movement, and pointing gestures, allowing teachers to convey visual emphasis during live instruction. In our broader instructional design, this VR-enhanced presentation phase is conceived as the first step in a larger sequence in which subsequent practice activities can provide students with direct access to the same virtual environment as a DVR space (e.g., for exploration or manipulation of 3D models), consistent with recommendations to align interactivity with specific learning goals rather than maximising it at all times (Dalgarno & Lee, 2010; Makransky & Petersen, 2019; Moreno & Mayer, 2007). Although similar environments could, in principle, also be rendered through head-mounted displays, in this study we deliberately selected a DVR configuration to ensure technological accessibility and scalability in a distance-learning context, following evidence on the practical constraints of immersive VR in higher education (Luo et al., 2021; Radianti et al., 2020; Stracke et al., 2025; Wild et al., 2024). In this study, we refer to this instructional format as a *VR-enhanced presentation*.

To explore the potential of desktop VR for synchronous online teaching at a distance, this study compares lectures delivered in the form of VR-enhanced presentations using Edison (experimental condition) with equivalent sessions using traditional video-conferencing platforms (control condition) across three small-scale pilots. This design enables a comparative investigation of the learning process during a lecture presenting declarative knowledge in two conditions by examining differences in knowledge gain, intrinsic motivation, and cognitive load, leading to the following research question:

What are the differences in knowledge gain, cognitive load, and intrinsic motivation between students participating in synchronous online lectures delivered as (1) a traditional video-conferencing presentation and (2) a virtual reality-enhanced presentation?

2. Methods

2.1. Research Design

The present study was conducted within three small-scale pilots to examine the effects of lecture delivery via DVR streaming software Edison. This integrated video was streamed live to function as web camera output in a video-conferencing platform – either Zoom or Kaltura. This integrated format (experimental condition) was compared to a conventional lecture format using standard video-conferencing platforms such as Zoom or Kaltura.

The study employed an experimental pretest-post-test design. Three small-scale pilots involved the redesign and delivery of synchronous online lectures across different courses, including educational sciences and chemistry. Each pilot was carefully co-designed with instructors and educational specialists to ensure instructional alignment and to test variations in visual presentation strategies.

Each of the three pilots consisted of a single lecture delivered in two conditions: one group of students attended the conventional online lecture format (control group), while the other attended the lecture with the VR-enhanced presentation using Edison (experimental group). Students were randomly assigned to one of the two conditions; to ensure proper randomization, student data were encrypted and randomisation software ALEA (FormsVision, n.d.) was used.

Within each pilot, two identical sessions were delivered by the same lecturer within the same time, with the same content and pedagogical structure, differing only in the use of Edison in the experimental condition.

2.2. Procedure

The research protocol for this study was reviewed and approved by the Ethical Committee of the Open University (OU) (under the reference number U202302314), ensuring compliance with ethical standards for research involving human participants.

Prior to each pilot, the content and workflow of the session had been aligned in collaboration with the course instructor. The affordances of the VR-enhanced presentation format were agreed on following the validated pedagogical template, including virtual camera positions and transitions like zooming in/out, types of shots, frequency of changing them, and non-verbal cues. In advance of the pilots, teachers rehearsed in the OU studio (see Appendix D1) to familiarise themselves with the VR-enhanced format and align posture, gesture, and eye contact with the instructional content and camera framing and ensure that the teachers were comfortable with the new delivery format.

Students were informed about the research in advance via the online course portal and received an information letter outlining the study's purpose, procedures, and conditions (see Appendix D2). Participation was voluntary, and students had the right to decline and skip participation in research, specifically completing the surveys, entailing data collection for scientific research, without any consequences. After

obtaining active informed consent through LimeSurvey (LimeSurvey GmbH, n.d.), participants could continue participation with filling in the pre-test in the same environment. At the end of the lecture participants filled in questionnaires via LimeSurvey as post-measurement. Importantly, participants were not informed in advance about the condition to which they had been assigned, which helped preserve the integrity of the experimental design. Recordings of both sessions (experimental and control) were made available after the second session via the university's learning management system, ensuring equal access to learning materials.

All student responses were collected in accordance with institutional ethical guidelines and the General Data Protection Regulation (GDPR; European Parliament, 2016). Prior to analysis, all data were fully anonymized by removing personally identifiable information. Anonymized datasets were transferred to IBM SPSS Statistics for statistical analysis, and to Microsoft Excel for qualitative analysis. Data were securely stored on encrypted university servers located within the European Union and managed according to the institution’s data protection policy. Access to the data was restricted to authorized research team members, ensuring compliance with GDPR requirements for data minimization, confidentiality, and secure storage.

The pilots were conducted as synchronous online lectures in a distance education setting, with both conditions delivered via a video-conferencing platform, specifically Zoom (Zoom Video Communications, Inc., n.d.) or Kaltura (Kaltura, Inc., n.d.). The overall format preserved the pedagogical structure and live interactivity typical of OU’s online courses, ensuring parity across pilots and conditions. Students were able to raise their hand, text questions in the chat, or unmute the microphone and ask questions. The teacher could respond verbally to questions in both conditions.

2.2.1. Traditional Video-Conferencing Presentation (Control Condition)

In the control condition, the lecture was delivered in a standard online classroom environment. Depending on the pilot, instructors presented from their home office (Pilots A and C) or a university office (Pilot B) using a basic webcam and screen-sharing setup. The teacher was seated throughout the session, and the webcam displayed a close-up of their upper body. While the setup limited non-verbal expressiveness and spatial gesturing, instructors used virtual pointers to guide attention to slide content. Students were encouraged to ask questions via microphone. Use of the chat function was permitted, with the instructor managing interactions autonomously. This approach reflects routine practice at OU.

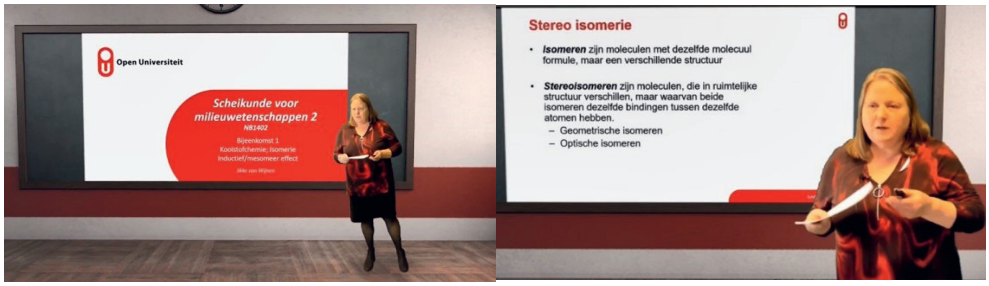
2.2.2. VR-Enhanced Video-Conferencing Presentation (Experimental Condition)

In the experimental condition, the same lecture was delivered using the VR-enhanced presentation format via Edison, with the live integrated stream embedded into Zoom or Kaltura. In this setup, instructors appeared full-body or half-body within a 3D environment, presenting beside slides or dynamic 3D models (in Pilot C). Lectures were streamed live from a dedicated studio on OU premises, equipped with

green-screen facilities (see Appendix D1). Instructors were standing throughout the session and independently advanced slides using a clicker.

Figure 1

Screenshots of the experimental condition; on the left: long shot; right: medium shot



The VR-enhanced presentation format in Edison featured dynamic camera transitions such as zoom-ins and zoom-outs used to open and close sessions smoothly and to signal topic shifts or highlight key concepts. Shot variation was also employed: long shots provided scene-setting or full views of 3D models (in Pilot C), while medium shots maintained a consistent visual focus during core lecture segments (see Figure 1). All camera operations were handled live by a trained moderator, who was briefly introduced at the beginning of each session. While instructors had access to a secondary monitor showing the student video grid, engaging with this screen required intermittent shifts in gaze away from the main camera.

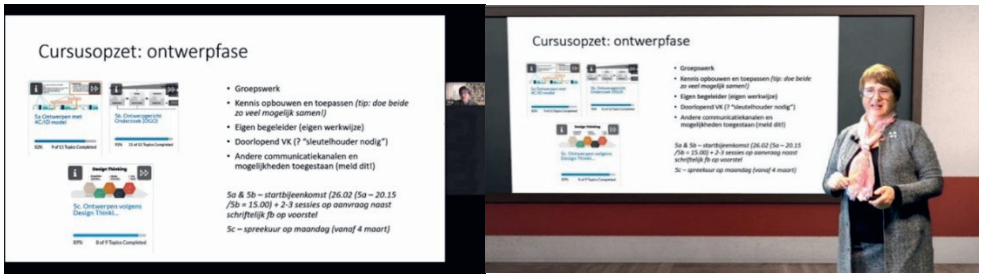
2.2.3. Pilot A: Lecture in Educational Sciences

Participants

Pilot A involved an introductory lecture in a pre-master's course in Educational Sciences at OU. A total of 26 adult students enrolled in the course were invited to take part in the study and were randomly assigned to one of two experimental conditions, with 13 participants in each group. Ultimately 10 students participated in the control condition and 11 in the experimental condition.

Figure 2

Pilot A screenshots: control condition (left) and experimental condition (right)



Conditions

Both conditions were delivered via Zoom. The 31-slide presentation previously developed for a conventional video-conferencing lecture was used in both conditions. In the control condition the teacher's video appeared as a small thumbnail alongside those of the participating students, while in the experimental condition the VR-enhanced presentation format was used (see Figure 2). The educational content was identical in both conditions and the lecture in both conditions took 120 minutes.

2.2.4. Pilot B: Lecture in Educational Sciences

Participants

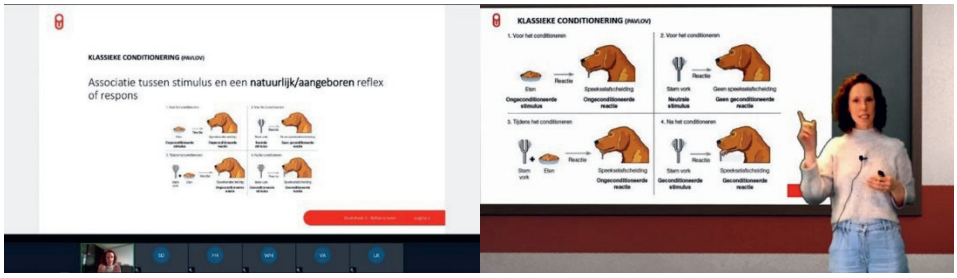
Pilot B took place within the Bachelor's programme in Educational Sciences at OU, which had 30 adult students enrolled. Students were invited to participate in the study and were randomly assigned to one of two experimental conditions. Of those assigned, 7 participants in the control condition and 6 in the experimental condition completed both pre- and post-measures.

Conditions

In this pilot, the control condition was delivered via Kaltura in conventional video-conferencing format with the teacher's video visible as a small thumbnail at the bottom of the slides, alongside other participants' videos. The experimental condition was delivered via Zoom as a VR-enhanced presentation (see Figure 3). Both conditions featured the same lecture with the duration of 120 minutes, structured around a sequence of 45 slides. Based on student feedback from Pilot A regarding legibility, a minor adjustment was introduced in the experimental condition: the font size was increased and several images were enlarged to improve on-screen readability. Apart from these visual modifications, the slide content and sequence were identical across conditions.

Figure 3

Pilot B screenshots: control condition (left) and experimental condition (right)



2.2.5. Pilot C: Lecture in Chemistry

Participants.

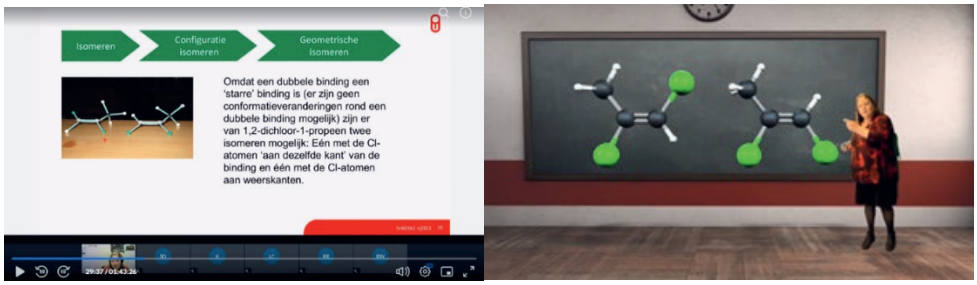
Pilot C was conducted during the first lecture of a chemistry course within the Bachelor's programme in Environmental Sciences at OU. This lecture focused on the structural models of various groups of chemical elements. The course had originally 26 students enrolled, who were randomly assigned to one of two experimental conditions. Of these, 7 participated in the control condition and 13 in the experimental condition.

Conditions.

In the control condition, the lecture was delivered via Kaltura using a conventional slide-based presentation format with teacher's video displayed at the bottom (see Figure 4). Static images of chemical models were included on the slides to illustrate different configurations.

Figure 4

Pilot C screenshots: control condition (left) and experimental condition (right)



The experimental condition featured the VR-enhanced presentation format and dynamic 3D models that had been custom-developed and animated in Blender to demonstrate rotational and mirroring effects. These models were integrated into the virtual classroom environment of Edison and presented in the "blackboard" area (see Figure 4).

The 3D models were rotated live during the lecture by a moderator, in response to and in coordination with the teacher's requests, to help illustrate key concepts more effectively. This enabled a more interactive presentation of spatial information and allowed students to observe molecular transformations in real time. In this condition, each 3D model was presented just before the corresponding static slide to scaffold understanding and support the mental rotation task.

Aside from the differences in the presentation of the molecular models, the lecture remained consistent between conditions. The same set of 43 slides was used in both groups throughout 120 minutes, and content delivery followed the same sequence.

2.3. Instruments

2.3.1. Knowledge gain

Knowledge gain was assessed in lectures focused on declarative knowledge in Pilots A and C, while Pilot B was excluded from this measurement, as the corresponding lecture focused on consolidating previously taught material rather than introducing new content.

In both Pilot A and Pilot C, participants completed a pre-test at the beginning of the session and a post-test immediately after the lecture. Each test consisted of five to six content-specific questions (see Appendix D1.1), compiled by the course instructor and reviewed by four subject-matter experts to ensure coherence, reliability, and content validity. The pre- and post-tests were constructed as parallel forms: they targeted the same learning objectives and content domain, but used different item wordings and examples to reduce simple recall of the pre-test items.

The pre-test assessed students' pre-existing declarative knowledge, while the post-test captured the knowledge acquired during the lecture. The difference between the two scores was used as an indicator of knowledge gain across the lecture.

2.3.2. Cognitive load

To assess cognitive load, the validated 10-item scale developed by Leppink et al. (2013) was employed. This instrument, extensively used in technology-enhanced and medical education research, operationalizes cognitive load theory by distinguishing between three types of cognitive load: intrinsic cognitive load (IL; 3 items), extraneous cognitive load (EL; 3 items), and germane cognitive load (GL; 4 items). Each item is rated on an 11-point Likert-type scale ranging from 0 ("not at all the case") to 10 ("completely the case"), capturing learners' perceived mental effort in relation to a specific instructional task. The IL items focus on the inherent complexity of the learning material in relation to learners' prior knowledge. The EL items target the cognitive demands introduced by the way the material is presented, including layout and clarity of instructions. The GL items assess the mental effort dedicated to processing, understanding, and constructing meaningful knowledge structures (schemas) (Leppink et al., 2013).

The cognitive load instrument has demonstrated robust construct validity and reliability across multiple studies (Hadie & Yusoff, 2016; Leppink et al., 2013). Internal consistency coefficients (Cronbach's α) for each subscale consistently exceed .80, indicating high reliability. In the present study, the Dutch version of the questionnaire was used. To ensure alignment with the learning tasks and context of the pilot intervention, minor linguistic and contextual adaptations were made, in accordance with the modification procedures suggested by Leppink and colleagues (2013). For example, item stems were adapted to refer explicitly to the VR and video-based learning environments used in the experimental and control conditions, respectively. The final version of the questionnaire is included in Appendix D1.2.

2.3.3. Intrinsic motivation

To assess students' intrinsic motivation, the Intrinsic Motivation Inventory (IMI) was administered (Ostrow & Heffernan, 2018). The translated version of the IMI was used to ensure cultural and linguistic appropriateness and was adapted slightly for clarity and contextual relevance to the instructional activities used in the study (see Appendix D1.3). The IMI is a multidimensional self-report questionnaire grounded in Self-Determination Theory (SDT) and has been widely used to measure motivation in educational contexts (Deci et al., 1994; Plant & Ryan, 1985; Ryan, 1982; Ryan et al., 1983; Ryan & Deci, 2000b).

In accordance with the original developers' recommendations (Ryan, 1982; Ryan et al., 1983, 1990), and consistent with applications in comparable studies (Bosch, 2024; Ostrow & Heffernan, 2018), three subscales relevant to the study's objectives were selected: Interest/Enjoyment, Value/Usefulness, and Relatedness.

The Interest/Enjoyment subscale consists of 7 items and is considered the most direct measure of intrinsic motivation. It assesses the inherent satisfaction and pleasure derived from the learning activity. An example item is: *"I enjoyed doing this activity very much."*

The Value/Usefulness subscale (7 items) captures the extent to which participants perceive the activity as personally meaningful or useful, reflecting the degree of internalisation of extrinsic motivation into more autonomous forms. For example: *"I believe this activity could be of some value to me."*

The Relatedness subscale (8 items) evaluates learners' feelings of social connectedness and belonging in the learning environment. This aligns with the SDT notion that satisfying the basic psychological need for relatedness enhances intrinsic motivation. An example item is: *"I felt really distant from the people in the activity"* (reverse scored).

Each item is rated on a 7-point Likert scale, ranging from 1 (not at all true) to 7 (very true). Negatively worded items were reverse-coded prior to analysis. Subscale scores were calculated as the mean of item responses within each dimension, with higher scores indicating stronger endorsement of the relevant motivational construct. The IMI has demonstrated good internal consistency, with Cronbach's alpha values typically exceeding .70 for the selected subscales (Bosch, 2024; Makransky & Petersen, 2021).

2.3.4. Questionnaires

To complement the quantitative measures and capture students' perceptions of the learning experience, three open-ended questions were administered at the end of the post-test. These questions invited participants to reflect on (1) what they appreciated about the presentation format, (2) what they found less effective and how they would improve it, and (3) how they envisioned instructors using such presentation formats at OU.

Responses were used to triangulate student experiences and provide contextual insights into aspects of the learning process not captured by the structured instruments. These qualitative responses were exploratory in nature and were not scored on any predefined scale.

3. Results

3.1. Data-analyses

Data analysis began with an initial screening of the dataset to identify missing values and anomalous response patterns. In pilot A two cases that had only partially completed scores on knowledge gain (only pre-test or only post-test) were excluded from further analysis. No outliers were identified or removed. Following data cleaning, descriptive statistics were computed for all measured variables in both the experimental and control conditions. Medians and interquartile ranges (IQRs) were reported alongside means and standard deviations to account for non-normal distribution patterns observed in several subscales.

Assumption Testing

Normality and homogeneity of variances were assessed prior to group comparisons. For each subscale of the Intrinsic Motivation Inventory (IMI), Cognitive Load (CL), and pre/post-tests of knowledge gain, normality was evaluated using both

the Kolmogorov–Smirnov and Shapiro–Wilk tests. The latter is considered more reliable for small samples (n < 50) due to its higher sensitivity to non-normality (Ghasemi & Zahediasl, 2012). Across the three pilots, these tests indicated deviations from normality for several subscales, which, together with the small and unequal group sizes, supported the use of non-parametric procedures.

To test the homogeneity of variances between control and experimental groups, Levene's test was applied using several estimators (mean, median, trimmed mean), along with the Brown–Forsythe test, which is more robust under non-normal conditions and small samples (M. B. Brown & Forsythe, 1974; Nordstokke & Zumbo, 2010; Zimmerman, 2004). Overall, these tests did not reveal strong violations of homogeneity of variances between conditions; however, given the small sample sizes and non-normality patterns noted above, we proceeded with non-parametric between-group comparisons.

To complement the statistical tests, boxplots were created for each construct in each pilot, using absolute deviations from the median and individually scaled y-axes to facilitate interpretation of variance and outlier structure. All analyses were conducted using IBM SPSS Statistics (v.29).

Non-parametric testing

Non-parametric analyses per pilot were conducted for all IMI, CL and knowledge gain scores. Specifically, the Mann–Whitney U test was selected for between-group comparisons of ranked scores across control and experimental conditions within each pilot (Field & Wilcox, 2017). This test does not assume normal distribution of the data and is appropriate for small, independent samples. The choice of the Mann–Whitney U test was based on the non-normal distribution patterns and small group sizes described above. In addition to *U* and *Z* statistics, the exact 2-sided p-value was reported given the modest sample sizes, which increases accuracy under conditions of tied ranks and low power.

3.2. Knowledge gain

In both Pilot A and Pilot C, students in the experimental (*VR-enhanced presentation*) and control (*traditional video-conferencing*) groups demonstrated comparable levels of pre- and post-test performance, as shown in Table 1 below. While post-test scores in Pilot A showed a trend favouring the experimental group, the difference in knowledge gain was not statistically significant (p = .809). Similarly, in Pilot C, no significant difference in knowledge gain was observed between groups (p = .393), with median gains close to zero in both conditions.

Table 1.
Student Performance on Declarative Knowledge Assessments Across Conditions

Measure	Pilot A					Pilot C				
	Experim.		Control		*p*	Experim.		Control		*p*
	n = 10		n = 11			n = 13		n = 7		
	Mdn (IQR)	M (SD)	Mdn (IQR)	M (SD)		Mdn (IQR)	M (SD)	Mdn (IQR)	M (SD)	
Pre-test	.30 (.20)	.27 (.18)	.30 (.13)	.27 (.13)	0.837	.67 (.42)	.53 (.25)	.67 (.33)	.64 (.33)	0.779
Post-test	.70 (.50)	.57 (.32)	.45 (.30)	.54 (.28)	0.066	.67 (.25)	.71 (.23)	.67 (.33)	.69 (.18)	0.803
Gain	.30 (.50)	.30 (.30)	.30 (.40)	.27 (.26)	0.809	.00 (.42)	.18 (.26)	.00 (.17)	.05 (.25)	0.393

3.3. Cognitive load

Across all three pilots, Mann–Whitney U tests revealed no statistically significant differences between experimental (VR-enhanced presentation) and control (traditional video-conferencing) conditions on most cognitive load subscales (see Table 2 below). The only exception was Pilot B, where the control group reported significantly higher intrinsic cognitive load than the experimental group (p = .022). For all other subscales and pilots, differences were non-significant, with p-values ranging from .173 to 1.000, and effect sizes interpreted as negligible to small.

Table 2.
Cognitive Load Subscale Distributions and Mann–Whitney U Test Outcomes

Scale	Pilot A			Pilot B			Pilot C		
	Experim. Mdn (IQR) n = 11	Control Mdn (IQR) n = 10	*p*	Experim. Mdn (IQR) n = 6	Control Mdn (IQR) n = 7	*p*	Experim. Mdn (IQR) n = 13	Control Mdn (IQR) n = 7	*p*
ICL	5.67 (4.33)	4.00 (5.83)	0.251	3.00 (1.33)	6.00 (2.33)	0.022	7.00 (3.00)	6.33 (2.33)	0.438
ECL	5.67 (1.67)	3.83 (3.83)	0.173	0.83 (2.75)	1.67 (2.67)	0.445	1.33 (2.33)	2.33 (1.67)	0.211
GCL	3.00 (3.25)	4.13 (3.75)	0.605	8.13 (1.88)	8.00 (2.00)	0.295	7.50 (2.00)	7.00 (1.75)	1.000

*Note***.** ICL = Intrinsic Cognitive Load, ECL = Extraneous Cognitive Load, GCL = Germane Cognitive Load. p-values are based on exact Mann–Whitney U tests comparing control and experimental groups within each pilot.

3.4. Intrinsic motivation

No statistically significant differences were found between the *VR-enhanced presentation* and *traditional video-conferencing* conditions on any intrinsic motivation subscales across the three pilots (see Table 3 below). While some small descriptive differences were observed in enjoyment, usefulness, and relatedness scores, these were inconsistent and did not reach significance.

Table 3.
Intrinsic Motivation Subscale Distributions and Mann–Whitney U Test Outcomes

Scale	Pilot A			Pilot B			Pilot C		
	Experim. Mdn (IQR) *n* = 11	Control Mdn (IQR) *n* = 10	*p*	Experim. Mdn (IQR) *n* = 6	Control Mdn (IQR) *n* = 7	*p*	Experim. Mdn (IQR) *n* = 13	Control Mdn (IQR) *n* = 7	*p*
Enj	3.43 (1.57)	2.86 (2.50)	0.863	5.07 (0.82)	5.29 (1.86)	0.445	5.86 (1.57)	5.29 (1.71)	0.241
Usf	3.57 (3.00)	3.79 (3.25)	0.809	5.86 (1.29)	5.86 (1.14)	0.628	6.43 (1.36)	6.00 (1.57)	0.757
Rel	4.50 (1.50)	5.13 (1.94)	0.557	5.44 (1.19)	4.75 (1.25)	0.181	5.88 (1.44)	5.25 (0.63)	0.183

*Note***.** Enj = Enjoyment subscale, Usf = Usefulness, Rel = Relatedness. *p*-values are based on exact Mann–Whitney *U* tests comparing control and experimental groups within each pilot.

4. Discussion and conclusion

This study examined whether a DVR-enhanced presentation format (Edison) differs from traditional video-conferencing in terms of knowledge gain, cognitive load, and intrinsic motivation during synchronous online lectures. Across three small-scale pilots in a European distance-learning university, no statistically significant differences were found between the experimental and control groups on any of the measured outcomes. One exception emerged in Pilot B, where students in the VR-enhanced condition reported significantly lower intrinsic cognitive load than their peers in the control group. However, given the number of comparisons performed across subscales and pilots, this isolated result should be interpreted with caution, as it may not withstand correction for multiple testing. Due to the small sample sizes in all pilots the findings should be considered exploratory. While the limited number of participants constrains the generalisability of results, the study offers initial insights into the potential of immersive presentation formats in online higher education.

Although the VR-enhanced presentation format did not yield measurable improvements, the results also indicate that it did not impair learning or negatively affect students' cognitive or affective responses. Within the limits of these small, exploratory pilots, this suggests that VR-enhanced presentation can be integrated into synchronous online lectures without observable detriment to the measured outcomes, that is, it appears pedagogically safe rather than demonstrably superior. The absence of clear benefits, however, underscores the need for more targeted instructional designs to determine when and how immersive visual formats can support learning in synchronous online education.

While no significant effects were observed for intrinsic motivation overall, the pattern of results offers a cautious indication that the VR-enhanced presentation format may influence learners' motivational responses, although not supported by statistically significant results in this study. Given the underpowered nature of the pilots, this pattern cannot be interpreted as evidence of motivational benefit, but it may inform hypotheses for future work. This subtle pattern suggests potential motivational benefits worth further exploration. Motivation in online learning contexts is known to fluctuate over time, and short-term exposure may not adequately capture

sustained engagement (Bağrıacık Yılmaz & Karataş, 2022; Hartnett, 2018; Ryan & Deci, 2000b). In this study, enjoyment may have been influenced by the novelty of the DVR-enhanced environment, an effect commonly reported in early-stage trials of immersive learning technologies (J. Lee et al., 2025; Miguel-Alonso et al., 2024; Tsay et al., 2020). While increased engagement in some pilots could reflect initial curiosity, it remains unclear whether such effects would persist beyond the first exposure. Longitudinal studies are therefore necessary to determine the durability of motivational responses over time. Conversely, not all experiences with the VR-enhanced format were uniformly positive. In Pilot A, several students reported technical issues during the session, including readability, which may have negatively affected their experience. Such challenges are not uncommon in early deployments of new systems and may have dampened enjoyment despite the instructional enhancements. Future research should explicitly account for learners' technical experiences, either by controlling for system usability or collecting more detailed user feedback to distinguish motivational responses attributable to pedagogical design from those related to tool reliability.

Perceptions of usefulness can also be influenced by the extent to which VR affordances were instructionally integrated. In Pilot C, the VR-enhanced presentation environment was used to support a segment of the lecture involving dynamic 3D visualizations of molecular structures, offering spatial and rotational perspectives that are difficult to achieve with static 2D slides. While this pilot aligns with established recommendations for leveraging immersive technologies to visualize abstract or complex phenomena, no statistically significant differences in perceived usefulness were observed. This may be due to the limited scope of application of VR elements within the session, the brief exposure time or the chosen format of interactivity being limited to the teacher (and not the student) in the present study. Future research should focus on domains where three-dimensional or dynamic processes are central to understanding – such as visualizing mechanical systems (e.g., engines), physiological mechanisms, or interactive simulations, where VR integration may offer a unique instructional advantage. Moreover, it will be essential to explore how affordances can be meaningfully transferred to learners themselves, enabling active engagement through manipulation, exploration, or collaboration within the virtual environment (Allcoat & von Mühlenen, 2018b; Makransky, Borre-Gude, et al., 2019; Radianti et al., 2020; B. Wu et al., 2020; H.-K. Wu et al., 2013). More comprehensive integration of such affordances, combined with targeted learning outcomes, could reveal clearer benefits in subsequent studies.

The construct of relatedness also warrants further investigation. Although both experimental and control groups consisted of the same course cohorts, participants may have differed in their prior familiarity with the instructor – a factor that has been shown to influence perceived social presence and connectedness (Kreijns et al., 2022; Lowenthal & Dunlap, 2010; Richardson et al., 2017). Learners who already have an established mental model of the instructor may not derive substantial added benefit from enhanced visual embodiment. In contrast, new students who lack this familiarity may find VR-enhanced presentations with realistic instructor representations more engaging or socially meaningful (Ackermans et al., 2025).

Future studies should consider this potential mediating variable by explicitly measuring prior teacher familiarity and varying the degree of instructor embodiment across conditions.

This study has several limitations that should be acknowledged. First, the small sample sizes in each pilot substantially limit statistical power and restrict the generalizability of findings. Larger, more representative samples are needed to clarify the reliability and scope of any observed trends. Second, the intervention with VR-enhanced presentation was applied only once in each pilot as a single lecture event. As such, the results reflect short-term exposure and may not capture sustained effects on learning or motivation. Future studies should adopt longitudinal designs in which VR-enhanced presentation is embedded across multiple sessions as part of the regular course structure. Third, there was considerable variation across pilots in terms of instructional objectives, subject matter, and the extent to which VR features were integrated. While this diversity contributes to show the broad applicability of DVR in distance education, it also limits the possibility of making direct comparisons across contexts and highlights the need for more standardized experimental conditions.

This study makes several contributions to the field of technology-enhanced learning, particularly in the context of synchronous distance education. First, it serves as a field-based validation of the instructional use of the VR-enhanced presentation afforded by Edison, which had been iteratively developed through a design-based research process (Holubinka et al., 2023).

In light of the non-significant differences between conditions, the absence of negative effects on learning or motivation across all pilots suggests that the VR-enhanced presentation can be implemented in synchronous distance education without observable detriment to the measured outcomes. From design-based research perspective, this outcome confirms the functional validity of the tool in real-world instructional settings and invites a broader discussion of its domain-specific suitability (Anderson & Shattuck, 2012; McKenney & Reeves, 2019). While the VR-enhanced presentation format was implemented here in relatively content-neutral contexts, its core affordances – real-time spatial demonstration, embodied instruction, and visual realism – may offer more pronounced benefits in disciplines with strong visual–spatial demands, such as engineering, biomedical sciences, or architecture (Makransky, Borre-Gude, et al., 2019; Santos Garduño et al., 2021; M. Sattar et al., 2020). Future research should investigate these affordances not only as isolated media features but as part of pedagogically orchestrated scenarios tailored to learners' cognitive needs (Holubinka et al., 2023; R. E. Mayer & Fiorella, 2021; Mulders et al., 2020; Radianti et al., 2020; B. Wu et al., 2020).

Importantly, the study highlights the potential of VR-enhanced lecture presentation formats to help address existing constraints in delivering visually or spatially demanding subject matter in online distance education, even though the present data do not demonstrate superior learning outcomes. Most current offerings in online and distance universities remain predominantly text-based or rely on slide-based asynchronous content, which can constrain instructional possibilities in visually or spatially demanding disciplines (C. E. Bond & Cawood, 2021; Means et

al., 2014; Zawacki-Richter & Naidu, 2016). Disciplines such as engineering, architecture, chemistry, and biology often require visual modelling, procedural demonstrations, or embodied spatial understanding, which traditional e-learning formats struggle to support. The VR-enhanced synchronous live presentation format piloted in this study enabled real-time spatial interaction between the instructor and 3D instructional elements, without requiring advanced technical teams or proprietary infrastructure. While promising, such affordances must be systematically evaluated in terms of their actual instructional benefit, rather than presumed value (R. E. Mayer & Fiorella, 2021; Parong & Mayer, 2018; B. Wu et al., 2020). Future research should therefore rigorously investigate how VR-enhanced formats impact learning processes and outcomes across different knowledge domains, particularly where spatial cognition, complex system modelling, or procedural simulation are central to the curriculum (Dalgarno & Lee, 2010b; Jiang & Fryer, 2024; Luo et al., 2021; Makransky & Petersen, 2021; Radianti et al., 2020). In addition, future iterations of DVR should explore the extent to which instructional affordances which are currently leveraged by instructors can be transferred to learners to support explorative educational designs, including interactive exercises, simulation-based inquiry, and game-like environments (Dalgarno & Lee, 2010b; Fowler, 2015; Won et al., 2023). Furthermore, questions of scalability, instructor workload, and equity of access should remain central to evaluating whether such formats can sustainably extend the reach and quality of online higher education (Holubinka et al., 2023).

At the same time, these findings should be interpreted as evidence of feasibility rather than superiority: they indicate that VR-enhanced formats can be deployed in authentic courses without observed negative effects in these pilots, but they do not show that such formats improve knowledge gain or motivation relative to traditional video-conferencing. To date, many remote university programs remain skewed toward text-based or verbally mediated disciplines (Means et al., 2014; Zawacki-Richter & Naidu, 2016), in part due to technical constraints in simulating the visual and spatial elements of in-person instruction. By demonstrating that immersive, 3D-enhanced live presentations, which formerly relied on professional studio production teams, can now be effectively implemented using accessible and scalable DVR tools, this study contributes to a growing body of research on the democratization of synchronous digital learning environments (Makransky, Terkildsen, et al., 2019; Petersen et al., 2022). Importantly, the technologies deployed here are compatible with widely available learning platforms, making them feasible for broader institutional uptake, pending instructional alignment and staff development (C. E. Bond & Cawood, 2021; Holubinka et al., 2023; Jensen & Konradsen, 2018).

This foundational validation invites further research not only into scaling VR-enhanced presentation applications across disciplines and cohorts, but also into expanding their pedagogical potential. While the present study focused on instructor-driven presentations, future iterations should explore how VR-enhanced environments can be used to support active learning, such as interactive manipulation of 3D models, simulation-based inquiry, or collaborative tasks within shared virtual spaces. Such developments would require careful instructional design to ensure that interactivity serves learning goals without overloading cognitive

resources (Makransky & Petersen, 2021; Marougkas et al., 2023; Moreno & Mayer, 2007; Petersen et al., 2022).

Although no statistically significant differences were found between conditions across the three pilots, this small-scale study offers an exploratory basis for future research into both the scalability and pedagogical affordances of VR-enhanced synchronous learning environments. While the current implementation focused primarily on instructor-led presentation, future iterations should explore how VR-enhanced environments can be used to support active learning, such as interactive manipulation of 3D models, simulation-based inquiry, or collaborative tasks within shared virtual spaces (Mikropoulos & Natsis, 2011; Radianti et al., 2020; Won et al., 2023). Such developments would require careful instructional design to ensure that interactivity serves learning goals without overloading cognitive resources (Makransky & Petersen, 2021; Marougkas et al., 2023; Moreno & Mayer, 2007; Petersen et al., 2022). Overall, this study offers an initial foundation for future research into how VR-enhanced technologies may be effectively aligned with pedagogical objectives in synchronous online learning contexts.

Chapter 5

Towards Meaningful and Sustainable Integration of Desktop VR-enhanced Presentations: a Multi-Site Focus Group Study

Educational technologies are often introduced through bounded pilots, yet institutions frequently struggle to embed new practices as routine, supported work. This “embedding problem” is central to whether innovations move beyond short-lived projects and become sustainable at institutional scale. We investigated how educational stakeholders across university contexts articulate what is required for the DVR-enhanced presentation tool (Edison) to become meaningfully integrated into routine practice across minimal, medium, and advanced hardware setups.

A qualitative, multi-site focus group study was conducted across three universities (AA, BB, CC) with 33 participants representing teaching, research, media design and production, and management roles. Participants viewed three compilation videos (Sets 1–3) depicting pilots of Edison enacted under minimal, medium, and advanced hardware setup conditions. Participants discussed value, purpose, and feasibility of integrating them. Data were analysed using the Framework Method, informed by Normalization Process Theory (NPT), with findings organised around Coherence and Collective Action dimensions, which were most densely evidenced in this dataset.

Across contexts, setup levels were linked to different expectations. Minimal setups were mainly valued as a low-threshold way to keep teacher and content together in short explanations. Medium setups were valued when they served a clear teaching purpose and when live operation could be supported. Advanced setups were mostly associated with high-quality, reusable short videos, but only when time, space, and specialist support were available. Meaningful integration of Edison is most likely to be supported through setup-specific ways of working, scenario-led guidance, and scalable “support plus autonomy” arrangements, rather than a single uniform approach.

This chapter is based on:

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1. Introduction

Educational technologies are commonly introduced through bounded pilots or local experimentation, yet institutions frequently struggle to embed and sustain new practices as routine work. This “embedding problem” is widely recognised in educational organisations and is central to whether innovations move beyond short-lived projects (Damschroder et al., 2009; Greenhalgh et al., 2004; May & Finch, 2009; Wood, 2017). Institutions also struggle to achieve scale in the sense of depth, sustainability, spread, and a shift in ownership from a small group of leading individuals to routine organisational practice (Coburn, 2003). In higher education, this challenge is compounded by persistent gaps between technological possibility, pedagogical intent, and demonstrable improvement in practice (Kirkwood & Price, 2014). Even where syntheses show that technology use can be associated with positive effects, such evidence does not, by itself, explain how technologies become institutionally sustainable or routinely integrated beyond individual initiatives (Damschroder et al., 2009; Greenhalgh et al., 2004; R. F. Schmid et al., 2014). Taken together, this body of research highlights a persistent field-level challenge: moving from experimentation to meaningful integration that is organisationally supported, routinely enacted, and open to continuous improvement (Coburn, 2003; May & Finch, 2009; Wood, 2017). Against this background, the present study examines how educational stakeholders across different university contexts articulate what is required for the desktop VR (DVR)-enhanced presentation tool Edison to become meaningfully integrated into routine practice across minimal, medium, and advanced hardware setups.

Understanding what is required for a specific educational technology to become meaningfully integrated into routine practice that would benefit the stakeholders requires an organisational, meso-level perspective in which the unit of analysis is the institution rather than the classroom alone. This meso-level perspective is relevant in both continuous improvement and school innovation research, as well as implementation science literature more broadly.

In school improvement and continuous improvement literature technology integration is seen as an organisational accomplishment, shaped by institutional policy, support structures, and capacity conditions rather than an outcome reducible to individual teacher competence or learner response (Sleegers et al., 2014; Sleegers & Leithwood, 2010; Thoonen et al., 2012; Tondeur et al., 2008, 2024; Vanderlinde & van Braak, 2010; Yurkofsky et al., 2020).

At the same time, implementation science and organisational change research provides a set of complementary theories, models, and frameworks that foreground meso-level conditions – organisational structures, resources, roles, routines, and wider policy environments – as determinants of whether new practices become workable and sustained in everyday settings. For example, the Consolidated Framework for Implementation Research (CFIR) synthesises multi-level determinants (e.g., inner setting, outer setting, implementation processes) to explain variation in implementation success across organisations (Damschroder et al., 2009,

2022). The Exploration–Preparation–Implementation–Sustainment (EPIS) framework similarly models implementation as a phased organisational process shaped by interacting inner and outer context factors (Aarons et al., 2011). For technology-intensive innovations, the Nonadoption, Abandonment, Scale-up, Spread, and Sustainability (NASSS) framework explicitly theorises why technology-supported change efforts succeed or fail as complexity unfolds across domains including the technology, organisational context, and wider system (Greenhalgh et al., 2017). Taken together, these frameworks converge on a core implication for educational technology: the "same" technology can be enacted differently across institutions because enactment is shaped by division of labour, professional expertise, resourcing, and organisational routines – not only by individual competence – a point also aligned with practice-based accounts of technology-in-use in organisations (Nilsen, 2020; Orlikowski, 2000, 2007)

Within this landscape, the Normalization Process Theory (NPT) is particularly useful when the analytic goal is to explain the work through which practices become routinely embedded under real-world complexity (May et al., 2009; May & Finch, 2009; Murray et al., 2010). In NPT, normalisation refers to the process through which a new way of working becomes incorporated into routine everyday practice, that is, when it is not only introduced and enacted but comes to be sustained as "normal" work within its social and organisational context (May et al., 2009, 2009). NPT explains how innovations become normalised in everyday practice by focusing on the work of implementation (introducing and enacting a practice), embedding (making it routine), and integration (sustaining it in context), operationalised through four dimensions – Coherence, Cognitive Participation, Collective Action, and Reflexive Monitoring (May et al., 2009; May & Finch, 2009; Murray et al., 2010). In the current study, we focus on integration: the conditions under which DVR use could become workable, supported, and sustained as routine organisational practice over time (May et al., 2009; May & Finch, 2009; Wood, 2017).

NPT is especially aligned with an institutional focus because it directs analytic attention to collective work, coordination, roles, and resource arrangements, enabling comparison of how the same technology becomes workable, legitimate, and sustainable under different institutional configurations. (May & Finch, 2009; May et al., 2009). NPT is also appropriate for studies positioned between early piloting and decisions about mainstreaming, because it can be used both retrospectively, to analyse how an innovation was enacted and what work it required, and prospectively, to identify likely challenges to routinisation and requirements for enhancing implementation potential (Murray et al., 2010).

NPT operationalises normalisation through four interrelated mechanisms: coherence (sense-making), cognitive participation (relational work to enrol and sustain participation), collective action (operational work to enact the practice), and reflexive monitoring (appraisal work to assess and adapt the practice) (May & Finch, 2009; Murray et al., 2010). NPT also treats implementation as inseparable from context, emphasising that implementation processes are accomplishments whose contexts are non-linear, emergent, and dynamic (May et al., 2016; Damschroder et al., 2009). This makes NPT well suited for comparative inquiry into technology

integration across multiple institutional settings, because it supports analysis of how similar technologies can generate different forms of work, coordination, and appraisal when enacted within different organisational configurations (May et al., 2016; Orlikowski, 2000). In this study, NPT is used both retrospectively to interpret anticipated enactment demands and prospectively as a sensitising framework to elicit stakeholders' judgments about what would be required for meaningful integration to be feasible and sustainable in their institutional contexts (Murray et al., 2010; May & Finch, 2009).

Against this background, the present study examines the integration of a specific DVR-enhanced presentation tool (Edison). The technology originates from broadcast-style presentation formats and was piloted across three universities with diverse instructional contexts and support arrangements. In each setting, enactment was organised through minimal, medium, and advanced hardware setups, producing comparable use cases that varied systematically in resource intensity, division of labour, and required expertise. These use cases were subsequently consolidated and presented to multi-stakeholder focus groups involving teachers, media/ design experts, and institutional managers. Analytically, the focus groups elicited stakeholders' sense-making about the technology's value and purpose (coherence) and stakeholders' conceptualisations of the work practices, skills, and institutional support required for enactment and future meaningful integration (collective action) (May & Finch, 2009; Murray et al., 2010).

The study addresses the research question "How do educational stakeholders across different university contexts articulate what is required for the DVR-enhanced presentation tool to become meaningfully integrated into routine practice across minimal, medium, and advanced hardware setups?"

2. Methodology

2.1. Research Design and study context

This study used a qualitative, multi-site focus group design to examine how educational stakeholders across three university contexts (AA, BB, CC) articulated what is required for the DVR-enhanced presentation tool to become meaningfully integrated into routine practice through minimal, medium, and advanced hardware setups. Focus groups were selected because they enable interactional sense-making, allowing participants to build, contest, and refine shared interpretations of the requirements for routine embedding and integration through dialogue rather than isolated accounts (Kitzinger, 1995). A qualitative, comparative case-based design was adopted to support systematic comparison across contexts and setups.

Before conducting the focus groups, the DVR-enhanced presentation tool had been piloted in diverse instructional settings across three European universities, Alicante University, Spain, further referred to as university AA, The Open University in The Netherlands, or university BB, and The University of Santiago de Compostela, Spain, further referred to as university CC. Although the same DVR tool Edison was used in all the cases, the pilots were shaped by substantial differences in available

resources, expertise, and infrastructural configurations across institutional contexts (see table 1), including differences in organisational support, educational mode (campus-based versus distance online education), and the pedagogical role assigned to the technology within the broader pedagogical setting. Rather than representing single, isolated trials, each institutional context comprised a set of pilots (further referred to as Sets) that differed in instructional purpose, pedagogical embedding, and operational execution, while relying on the same underlying DVR technology. These variations were crucial for interpreting participants' reflections, as the focus groups drew directly on the contrasting Set videos produced at each site.

Within the pilots, the DVR-enhanced presentation tool was either used by teachers as part of regular educational practice, or by students who produced artefacts created within course activities. The focus groups thus did not speculate on hypothetical uses of the technology but reflected on already enacted practices situated within real institutional conditions and constraints (Kitzinger, 1995; Ritchie, 2014a).

2.1.1. University AA: Minimal Resource, Teacher-Driven Implementation

University AA is a campus-based institution where teaching is primarily organised through face-to-face lectures and seminars. Several teachers piloted a DVR-enhanced presentation tool in their courses. . The pilots focused on producing recorded instructional videos that paralleled existing face-to-face lectures. The implementation used the standard Edison desk setup, a compact configuration designed for seated presentations (Figure 1).

The setup included a small chroma key backdrop positioned behind the presenter, a single camera and monitor, and a stream deck used to control slides and camera viewpoints. The teacher operated all components independently. This low-threshold configuration required little space and no additional staff, but limited presenter mobility and compositional possibilities, illustrating enactment under minimal institutional and technical support conditions.

Figure 1

Studio Setup at University AA



Note. A minimal Edison desk setup used for seated presentations, consisting of a small chroma key backdrop, a single camera and monitor, and a stream deck operated directly by the teacher.

Across the set of use cases, DVR-enhanced presentation tool functioned as a supplementary instructional medium. The recordings were made available to students after live sessions, to support students who had been absent or who wished to revisit core explanations. The technology was not used during live teaching, nor did it substantially alter the structure of the classroom interaction or the sequencing of instructional activities. Overall, Edison was positioned as an additional format alongside established teaching practices rather than as an integrated component of lesson orchestration or course design.

2.1.2. University BB: Research-Led Implementation With Moderate Media Support

University BB is a fully distance-learning university with teaching primarily delivered online and supported by established organisational structures for media-enhanced instruction. Within this institutional context, Edison was implemented through a set of pilots integrated into regular course delivery, rather than as add-on materials.

The development of the pilots was supported by feedback from a research team with expertise in media didactics, educational design, and technology-enhanced learning, working in collaboration with institutional media design experts and teachers who used Edison in their courses. The pilots comprised two main formats. In asynchronous courses, teachers used Edison to produce recorded mini-lectures that replaced conventional video recordings. In synchronous courses, teachers delivered live online lectures from within the virtual environment, supported by a technical facilitator who operated camera perspectives, scene transitions, and virtual elements. Students attended these sessions remotely and interacted verbally, while the presenter navigated and manipulated the three-dimensional environment on their behalf.

The university developed a corner chroma key installation in which two adjacent walls and the floor were covered in green screen material, allowing for a standing presenter view and more dynamic integration within the virtual environment (Figure 2). This configuration expanded presenter movement and enabled varied camera angles and 3D model manipulation (Figure 2).

While the setup remained low-cost relative to professional studios, it required a dual-role operational model, with a technical facilitator supporting camera switching, scene transitions, and virtual-environment control. This configuration demonstrated what Edison could achieve under moderate resource conditions supported by media-didactic and media-design expertise. Overall, across this set of pilots, Edison was embedded as a core instructional medium, shaping how content was presented, sequenced, and visually structured during teaching.

Figure 2

Studio Setup at University BB



Note. A low-cost corner chroma key installation enabling standing presenter views, with expanded movement space and multiple camera angles, operated jointly by a presenter and a technical facilitator.

2.1.3. University CC: Professionally Supported Studio Implementation

University CC is a campus-based institution with access to a professional broadcasting studio and a dedicated audiovisual production team. Within this context, Edison was implemented through a set of resource-intensive pilots characterised by high production values and complex workflows.

Figure 3

Studio Setup at University CC



Note. A professional broadcasting studio equipped with a full chroma key room, three cameras, dedicated lighting, a control room, and a multi-role production team supporting recording and operation.

The studio featured a full chroma key room (walls and floor), three cameras, dedicated lighting, and a separate control room for real-time operation (Figure 3). Recordings were supported by a multi-role production team (e.g., camera, sound, and technical direction).

The set of use cases differed from those at Universities AA and BB in that Edison was frequently used as part of project-based and participatory educational activities. In several pilots, students were involved in producing audiovisual artefacts using the

technology, either individually or collaboratively, often in close cooperation with technical staff. In other cases, teachers worked with the production team to create highly polished instructional recordings.

The research team at CC possessed strong expertise in media production and educational research, which shaped an approach to using Edison that prioritised high production quality and exploration of the technology's visual potential. Teachers collaborated closely with professional production staff, resulting in workflows that enabled sophisticated audiovisual outcomes and experimentation with complex visual compositions. This mode of implementation required substantial coordination and specialised knowledge, reflecting an institutional configuration in which Edison was embedded within professionally supported media-production practices.

Together, these pilot cases represent an upper bound of what could be achieved with Edison under highly supportive conditions that may not be available at scale.

2.1.4. Comparative Overview of Institutional Contexts Across the Three Universities

Taken together, the three institutional contexts illustrate a structured variation in how the same DVR technology was enacted within higher education. Contextual differences between the cases shaped not only the pedagogical roles assigned to the technology but also the feasibility, scalability, and organisational dependencies associated with its use. An overview of these institutional characteristics is provided in Table 1, which served as a comparative reference point for both the analytical framing of the study and the subsequent focus group discussions.

Table 1

Comparative Characteristics of Pilot Implementations Across Universities AA, BB, and CC

Feature	University AA	University BB	University CC
Teacher involvement	Teacher-led; independent use	Teachers in collaboration with educational/TEL researchers.	Teachers in collaboration with audiovisual communication researchers
Media-production expertise	Minimal	Medium; access to media-design staff	High; professional studio personnel
Media-didactic / TEL design expertise	Minimal	High; access to TEL researchers and practitioners	Minimal
Technical configuration	Minimal desk setup; single web camera; seated presenter	Medium: corner green screen; single web camera; standing presenter	High full chroma key studio; multi-camera
Operational model	Fully teacher-operated	Teacher + facilitator	Teacher + production-team operated

Resourceintensity /production team	Low: teacher alone	Medium: teacher with an operator	High: production team
Type of education	Face-to-face	Distance education	Face-to-face
Instructional embedding / didactical role	Supplementary to lectures	Core instructional medium	Participatory and production-oriented

2.2. Data collection procedure

Data were collected through a structured, multi-stage focus group workflow conducted at each of the three participating universities (AA, BB, and CC). The workflow was designed to support systematic comparison across institutional contexts and across minimal, medium, and advanced hardware setups, while enabling participants articulate what is required for the DVR-enhanced presentation tool to become meaningfully integrated into routine practice, and on the work practices, skills, and institutional support required to enact it. Procedural details are provided in 2.2.1.

Importantly, participants at each site were presented not only with use cases from their own institution, but with all three sets of pilot use cases (Universities AA, BB, and CC). This design enabled comparative reasoning about how institutional conditions shaped enactment of the DVR technology Edison .

Prior to the focus groups, the sets of pilot use cases were compiled into use-case videos, hereafter referred to as Set 1 (University AA), Set 2 (University BB), and Set 3 (University CC). Each set represented a distinct institutional configuration of Edison, including differences in pedagogical embedding, operational models, and resource intensity (see Table 1). These videos functioned as elicitation artefacts, providing a shared and concrete reference point for discussion across focus groups. This aligns with video-elicitation approaches in which audiovisual records of practice prompt situated reflection and support accounts anchored in observable examples rather than abstract or decontextualised descriptions (Derry et al., 2010; Henry & Fetters, 2012; Li & Ho, 2019). Session-level standardisation is described in Section 2.2.1.

Set 1 (University AA) compilation video featured low-resource, teacher-led supplementary uses in social science teaching, centred on criminology/sociology-oriented content presented through short presentation-style recordings. The cases primarily integrated slides and occasional embedded media to support conceptual explanation and course communication, with an emphasis on teacher presence rather than 3D visualisation. Overall, Set 1 illustrated a minimal, largely teacher-operated configuration oriented toward lecture-style presentation under constrained production capacity.

Set 2 (University BB) compilation video featured medium-resource use in a distance-teaching context shaped by media-didactic/TEL design input and a presenter–facilitator operational model (Table 1). The cases spanned a studio-style

data analytics lesson with integrated slides and dynamic framing; a procedural software demonstration of an online survey tool controlled via tablet; and a psychology case presentation designed to bring a text-based case to life through an interview-with-actor format. The set also included spatially oriented exemplars in which the technology supported 3D and environment-based explanation, including chemistry-focused 3D model rotation for mirroring and mental-rotation tasks, a real-scale artefact demonstration (obelisk), and a virtual environment walkthrough (Egyptian temple setting).

Set 3 (University CC) featured high-resource enactment in a professionally supported studio environment with specialist staff and infrastructure (Table 1). The cases combined minimalist micro-modules that prioritised low-distraction staging (neutral backgrounds, simple cues, embedded video) with interaction-intensive exemplars that leveraged presenter movement and purpose-built visuals, such as walking on a map to explain historical expansion and moving along a timeline to support narrative analysis of a film. Additional examples demonstrated broadcast-style presentation (titles, transitions, studio aesthetics), 3D model showcasing (e.g., a bridge model with zoom and camera sweeps), and an analogy-based virtual environment (courtroom setting) used to frame a mathematics concept.

2.2.1. Focus group procedure

The study was conducted in accordance with ethical guidelines for research involving human participants and was approved by the ethics committee at the coordinating university (approval number U202302314). All participants received an information letter prior to participation detailing the aims of the study, the data collection procedures, and data handling practices and gave informed consent. Each focus group session lasted approximately 120 minutes, allowing sufficient time for the sequential presentation of all three sets of use cases, and in-depth group discussion.

Focus groups were conducted separately at each of the three participating universities (AA, BB, and CC), following an identical procedure. At each site, participants were first introduced to the research project and to the DVR technology Edison , including a brief explanation of the different institutional contexts in which the technology had been implemented. Sessions then followed the protocol in Appendix E.1. Focus groups were conducted in the institutional working language at each site. All sessions were moderated by researchers fluent in the language of the session. Where sessions were not conducted in the shared analysis language, transcripts were translated using a documented procedure designed to preserve meaning and analytic traceability as described in section 2.3.1 below (Tong et al., 2007).

The focus group sessions were guided by the protocol provided in Appendix E.1, supported by a PowerPoint presentation and the pilot set videos shown during the sessions. Each focus group session was structured around the sequential presentation of the three sets of pilot use cases corresponding to Universities AA, BB, and CC. All participants, regardless of their home institution, were exposed to all three sets of cases. Across sites, videos (under 5 minutes each) were shown in a

standardised order (Set 1 → Set 2 → Set 3), using the same prompt set and timing structure to maintain comparability of elicited responses.

2.2.2. Participants

A total of 33 participants took part in the focus groups across the three university contexts (AA, BB, and CC). Participants were purposively recruited to represent stakeholder roles relevant to institutional enactment and support of the Edison technology, including teachers, researchers, media design and production experts, and management and administration staff. Group sizes varied by context (AA: n = 6; BB: n = 18; CC: n = 9). Across all contexts, teachers constituted the largest stakeholder group (n = 18), followed by researchers (n = 7), media design and production experts (n = 4), and management and administration participants (n = 4) (see Table 2).

Table 2

Number of focus group participants by expertise and university

University	Focus group participants (n)	Teachers	Researchers	Media design and production experts	Management and administration
AA	6	5	0	0	1
BB	18	9	6	3	0
CC	9	4	1	1	3
Total	**33**	**18**	**7**	**4**	**4**

Note. Researchers includes researcher, PhD researcher, and professor roles.

2.3. Data analyses procedure

The study employed a qualitative data analysis approach grounded in Framework Analysis, operationalised through the Framework Method (Gale et al., 2013; Smith & Firth, 2011), to enable systematic within-case and cross-case comparison via a matrix output (rows as cases, columns as codes) that supports transparent data reduction while retaining links to source excerpts (Gale et al., 2013; Ritchie, 2014a; Smith & Firth, 2011).

The analysis was guided by a pragmatic epistemological stance, focusing on generating practically relevant insights into how educational stakeholders across different university contexts articulate what is required for the Edison technology to become meaningfully integrated into routine practice across minimal, medium, and advanced hardware setups.

2.3.1. Data preparation and translation

Audio recordings were transcribed verbatim. Where data were collected in languages other than English, transcripts were translated into English for analysis. Translation followed a meaning-oriented approach aimed at preserving conceptual and contextual equivalence rather than literal wording. To support consistency and

reduce avoidable translation artefacts, a two-step workflow was used: (1) an initial first-pass translation using a high-quality neural machine translation tool DeepL (DeepL SE, n.d.), followed by (2) bilingual researcher review and correction against the source transcript. A second bilingual reviewer then checked a subset of translated transcripts for conceptual equivalence, resolving discrepancies through discussion and documenting agreed decisions in a translation log. This workflow aligns with qualitative translation guidance emphasising conceptual rather than literal equivalence, the involvement of translators embedded in the research team, and iterative discussion-based checking (Squires, 2009; Temple & Young, 2004; van Nes et al., 2010). All written materials used during data collection were likewise translated to ensure conceptual consistency across contexts.

2.3.2. Framework analysis procedure and coding strategy

Following the staged procedure commonly reported for the Framework Method, analysis proceeded through seven interconnected steps: (1) transcription, (2) familiarisation, (3) initial coding, (4) development of an analytical framework, (5) indexing the full dataset using that framework, (6) charting into a framework matrix, and (7) interpretation through within-case and cross-case comparison (Gale et al., 2013; Ritchie, 2014a).

Step 1–2: Transcription and familiarisation. Audio recordings were transcribed verbatim and translated whenever necessary as described above. Familiarisation involved repeated reading of transcripts alongside session notes, with analytic memos capturing (a) salient contrasts across institutional configurations, (b) recurrent reasoning about value and purpose, and (c) early indications of organisational conditions affecting meaningful integration (Gale et al., 2013).

Step 3–4: Initial coding and analytical framework development. Coding was semantic (capturing explicit meaning) and primarily deductive, aligned with the research questions. Following familiarisation, Normalization Process Theory (NPT) was selected as the primary meso-level organisational lens for structuring the analytical framework, as it provides a systematic vocabulary for analysing the work stakeholders anticipate is required to implement, enact, and embed an innovation within institutional practice (May et al., 2009; C. May & Finch, 2009; Murray et al., 2010). Four NPT dimensions with corresponding subdimensions served as a backbone for the codebook development, including Coherence (subdimensions: Differentiation; Communal specification; Individual specification; Internalisation), Cognitive Participation (subdimensions: Initiation; Enrolment; Legitimation; Activation), Collective Action (subdimensions: Interactional workability; Relational integration; Skill-set workability; Contextual integration), and Reflexive Monitoring (subdimensions: Systematisation; Communal appraisal; Individual appraisal; Reconfiguration) (May et al., 2009; May & Finch, 2009; Murray et al., 2010). Complementary micro-level code families were applied to capture pedagogical and mechanism-relevant content explicitly raised by participants, including technology integration processes, operationalised through the PICRAT framework (Kimmons et al., 2020), and pedagogical mechanisms, drawing on established theories of cognitive load (Sweller, 1988, 2010; Sweller et al., 1998b), intrinsic motivation (Deci

& Ryan, 1985; Niemiec & Ryan, 2009; Ryan & Deci, 2000a), instructional design and multimedia learning (R. E. Mayer, 2005; R. E. Mayer & Fiorella, 2021; Richardson et al., 2017; Stull et al., 2018; van Wermeskerken et al., 2018), and affordances (Bornstein & Gibson, 1980; Conole & Dyke, 2004b). Codebooks with operational definitions are provided in the appendices (see Appendix E.2). The initial framework was drafted by the primary analyst and then revised through structured review with a second coder and the wider team, focusing on code definitions, inclusion–exclusion criteria, and boundary cases.

An initial analytical framework was drafted by applying the codebooks to a purposively selected subset of transcripts representing variation across institutional contexts and case sets. During this phase, code boundaries were refined, redundancies were resolved (merge/split decisions), and inclusion–exclusion rules were clarified to ensure that the framework could be applied consistently across the full dataset while remaining sensitive to case-specific content (Gale et al., 2013; Ritchie, 2014a). For this study, an “excerpt” was defined as a coherent meaning unit within the transcript, which could comprise part of a turn or multiple adjacent turns, segmented to preserve the context necessary to interpret stakeholder reasoning.

Step 5: Indexing. The finalised analytical framework was then applied systematically to the full set of focus group transcripts (indexing). Indexing retained explicit source pointers for each coded segment (institution, case set, transcript identifier, excerpt range) to preserve the audit trail from coded data to interpretation and reporting (Gale et al., 2013; Ritchie, 2014a). The primary analyst indexed the full dataset using the agreed framework. To support consistent application, a second coder reviewed a stratified 15% subset (across university contexts and case sets), with discrepancies resolved through discussion and documented refinements propagated where needed (Gale et al., 2013). Indexing yielded 225 coded excerpts (analyst-defined meaning units), with 351 code applications across 48 unique codes; excerpts could receive multiple codes where warranted by the analytic framework.

Step 6: Charting into a framework matrix. Indexed data were charted into a framework matrix, summarising coded material within each cell while retaining sufficient contextual detail to avoid decontextualisation. Charting was treated as analytic work – summaries were written to preserve meaning, tone, and boundary conditions, and each cell retained pointers to candidate quotations and excerpt ranges to enable verification (Gale et al., 2013; Ritchie, 2014a).

The matrix was designed to enable systematic comparison across (a) university contexts (AA, BB, CC), (b) case sets (1–3) within each context, and (c) analytic level (meso-level NPT lens; micro-level mechanism lenses). Operationally, (1) the case axis differentiated university × case-set units (e.g., AA1, AA2, AA3; BB1…; CC3); and (2) the framework axis consisted of the meso-level and micro-level code families and their constituent codes. Each cell contained: (i) a concise summary of patterned meaning, (ii) boundary notes or deviant instances where relevant, and (iii) excerpt-range anchors and candidate quotations for traceability (Gale et al., 2013).

Step 7: Interpretation and comparative analysis. Interpretation proceeded through two linked comparative passes. First, meso-level comparison was

conducted using the NPT-informed matrix to identify shared patterns and case differences in how stakeholders articulated institutional conditions shaping meaningful integration and scalability. Second, micro-level charted data were used to explain mechanisms that stakeholders explicitly connected to enactment work (e.g., Cognitive Load-related concerns, perceived affordances, and instructional design implications), supporting explanatory linkage across levels while remaining anchored in the matrix and underlying excerpts (Gale et al., 2013).

Data management for coding and retrieval was supported in Dedoose (*Dedoose (Version 9.2)*, 2025). An auditable trail was maintained through versioned codebooks, a coding and translation decision log, analytic memos, and matrices containing excerpt identifiers and quotation pointers that enable verification from interpretations back to source transcripts (Gale et al., 2013).

3. Results

This section reports findings from the framework analysis, using a matrix-based approach to support transparent within-case and cross-case comparison (Gale et al., 2013; Ritchie, 2014a; Smith & Firth, 2011). The analysis is informed by NPT, which conceptualises implementation and integration as work through which practices are made meaningful and enacted in everyday settings (May & Finch, 2009; May et al., 2009; Murray et al., 2010).

Findings address the research question: How do educational stakeholders across different university contexts articulate what is required for the Edison technology to become meaningfully integrated into routine practice across minimal (Set 1), medium (Set 2), and advanced (Set 3) hardware setups. Results are organised in two parts – Coherence and Collective Action – to capture (a) sense-making about value and purpose and (b) enactment requirements in institutional practice (May & Finch, 2009; May et al., 2009).

Although NPT specifies four generative mechanisms, this analysis foregrounds Coherence and Collective Action because these were the most densely evidenced in the dataset, given the study's developmental context and its prospective focus on whether, how, and under what conditions the technology could be meaningfully integrated within institutional settings. Consistent with NPT, prospective and early-stage inquiry can make sense-making (Coherence) and operationalisation of practice (Collective Action) especially visible, while Cognitive Participation and Reflexive Monitoring may be less fully evidenced when routinised use, sustained engagement over time, and longitudinal appraisal practices are not yet established (May et al., 2009; McEvoy et al., 2014; Murray et al., 2010).

3.1. Coherence (Sense-Making)

Results are presented as a comparative, integrative synthesis across the three setup levels (Set 1 – Set 3) and across the three institutional contexts (AA, BB, CC). AA, BB, and CC denote the three participating universities; identifiers such as AA1, BB2, and CC3 refer to focus group discussion segments by university and setup set (not individual participants). To structure this synthesis, we report findings through the

four NPT Coherence subdimensions: Differentiation, Communal specification, Individual specification, and Internalisation.

3.1.1. Differentiation

Across setups, stakeholders' sense-making moved from pragmatic improvement (Set 1), to function-justification scrutiny (Set 2), and finally to communication and product-quality standards (Set 3). Across the universities, this progression also marked a shift from "is it different?" (Set 1) to "is it warranted?" (Set 2) and "is it credible as a communicative product?" (Set 3).

Under the minimal setup (Set 1), participants differentiated Edison primarily through pragmatic gains in online explanation, especially by keeping teacher and content perceptually connected. In University AA, participants described the format as "more natural, more dynamic, more engaging" (AA1), while participants in University CC valued avoiding the screen-sharing trade-off where "you no longer see the lecturer" (CC1). However, differentiation weakened when the enactment resembled ordinary slide delivery: "if you just use it for a PowerPoint-style presentation… what is the added value?" (CC1). Participants in University BB articulated this boundary explicitly by benchmarking against existing multimedia slide practices: "how is this different from using a standard PowerPoint?" and "from a teacher perspective, I'm not sure what that brings extra" (BB1).

As complexity increased (Set 2), participants treated differentiation as conditional on a defensible function rather than on visual richness. In University BB, participants questioned the environment itself – "why would you need to render the room?" (BB2) – while in University AA participants argued that if the goal is classroom reproduction, alternatives are "more practical" (AA2). Across these accounts, "new" was framed as something that must be justified as functionally necessary, not merely more elaborate.

Under the advanced setup (Set 3), differentiation often shifted away from platform distinctiveness and toward communicative performance and quality standards. Participants in University CC minimised platform importance – "the person who communicates is 98 percent" (CC3) – while participants in University BB positioned effectiveness as the primary criterion: "It first starts with effectiveness… If it is not effective, then motivation is irrelevant" (BB3). In University AA, participants tied this shift to design integrity, emphasising that increased sophistication raises the stakes of coherence: "Visual–verbal coherence is important… if you don't [keep] everything consistent… your message is undermined" (AA3).

3.1.2. Communal specification

Across the three sets, stakeholders described a clear shift in purpose: from using the technology mainly to provide explanations students could revisit later (Set 1), to designing the presentation so its learning value could be justified and defended (Set 2), to creating polished media products with clearly defined instructional functions (Set 3). Across universities, shared purpose-making functioned as a gatekeeping mechanism: participants repeatedly treated purpose as something that must be stated before the format can be legitimised as routine practice.

In Set 1, participants in University AA articulated a bounded shared purpose: the setup “works very well for asynchronous learning” for “explaining a concept” or “giving an introduction,” but not where “you need a lot of interaction” (AA1). In the distance-learning University BB, participants expressed communal specification as a purposeful didactic choice that begins with diagnosing the learning need: “what’s your problem right now?” and “what do you want your students to learn from your media?” (BB1). Across these accounts, purpose was treated as legitimate when it followed from a learning problem rather than from format enthusiasm.

In Set 2, participants in University BB narrowed communal specification around learning outcomes and goal alignment: “the thing we need to bank is the learning outcomes,” and “you need to have the goal align” (BB2). This also served as a safeguard against purposeless design flourishes, where “Zooming in and out… has no educational purpose” (BB2). In the University AA Set 2 discussion, purpose-making centred on preventing misrepresentation in abstract topics; participants noted that visual illustrations can “distort what you’re trying to explain,” raising “the question of how to connect with a narrative pathway” (AA2).

In Set 3, participants in University CC stabilised shared purpose by reclassifying the output type: “Maybe these are not classes, they are television programs,” better suited as “an informational micro-module” or “a four-minute illustrative video… a transfer product” (CC3). Participants in University AA recognised value in creativity – “the opportunity to be creative” (AA3) – while still embedding this within feasibility constraints such as access to “good footage” (AA3). Participants in University BB maintained the purpose criterion as demonstrable function, returning to effectiveness as a gatekeeper of value: “It first starts with effectiveness… If it is not effective, then motivation is irrelevant” (BB3).

3.1.3. Individual specification

Across setups, individual specification shifted from teacher-as-producer tensions (Set 1), to autonomy and dependency trade-offs (Set 2), to role-fit boundaries and level-specific applicability (Set 3). Across the universities, these shifts were expressed as increasingly explicit boundary work around who can enact Edison, under what conditions, and for which types of outputs.

Under the minimal setup (Set 1), individual specification was articulated through the work and accountability attached to durable teaching artefacts. Participants in University AA described recorded delivery as “pure staging,” requiring attention to “gestures” and downstream consequences of recording (AA1), and they explicitly linked enactment to governance routines: “If it hasn’t been reviewed, nothing gets released” (AA1). They also noted how durable outputs reshape teacher self-presentation, as “All the humour disappears” when teachers anticipate potential misinterpretation (AA1).

As complexity increased (Set 2), participants in University CC crystallised individual specification as an autonomy–dependency trade-off: “It adds value, but I think you lose autonomy… now you can’t do it yourself” (CC2). In these accounts, the medium setup was framed as valuable but less individually enactable because

value was associated with reliance on support roles or constrained operational modes.

Under the advanced setup (Set 3), participants in University CC drew the sharpest role-fit boundaries by redefining where Edison "belongs" in institutional practice: "I would not use it for teaching… I would use it in the context of the project," for "small micro-modules" and "project-end videos" (CC3). They also differentiated by level, seeing limited fit for "undergraduate" but more plausible use at "Master's" level, where content has sufficient "weight and a workload" to justify the effort (CC3). In parallel, participants in University AA foregrounded the capacity to sustain high-integrity design work under increased sophistication, emphasising that "Visual–verbal coherence is important… if you don't [keep] everything consistent… your message is undermined" (AA3).

3.1.4. Internalisation

Across setups, internalisation depended on whether stakeholders could articulate a credible return on investment. The nature of that return shifted from barrier-lowering and basic communication gains (Set 1), to clarity and context-fit (Set 2), to production-quality thresholds and product legitimacy (Set 3).

In Set 1, internalisation was articulated as a labour–reward calculation. Participants in University AA asked the value question directly: "For lecturers… what is the reward?" given that "it is a lot of work" (AA1). Participants in University BB voiced a comparable boundary by questioning what the setup adds beyond familiar multimedia slide practices: "from a teacher perspective, I'm not sure what that brings extra" (BB1). Participants in University CC expressed internalisation through barrier-lowering confidence – "I can do this" – while also identifying a threshold below which use would not begin ("if it's too complicated, you won't even start") (CC1).

In Set 2, internalisation strengthened when participants could name a clear representational payoff or access-related value. Participants in University BB highlighted teacher visibility as a source of connection: "Here I can SEE them" (BB2). Participants in University CC similarly emphasised clarity ("much, much clearer… visually, without the need for sound") while delimiting internalisation through context-fit constraints: "for a face-to-face class… it's heavy" (CC2).

In Set 3, internalisation was often articulated in threshold terms tied to production quality and legitimacy. Participants in University CC described a shift point – "Now I'm going to completely change my opinion" – because "image quality is well integrated… we don't see those problems" (CC3). At the same time, internalisation remained bounded by uncertainty about routine translation: "in the classroom, I don't know what to do with myself" (CC3). Participants in University BB reinforced that quality alone is not sufficient without a defensible function: "It first starts with effectiveness" (BB3). Participants in University AA recognised creative promise while foregrounding feasibility constraints and resourcing ("where do I get good footage?") (AA3).

3.1.5. Summary implications across Set 1–Set 3

Across the three setups, Coherence accounts show an escalation in what stakeholders treated as a defensible value proposition. Under minimal setups (Set

1), sense-making remained strongest when value could be framed as low-threshold improvement, but weakened when enactment duplicated familiar slide-based practices or when labour exceeded perceived benefit (AA1, BB1, CC1). Under medium setups (Set 2), participants tightened purpose criteria and framed value as contingent on demonstrable payoff and context-fit, particularly where the setup could feel “heavy” outside of specific use cases (AA2, BB2, CC2). Under advanced setups (Set 3), participants increasingly assessed value through production-quality thresholds and role-fit boundaries, often delimiting routine applicability while reframing outputs as product-oriented work that must remain effective and feasible under institutional resourcing constraints (AA3, BB3, CC3).

3.2. Collective Action (Enactment)

This subsection reports stakeholders’ accounts of what is required to enact Edison as routine practice across minimal (Set 1), medium (Set 2), and advanced (Set 3) setups. To structure this synthesis, we report findings through the four Collective Action components: Interactional workability, Relational integration, Skill-set workability, and Contextual integration.

3.2.1. Interactional workability

Across setups, interactional workability shifted from dual-attention fragility (Set 1), to self-production overload despite efficiency gains (Set 2), and then to space-, staging-, and scenario-dependent production (Set 3). Across the universities, this trajectory reflects a shift from managing concurrent teaching and technical control (Set 1) to managing production as a performance task (Set 2), and finally to managing staging constraints and time investment as conditions for enactment (Set 3).

Under the minimal setup (Set 1), enactment was described as fragile when teachers must carry teaching and production simultaneously. Participants in University CC captured this as the lecturer being “quite constrained” by attending to technical aspects alongside “their role as a lecturer” (CC1). Participants in University BB described how attention could shift away from the intended content focus: “my attention went to those more salient things, not to the actual content” (BB1). This fragility was amplified by low tolerance for seductive or distracting details, where even a reflection could dominate: “I was distracted… I saw the screen in it… I was not actually paying attention to the content” (BB1).

As complexity increased (Set 2), participants acknowledged the instructional efficiency of demonstrations for procedural knowledge acquisition, but re-described enactment as a high-demand performance-and-production task. Participants in University AA characterised enactment “like making a documentary while doing everything yourself” (AA2), describing concurrent coordination demands: you have to “perform your teaching” while being responsible for “the whole production,” leading to the judgement, “I find it complicated” (AA2). Participants in University CC added that bringing the studio into a live teaching setting would require broadcasting and is “a bit complex” (CC2), reinforcing that interactional workability tightens when live coordination and production are combined.

Under the advanced setup (Set 3), interactional workability became explicitly dependent on staging conditions and on whether the scenario justified the effort. Participants in University CC stressed that space is an active constraint: “Walk around a larger space… Full body,” but “if there is no longer enough room, that limits you,” and “the space you have is not neutral” (CC3). While advanced demonstration can be valuable (“show very specific details”), enactment remained bounded by purpose and effort: “it depends on what you want to explain,” and “whether it is worth the effort” (CC3). This culminated in a time–value threshold: “You have to give it added value. Otherwise, you are not going to invest your time” (CC3).

3.2.2. Relational integration

Across setups, relational integration shifted from trust in baseline quality and scalable support (Set 1), to trust in representational meaning and professional audiovisual standards (Set 2), to trust in scenario-fit to avoid distraction and communicate clearly (Set 3). Across the universities, relational integration was articulated as a confidence condition that links quality expectations to the feasibility of routinising enactment.

In Set 1, participants in University CC framed confidence as a support–capability problem: “how much support do you need, and how much are you capable of producing yourself?” (CC1). Trust was directly tied to scalability: if “you need full support all the time, that’s not going to scale” (CC1). Participants in University BB similarly treated minor quality issues as undermining acceptability, implying a need for minimum production standards even under minimal setups (BB1).

In Set 2, relational integration became more meaning-focused. Participants in University AA warned that in abstract domains, illustration can alter what is being taught: “Once you illustrate them, you are no longer explaining the concept,” because the added element “might distort what you’re trying to explain” (AA2). In these accounts, trust depended on disciplined coordination, including “how to connect with a narrative pathway” (AA2). Participants in University CC added that reliability also depends on audiovisual professionalism, including ensuring what is said “is heard well,” and that “properly sound-designing a video… is really a profession …because it is very, very, very complicated” (CC2).

In Set 3, participants in University BB framed trust as scenario design that preserves communicative intent. Advanced enactment was described as acceptable when guided by “good scenarios,” because “otherwise it becomes distracting,” with the aim of a scenario “where it helps to communicate what you want to communicate” (BB3). In these accounts, relational integration hinged on coherent scenario-fit rather than on the presence of advanced features per se (BB3).

3.2.3. Skill-set workability

Across setups, skill-set workability moved from dual-role fluency (Set 1), to production-literate teaching routines (Set 2), and then to staging and production competence that must justify time investment (Set 3). Across the universities, this progression reflects an expanding competence profile that shifts from handling the technology while teaching (Set 1) to coordinating production while teaching (Set 2) and then to staging and scenario work as a skilled performance (Set 3).

Under the minimal setup (Set 1), the skill challenge was framed as maintaining teaching while handling production demands. Participants in University CC described the lecturer as “constrained” by having to attend to technical tasks alongside teaching (CC1). They also expressed the practical skill boundary through the support–capability question, arguing that enactment depends on what staff are “capable of producing” themselves and what requires help (CC1).

As complexity increased (Set 2), skills were conceptualised as documentary-style production competence. Participants in University AA made the competence bundle explicit: you must manage “how you look,” how the recording will be, whether gestures match actions, while simultaneously teaching, and still carrying responsibility for “the whole production” (AA2). The difficulty was framed not as mere unfamiliarity, but as a demanding coordination task that makes enactment “complicated” (AA2).

Under the advanced setup (Set 3), competence expanded to include full-body staging, spatial constraints, and high-effort scenario design. Participants in University CC described how space changes “how you speak, how you gesture, and what you can show” (CC3), and treated the skill requirement as inseparable from justification: even if you are comfortable with technology, “it requires an investment of time,” and you must produce “added value” to make that investment worthwhile (CC3).

3.2.4. Contextual integration

Across setups, contextual integration evolved from defining a scalable support model and basic quality assurance (Set 1), to resourcing professional audiovisual production and context-fit choices (Set 2), to treating advanced enactment as product-oriented work with time and production support (Set 3). Across the universities, contextual integration was articulated as the institutional decision space in which support arrangements, quality expectations, and scenario selection are stabilised as routine practice.

In Set 1, contextual integration was framed as the institutional arrangement of the support–capability balance. Participants in University CC argued that viable enactment requires “some support but still autonomy,” while “full support all the time” is viewed as non-scalable (CC1). Participants in University BB similarly implied that even minimal setups require baseline production standards to maintain acceptability (BB1).

With increased complexity in Set 2, contextual integration was articulated as explicitly professionalised. Participants in University CC argued that audiovisual quality is a profession (CC2), implying that institutions must resource specialist support if they expect consistent production quality. They also reframed context-fit for face-to-face teaching as “paradoxical” because the setup resembles a real class, yet “if it’s face-to-face, it wouldn’t make sense for you to go into it… you’re already there” (CC2). Instead, they located value in supporting model manipulation (“turning it around [rotating] helps students understand things better”) (CC2). In these accounts, contextual integration therefore involved not only resourcing, but stabilising when this enactment form is warranted.

In Set 3, contextual integration was framed through thresholds about time investment and about the type of output being produced. Participants in University CC's "program" framing and their rejection of use for "conventional class[es]… the ones we have every day" (CC3) indicated that advanced setups were more plausibly integrated as a different kind of product (micro-modules, transfer content), backed by time allocation and production support. Participants in University BB reinforced that enactment must be scenario-led to avoid distraction and preserve communicative purpose (BB3).

3.2.5. Summary implications across Set 1–Set 3

Across the three setups, Collective Action accounts show an escalation in enactment requirements that parallels increasing setup complexity. Under minimal setups (Set 1), participants foregrounded feasibility under dual-role constraints and argued for a scalable support model that preserves autonomy while avoiding "full support all the time" (BB1, CC1). Under medium setups (Set 2), enactment was framed as demanding production work that becomes "complicated," implying a need for stable routines and professionalised support, alongside context-fit decisions about when the setup is warranted (AA2, CC2). Under advanced setups (Set 3), enactment was treated as staging- and scenario-dependent, with time investment requiring "added value," and advanced use framed as a "program" rather than "conventional class[es]," indicating a need to embed it as product-oriented work supported through time allocation, space, and production roles (BB3, CC3).

4. Discussion/Conclusions

4.1. Overview of organisational learning from the comparative analysis

This study investigated how institutional stakeholders from three universities articulated what is required for the DVR-enhanced presentation tool (Edison) to become meaningfully integrated into routine practice across three university contexts and three hardware setups (minimal, medium, and advanced). Using NPT as the theoretical lens, the analysis treated meaningful integration into routine practice as the work required to make practices around the use of the DVR-enhanced presentation tool both meaningful and workable in institutional settings (May et al., 2009; May & Finch, 2009; Murray et al., 2010).

The central organisational insight is that stakeholders required increasingly strong justification for Edison as configurations became more complex. As complexity increased, legitimacy shifted from solving a concrete communication problem, to requiring explicit educational function and learning-goal alignment, and then to meeting production-quality thresholds and scenario-fit requirements. This pattern suggests that value is seen not as a property of Edison as an artefact but an emergent judgement tied to the organisational distribution of work and the conditions under which enactment can be sustained (May & Finch, 2009; Orlikowski, 2000).

Rather than reiterating the coherence and enactment results, we interpret them here as showing a coupling between sense-making and operational feasibility: coherence strengthened when stakeholders could specify what makes Edison distinct *and* when collective action demands remained proportionate to that distinctiveness. Conversely, coherence weakened when enactment resembled existing tools or when additional layers increased work without a defensible function. In NPT terms, this coupling helps explain why configurations that appear "more advanced" are not automatically perceived as more integrable: escalating collective action demands can undermine internalisation unless they are justified by clearly articulated purposes and credible returns on investment (May et al., 2009; May & Finch, 2009; Murray et al., 2010).

Treating hardware setups as institutional design choices, stakeholders across contexts described minimal, medium, and advanced setups as qualitatively different institutional propositions because each redistributed work across teachers, media experts, and organisational supports in different ways. This indicates that scaling is less a matter of encouraging individual use and more a matter of designing configuration-specific operational models, including quality thresholds, role expectations, and resourcing pathways that make enactment and integration sustainable (Coburn, 2003; May & Finch, 2009).

4.2. Practical implications for meaningful integration

The Results support four practical implications for institutions seeking meaningful integration of the DVR-enhanced presentation tool (Edison) across resource configurations.

1. **Design differentiated implementation scenarios not only by setup level.**

Across the minimal, medium, and advanced hardware setups, stakeholders described qualitatively different value propositions and enactment requirements. Stakeholders did not assume that higher technical complexity would automatically produce greater educational benefit. Instead, they emphasised that different setups enable different forms of use and therefore require different success criteria. Institutions can use this lens to define setup-specific use cases and context-specific criteria for what counts as a successful, sustainable integration.

2. **Make scenario fit and educational function the primary governance criterion.**

Across contexts, stakeholders repeatedly subordinated sophistication to effectiveness and rejected purposeless features. Institutional guidance should therefore foreground scenario fit, goal alignment, and communicative function as primary criteria for legitimising use. These criteria directly support coherence work, and they can also reduce uncertainty about role expectations and reliability in the integration process (May & Finch, 2009; Murray et al., 2010).

3. **Build a scalable "support plus autonomy" operational model.**

Stakeholders repeatedly framed scalability as incompatible with full support for all use. Institutions can operationalise contextual integration by clarifying what teachers are expected to produce independently, what requires specialist support,

and what minimum quality standards must be met before release. This implication follows stakeholders' framing of support as the key condition for scalable enactment (May & Finch, 2009).

4. **Treat advanced enactment as product-oriented work with explicit resourcing.**

In advanced hardware setup cases, stakeholders commonly reframed outputs as micro-modules or transfer products rather than routine classes and described time–value thresholds. Institutions seeking advanced use should explicitly embed this work as product-oriented production, with defined time allocation, professional production support, and scenario development processes.

4.3. Limitations

Several limitations follow from the study. First, the study is based on focus group accounts of educational stakeholders who evaluated the pilot cases of the Edison use in different context based on the video presentations, rather than on participants' first-hand use of the tool or longitudinal observation of routine use. This supports inference about stakeholder sense-making and anticipated work, but more limited inference about how Edison would be integrated after sustained institutional enactment. Second, the analysis foregrounded Coherence and Collective Action because these were most densely evidenced. As the Results note, Cognitive Participation and Reflexive Monitoring were less elaborated in this developmental, prospective context, which constrains claims about sustained enrolment and long-term appraisal processes that typically become visible after routinisation (May et al., 2009; McEvoy et al., 2014; Murray et al., 2010).

Third, participant composition differed across contexts, including uneven numbers across universities and role distributions, as well as uneven individual experience with Edison technology, which may have influenced which concerns were most prominent in the discussions. Fourth, where translation was required, meaning-oriented translation and bilingual review were used, yet cross-language qualitative research always introduces the possibility of subtle meaning shifts that cannot be fully eliminated (Squires, 2009; Temple & Young, 2004; van Nes et al., 2010). Finally, the findings are technology-specific in their concrete content. Transferability is most defensible at the level of organisational work patterns, such as support–autonomy trade-offs and scenario-led governance, rather than as universal claims about all VR-enhanced presentation technologies (Orlikowski, 2000).

4.4. Future research

Future work can extend this study in three directions. Firstly, a longitudinal design could examine how stakeholder-defined thresholds, governance criteria, and support models relate to later embedding, including whether coherence and collective action accounts evolve as the DVR-enhanced presentation tool (Edison) becomes more routinised. This would also enable fuller analysis of Cognitive Participation and Reflexive Monitoring, as sustained enrolment, legitimation, and

appraisal practices become more established over time (May et al., 2009; Murray et al., 2010).

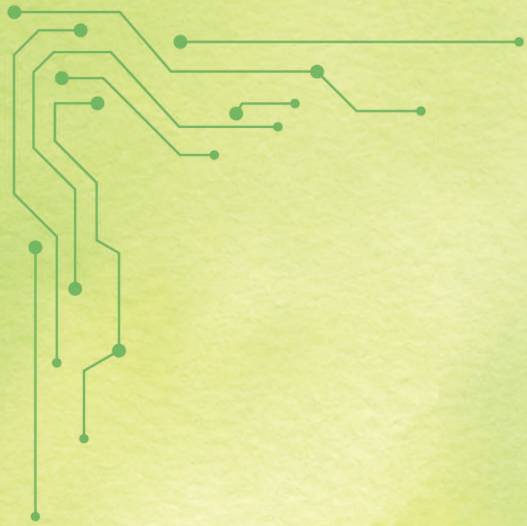
Secondly, future studies could triangulate stakeholder accounts with observational data and organisational artefacts such as production workflows, quality assurance processes, staff time allocation, and support tickets. Such triangulation would allow stronger claims about enactment workability and contextual integration under real operating conditions (May & Finch, 2009).

Finally, an applied line of work could be developed and tested to provide differentiated support packages for minimal, medium, and advanced setups with the goal of strengthening meaningful integration and scalability of Edison within institutional teaching practice. These packages could be aligned with NPT constructs as implementation outcomes, for example coherence clarity, collective action feasibility, and reflexive monitoring infrastructure (Murray et al., 2010).

4.5. Conclusions

Across three university contexts and three hardware setups (minimal, medium, and advanced), stakeholders described that the justification needed for using the DVR-enhanced presentation tool (Edison) increased as the setup became more complex. In minimal setups, Edison was mainly valued for improving communication in online teaching. In medium setups, stakeholders expected clearer educational purpose and alignment with learning goals. In advanced setups, they also expected high production quality and treated outputs more like reusable educational products than like one-off classes. Stakeholders' descriptions of what it takes to use Edison in practice also changed with setup complexity, highlighting increasing demands on teachers' attention, a growing need for professional audiovisual support, practical constraints on how sessions can be staged, and the importance of support models that can scale.

Taken together, the findings point to a constructive pathway for meaningful integration of Edison. Institutions can increase the likelihood of sustained use by defining setup-specific ways of working, using scenario-based guidance to decide when Edison is instructionally warranted, and allocating explicit time and support for advanced, product-like outputs. Framed in this way, the variability across configurations becomes an actionable design space: rather than aiming for one uniform approach, institutions can choose the level of complexity that fits their goals and resources, and then support that choice with matching roles, quality standards, and resourcing (May & Finch, 2009; Murray et al., 2010).





Part IV
Theoretical Understanding

Chapter 6

Towards Holistic Integration of Technology in Education: Introducing the HITE Framework

Educational institutions across sectors are under increasing pressure to integrate digital technologies in ways that are pedagogically meaningful, organisationally sustainable and aligned with broader societal values. Existing approaches often focus either on classroom-level innovation or on organisational change processes, leaving limited guidance on how these levels can be connected in practice. This paper introduces the Holistic Integration of Technology in Education (HITE) Framework, a conceptual framework that brings together technological, pedagogical, contextual, managerial and value-related considerations into a coherent structure for analysing and guiding technology integration.

The framework was developed through a multi-stage process that combined empirical insights from a single institutional case study, theoretical synthesis across technology-enhanced learning and organisational literatures and iterative refinement through expert review, following principles of conceptual framework analysis.

HITE comprises four relatively static dimensions: *Technology*, *Pedagogy*, *Context* and *Values*, and a fifth, integrative dimension, *Management*, which focuses on how decisions and processes unfold over time. Rather than replacing existing conceptual frameworks, technology acceptance models or implementation frameworks, HITE extends and connects them by offering a cross-level perspective that links classroom design with institutional strategy and ethical commitments.

The paper outlines the five dimensions, illustrates their interrelations and discusses how the framework can be used by stakeholders in primary, secondary, vocational and higher education to structure reflection, support decision-making and plan context-sensitive, value-aware integration trajectories.

This chapter is based on:

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1. Introduction

Across educational systems worldwide – from primary and secondary schools to vocational colleges and universities – institutions are challenged to integrate digital technologies in ways that are pedagogically meaningful, organisationally sustainable, and socially responsible (Biesta, 2009, 2020a; Caird & Lane, 2015; Castañeda & Selwyn, 2018a; Consoli et al., 2023; Eynon et al., 2025; Fawns, 2022). Technology-enhanced education is now expected not only to support learning but also to reflect shifting societal values and priorities in what has been described as a postdigital condition, where digital technologies are taken-for-granted infrastructures entangled with social, political, and ecological concerns rather than novel add-ons (Jandrić & Knox, 2022; Knox, 2019; Selwyn & Jandrić, 2020). Yet, despite decades of innovation and investment, the integration of technology at institutional level remains difficult to sustain. In practice, efforts are often siloed across programmes and units, vary substantially by course and teacher, and fail to become embedded beyond time-limited pilots (M. Bond et al., 2019; Caird & Lane, 2015; Howard et al., 2019; Ley, 2020). This paper argues that sustainable and meaningful integration of technology requires an approach that explicitly links the micro-level interplay of technology and pedagogy at the classroom level with the meso-level of organisational structures, governance routines, and institutional values that mediate how educational practices are coordinated, resourced, and sustained (Geijsel et al., 2009; Giuffrida & Hall, 2023; Howard et al., 2019; Ley, 2020; Thoonen et al., 2012). Such alignment is essential to ensure that digital innovations contribute not only to learning goals of a single institution, but also to institutional coherence and broader social purposes (Biesta, 2009, 2020a; Caird & Lane, 2015; Fawns, 2022).

A key reason for the persistence of fragmented practice lies in the conceptual division that still characterises much research in technology-enhanced learning. Much of the literature continues to position innovation as either technology-driven or pedagogy-driven, implicitly separating what tools do from what teachers do and thereby under-theorising their interaction (Bayne, 2015; Fawns, 2022; E. Hamilton & Friesen, 2013). In response, Fawns (2022) argues that treating pedagogy as “driving” technology, or vice versa, constructs a misleading dichotomy and obscures how methods, technologies, purposes, values, and contexts are always mutually shaping within what he terms an entangled pedagogy (Fawns, 2022). Educational outcomes are not caused by tools or methods in isolation but emerge from complex “entanglements” of technologies, pedagogies, purposes, values, and contexts (Biesta, 2009; Fawns, 2022; E. Hamilton & Friesen, 2013). This view echoes Salomon’s (2000) early warning that neither side should allow “the technological tail to wiggle the educational dog,” nor should technology be “domesticated” into existing routines without meaningful pedagogical change. When technologies merely substitute previous tools, the result is trivial innovation and wasted resources (Bayne, 2015). What is needed instead is a form of reciprocal shaping in which pedagogical purposes and values guide how technologies are configured and used, while technologies, in turn, can open new pedagogical possibilities (Fawns, 2022; E.

Hamilton & Friesen, 2013). In this regard, Conole and Dyke (2004) clarify that technologies provide a set of learning affordances, such as accessibility, immediacy, diversity, communication, collaboration, and reflection, that shape what forms of pedagogical activity are possible (Conole & Dyke, 2004a). Crucially, these affordances are not inherent properties of the technologies themselves; rather, they emerge from the relationship between technological characteristics, users' capabilities, pedagogical intentions, and the wider educational context. Together, these perspectives underline that neither technological features nor instructional designs alone explain educational effects; meaningful integration requires examining how pedagogical and technological dimensions continuously shape one another within the broader social and organisational environments in which education takes place.

At the same time, the responsibility for integrating technology cannot rest solely with individual teachers. Teacher-centred frameworks such as Technological Pedagogical and Content Knowledge (TPACK) have substantially advanced understanding of the knowledge base required for teaching with technology and have motivated extensive work on assessing teachers' technological, pedagogical and content knowledge (Koehler & Mishra, 2009; Schmidt et al., 2009; Voogt et al., 2013), yet this research is usually operationalised at the level of individual teachers and their professional development, with organisational conditions treated more unevenly (M. Schmid et al., 2024; Voogt et al., 2013). When educators face chronic workload and resource constraints, their scope to experiment with tools or redesign curricula is shaped by organisational routines, infrastructure, support access, and policy alignment rather than competence alone (Hew & Brush, 2007; Howard et al., 2019; Petko, 2012; Thoonen et al., 2011). Evidence from school improvement research likewise underscores that leadership practices and school organisational conditions are decisive for sustaining change, yet these models typically remain generic with respect to how technology-related work becomes routinised in everyday practice (Geijsel et al., 2009; Hubers, 2020; Thoonen et al., 2012). Consequently, meaningful integration requires collective processes that distribute agency and responsibility across teachers, students, instructional designers, managers, and technical staff rather than locating it solely in individual teacher competence (Castañeda & Selwyn, 2018a; Howard et al., 2019; Tondeur et al., 2012).

Distinctions between initial uptake, routine use, and meaningful integration are therefore crucial. User-acceptance frameworks such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) help explain perceived usefulness and ease of use, but they remain largely agnostic about whether a technology is educationally warranted, aligned with institutional values, or socially desirable (Castañeda & Selwyn, 2018a; Davis, 1989; Venkatesh et al., 2003). Mid-range organisational implementation frameworks do address the organisational level more directly, including Diffusion of Innovations (DOI) as an organisational explanation of how innovations spread (Greenhalgh et al., 2004; Rogers, 2002), the Promoting Action on Research Implementation in Health Services framework (PARIHS) as a facilitation-oriented view of evidence, context, and facilitation (Rycroft-Malone, 2004; Rycroft-Malone et al., 2002), the Consolidated

Framework for Implementation Research (CFIR) as a determinant typology across inner and outer settings (Damschroder et al., 2009), and Normalization Process Theory (NPT) as a theory of the collective work through which practices become embedded (May et al., 2009; C. May, 2013; May & Finch, 2009). Education-specific organisational models such as the e-capacity model additionally specify school-level capacity conditions for sustainable ICT-related change (Vanderlinde & van Braak, 2010). However, even taken together, these organisational frameworks remain insufficient for the present problem because they are primarily designed to explain and organise how integration happens, not to determine whether integration should be initiated. They are comparatively purpose- and value-agnostic in educational terms, and they tend to operationalise sustainability as continued use or institutionalisation rather than as the deeper, multi-dimensional durability emphasised in education reform research (Coburn, 2003) and in implementation science debates on sustainment (Chambers et al., 2013; J. E. Moore et al., 2017; Wiltsey Stirman et al., 2012). This leaves an analytically and practically consequential gap at the organisational level: a framework may support facilitation of integration while still failing to test whether the proposed integration serves education-specific purposes.

This gap is amplified by institutional governance dynamics that shape technology-related decisions. In many institutions, platforms and infrastructures are configured through negotiations among administrators, technical units, and commercial providers, with downstream consequences for what teaching and learning can practically become (Fawns, 2022; Komljenovic et al., 2025). Recent work on digitalisation and platformisation shows how procurement and “lock-in” dynamics can prioritise financial metrics and operational efficiencies over educational relevance, while redistributing decision-making authority away from frontline educational actors (Kerssens & Dijck, 2022; Komljenovic, 2022; Komljenovic et al., 2025). In parallel, datafication can shift teacher work toward producing and maintaining institutional data infrastructures, with implications for teacher autonomy and professional judgement (Selwyn, 2021).

At the same time, educational institutions carry a societal mandate that extends beyond immediate instructional concerns. Schools, colleges, and universities shape the citizens, professionals, and cultural values of the future. They contribute not only to qualification but also to socialisation and subjectification, which makes questions of educational purpose unavoidable when evaluating whether technology integration is warranted (Biesta, 2009). Because digital infrastructures become embedded in the everyday organisation and governance of education, technology choices have long-term implications for how societies learn, communicate, and work (Castañeda & Selwyn, 2018a; Williamson, 2018). Meaningful integration therefore requires planning for multi-year horizons and asking what values, dispositions, and capacities are being cultivated in learners who will enter civic life and the labour market over the coming decades (Biesta, 2009). For integration to be socially responsible, day-to-day instructional choices need to remain connected to broader societal goals, such as, e.g. equality, right for education, inclusion, and democratic participation (Lozano-Díaz & Fernández-Prados, 2020).

The Holistic Integration of Technology in Education (HITE) Framework is proposed in response to the identified gap. Building on research that frames educational effects as emerging from entanglements of technologies, pedagogies, purposes, values, and contexts (Biesta, 2009; Fawns, 2022), and recognising that organisational capacity, governance arrangements, and long-term sustainment shape what educational actors can enact (Chambers et al., 2013; Coburn, 2003; Selwyn, 2021; Williamson, 2018), this paper takes a first step by conceptualising the core dimensions that should be addressed if meaningful integration is to be analysed at the organisational level.

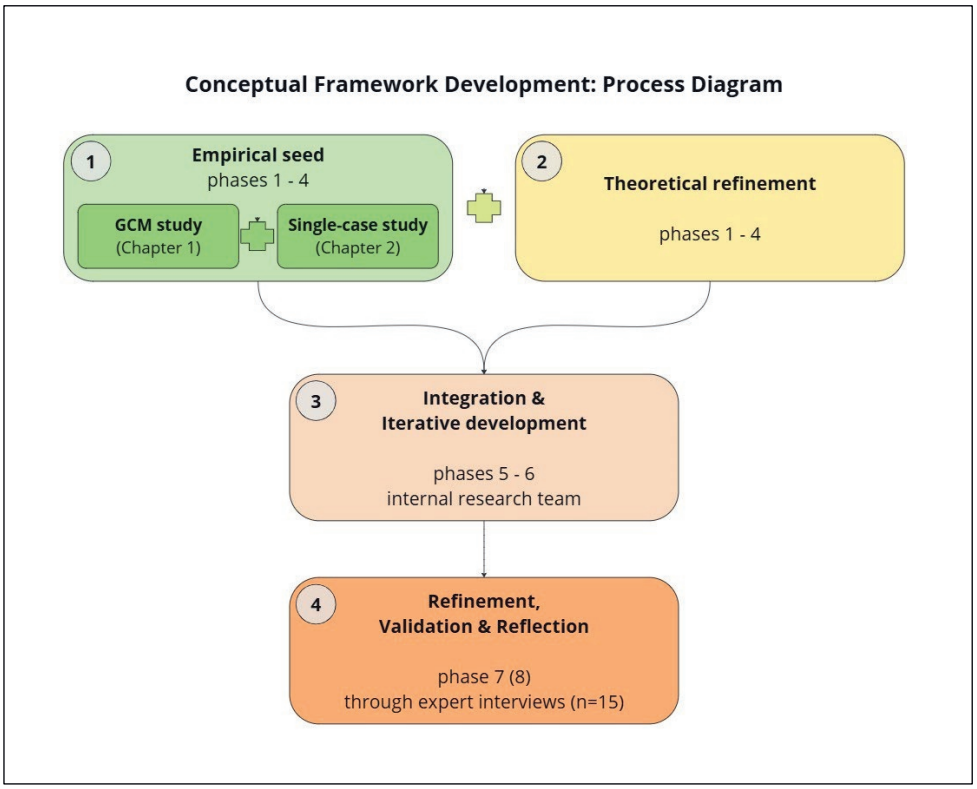
2. Development of the HITE Framework

The HITE framework was developed using Jabareen's (2009) qualitative methodology of conceptual framework analysis, which treats a conceptual framework as a network or plane of interlinked concepts constructed through iterative phases of (1) mapping selected data sources, (2) extensive reading and categorising, (3) identifying and naming concepts, (4) deconstructing and categorising concepts, (5) integrating concepts, (6) synthesising and re-synthesising them into a coherent framework, and (7–8) validating and rethinking the framework through external critique (Jabareen, 2009). In line with work that treats conceptual frameworks in educational technology as structured, theory-informed ways of clarifying key constructs and their relationships to guide analysis, rather than as descriptive lists of categories, the HITE Framework was developed by applying these phases to a combination of empirical and theoretical sources (Antonenko, 2015; Gregor, 2006; Ravitch & Riggan, 2016).

In phases 1 – 3 we drew on two linked empirical studies on the meaningful and scalable implementation of a desktop VR presentation tool Edison at the organisational level: a group concept mapping (GCM) study with stakeholders from two European universities (one distance-learning, one campus-based; (Holubinka et al., 2023) and an in-depth interview study in a European distance-learning university (Chapter 2). The GCM study, following standard procedures of brainstorming, sorting, rating, and multivariate analysis, yielded five stakeholder-generated clusters of requirements for institutional implementation: *Evaluation*, *Institutional Requirements, Maintenance and Training, Student Requirements, Affordances and Infrastructure* (Holubinka et al., 2023). An interview-based qualitative study at a distance-learning university examined stakeholder perspectives on the complex, interdependent factors shaping the meaningful and scalable integration of desktop VR technology within a single institutional setting (Holubinka et al., 2026). Using template thematic analysis informed by a critical realist perspective, the study identified five interdependent themes: *Context, Values, Technology, Pedagogy*, and *Management*. These themes capture clusters of factors that influence the meaningful integration of VR technology in the university setting. They also informed the initial architecture of the HITE framework (Brooks et al., 2015; Clarke & Braun, 2017; Fletcher, 2017).

Figure 1

Process Diagram for Conceptual Framework Development (Jabareen, 2009).



In phases 4 – 6 the empirically derived clusters and themes were analysed in terms of their attributes, underlying assumptions, and functional roles (Jabareen, 2009). Concepts were examined to determine whether they referred primarily to relatively stable contextual features (e.g., student population, institutional processes, infrastructure), normative commitments (e.g., equity, accessibility), technological characteristics, pedagogical patterns, or coordination and governance processes, and were subsequently grouped under the higher-order categories *Context, Values, Technology, Pedagogy,* and *Management*. Related concepts were then combined into sub-dimensions within each category, and the relationships among categories were iteratively specified and refined with the support of relevant literatures in educational technology, organisational learning, and implementation research, consistent with the view of conceptual frameworks as theory-based, evidence-informed arguments (Antonenko, 2015; Gregor, 2006; Ravitch & Riggan, 2016). Through these cycles of deconstruction, integration, and synthesis, the architecture of HITE stabilised as a five-dimensional framework in which *Context, Values, Technology, Pedagogy*, and *Management* are analytically distinct yet interdependent domains for analysing and guiding meaningful integration at the organisational level.

In phases 7 – 8 the consolidated framework was subjected to external critique and cross-contextual testing (Jabareen, 2009). Fifteen in-depth, semi-structured interviews were conducted with experts from multiple countries, institutional contexts, and technological domains (see Table 1). Expertise spanned technology-enhanced learning, educational design, didactics, organizational studies, media design, media and communication studies, school improvement, ethics in technology-enhanced learning, and value-sensitive design. Participants were invited to engage with HITE at a conceptual level (reviewing and critiquing definitions, boundaries, and relationships between dimensions) and/or at a practical level (applying the framework to contexts familiar to them and reflecting on its clarity, completeness, and usefulness for reasoning about meaningful, sustainable and scalable integration). Feedback was synthesised into targeted refinements including adjustments to terminology and sub-dimensions to enhance conceptual precision and usefulness. Interviews and revisions continued until no further substantive conceptual changes were proposed, indicating that the framework had reached a stable form suitable for presentation and further empirical application (Jabareen, 2009).

Table 1

Characteristics of Expert Interviews Used to Validate the HITE Framework

Aspect	Description
Participants	15 experts with experience in technology-enhanced learning and teaching,
Countries represented	Netherlands (n = 6), Germany (n = 3), Switzerland (n =2), Denmark (n = 1), Spain (n = 1), Belgium (n = 1), Australia (n = 1).
Educational contexts	Higher education (campus-based (n = 10) and distance (n = 2)), K-12 education (n = 3)
Technology domains	Immersive VR, chatbots based on large language models (e.g., ChatGPT), AI-powered tools for generating multiple-choice questions, AI-supported presentation-skills tutor tools; Learning Management Systems (LMS)
Roles and expertise profiles	Early-career researchers with focused expertise in specific application or theoretical domains (n = 6); mid-career researches with established research in their field (n = 3); seasoned researchers with long-standing expertise and experience (n = 6).

Note: For privacy reasons, participant characteristics are reported in aggregate and selectively. Combined reporting is designed to avoid de-anonymising individual experts.

Through the application of Jabareen's (2009) phases, HITE was developed as an empirically grounded and theory-informed conceptual framework. Its empirical basis comprised a linked group concept mapping study and a single-institution interview case study, which informed the selection, definition, and relational structuring of the framework's dimensions (Jabareen, 2009). The resulting framework is presented as an analytic instrument for organising inquiry into meaningful integration of technology at the organisational level by clarifying core concepts and their inter-relations, rather than a static classification of factors (Antonenko, 2015). Accordingly, HITE provides

an initial conceptual basis for subsequent empirical refinement and, in later work, for theory for design and action efforts at the institutional level (Gregor, 2006).

3. The HITE framework

The HITE framework provides a meso-level structure for aligning pedagogical, technological, contextual, and managerial processes that enable meaningful integration of technology in an educational institution. It is termed “holistic” because it brings together multiple dimensions (Context, Technology, Pedagogy, Values, Management) and stakeholder perspectives (teachers, students, designers, managers, technical staff) into a single workflow, rather than treating technology integration as a purely technical, pedagogical, or managerial issue. Designed to be technology-agnostic and applicable in various educational settings, the framework comprises five interdependent dimensions: Context, Pedagogy, Technology, Values, and Management, each addressing a specific guiding question. The Context dimension defines *where* integration occurs by considering stakeholder profiles, teaching and learning processes, and available infrastructures. The Technology dimension specifies *what* is being integrated, focusing on technological affordances, learning benefits, and potential risks or constraints. The Pedagogy dimension explains *how* technology supports learning through established learning theories and instructional design models that align goals, activities, and feedback. The Values dimension clarifies *why* integration should take place by making explicit the ethical, epistemic, and cultural orientations that guide educational decisions. Finally, the Management dimension outlines the workflow for integration and the way it can be coordinated and sustained through iterative evaluation, communication among stakeholders, and strategic alignment across the other dimensions. Together, these dimensions form a coherent and adaptable structure that can support the process of designing, implementing, and maintaining technology integration on the institutional level that is pedagogically grounded, contextually appropriate, and ethically informed.

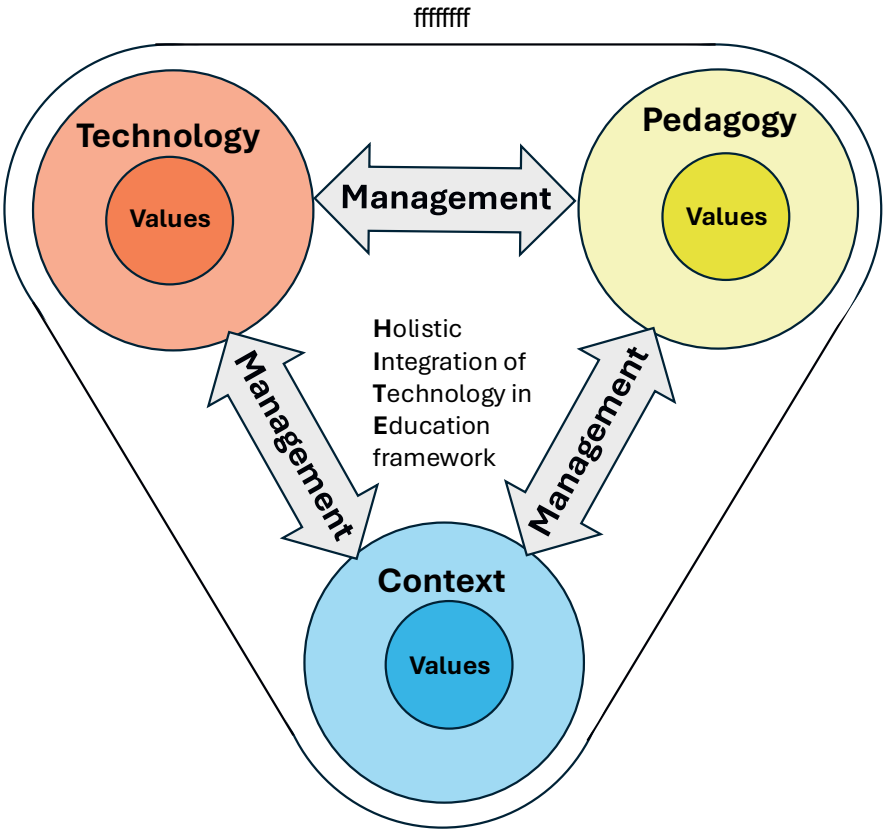
3.1. Context Dimension

The Context Dimension defines the *where* of meaningful technology integration. It delineates the institutional and organizational environment within which teaching, learning, and technology integration take place. While micro-level pedagogical decisions determine how technology mediates learning activities, the meso-level organizational structures, resources, and working cultures determine whether such innovations can be meaningfully sustained and adopted across the institution. The context thus encompasses the institutional ecology in which technology is embedded: the constellation of stakeholders and their interrelations, the established teaching and learning processes, and the material and digital infrastructures that enable or constrain educational practices. In this dimension, meaningful integration is understood not as the isolated use of technology by individual teachers, but as an organizational capability shaped by the interplay between human agency, institutional strategy, and infrastructural readiness. Accordingly, the Context

Dimension is structured around three interrelated subdimensions: *Stakeholder Profile, Teaching and Learning Processes*, and *Existing Infrastructure***,** which together outline the institutional conditions under which technology becomes part of educational practice.

Figure 2

A visual representation of the *HITE framework*.



3.1.1. Stakeholder Profile

Understanding the institutional context of technology integration begins with mapping the diverse stakeholder profiles that define educational practice. Each stakeholder group – teachers, students, instructional designers, technical staff, and institutional managers – brings specific purposes, competencies, motivations, and accessibility needs that collectively shape the trajectory of meaningful integration. This subdimension examines how individual and collective characteristics interact with institutional conditions by considering stakeholders' prior experience with technology, their skills and available devices, their motivations and perceived value

of use, as well as the limitations, side-effects, and practical constraints that collectively determine how technology becomes embedded in practice.

Drawing on ecological perspectives on learning environments (Bateson, 2019; Biesta, 2015), the institution can be conceptualized as a multilayered system in which individual capabilities, pedagogical routines, and structural arrangements continuously interact. Within this ecosystem, each stakeholder group contributes distinct technological skills, levels of experience, and access to devices and connectivity, which define the practical feasibility of integration (van Deursen & van Dijk, 2011; Compeau & Higgins, 1995). Their motivations and expected value, ranging from improved learning outcomes and workload efficiency to inclusivity or institutional prestige, shape whether technologies are perceived as supportive or disruptive to existing work processes (Eccles & Wigfield, 2002). Equally, limitations and constraints, such as time, training availability, policy requirements, or accessibility barriers, influence the extent to which innovations can be equitably adopted (Cinquin, Guitton, & Sauzéon, 2019).

Importantly, each stakeholder group also embodies particular values, priorities and concerns that orient their potential use of technology. For example, students may prioritise usability and fairness, teachers may emphasise pedagogical effectiveness and workload balance, while institutional managers may focus on coherence, accountability, and sustainability. Mapping these diverse priorities makes visible where technology aligns with established institutional purposes and where tensions emerge. Such mapping also establishes a foundation for subsequent value alignment – a process of reconciling educational, ethical, and organizational considerations across groups to ensure that technology serves collectively defined aims rather than isolated interests.

3.1.2. Teaching and learning processes

The second subdimension of the Context Dimension concerns the teaching and learning processes that act as baseline conditions for how learning is organised in the institution, including the way interaction, guidance, practice and feedback are typically structured (Garrison et al., 1999; Garrison & Kanuka, 2004; M. G. Moore, 1989; Nicol & Macfarlane-Dick, 2006). These processes constitute the pedagogical system into which any new technology must be situated, and they therefore shape both the practical feasibility and the conceptual boundaries of meaningful integration (Garrison et al., 1999). They encompass the type of learning content, the mode of delivery and guidance, and the approach to assessment, all of which are framed by the institution's overarching educational model and its assumptions about how learning occurs. In practice, this includes how interaction and communication, teaching presence, and learner support are organised across time and settings.

Institutions differ widely in their dominant forms of organization. Some emphasize synchronous, teacher-guided interaction that relies on immediate communication and co-presence, whereas others favour asynchronous, self-paced learning, which prioritizes learner autonomy and temporal flexibility (Garrison et al., 1999; M. G. Moore, 1989). These arrangements are often interwoven with blended configurations, where digital and in-person components alternate or complement

each other (Garrison & Kanuka, 2004). Similarly, assessment practices – whether formative, summative, or competency-based – reflect not merely evaluation methods but underlying beliefs about learning progression, accountability, and feedback (Black & Wiliam, 1998; Hattie & Timperley, 2007; Nicol & Macfarlane-Dick, 2006). Mapping these modes and practices clarifies the expectations that structure the learning experience, regardless of technological mediation.

The type of learning content further defines the instructional context. Content may be predominantly textual, visual, procedural, or experiential, and each form carries implications for how knowledge is represented, sequenced, and assessed (Ainsworth, 2006; R. E. Mayer & Moreno, 2003). The TPACK framework highlights that effective educational design depends on the alignment among content characteristics, pedagogical strategies, and potential technological means (Mishra & Koehler, 2006). In this context, the relevance of any technological affordance or hypothesized learning benefit can only be meaningfully judged in relation to these pre-existing forms of content and instructional practice and the actions demanded by the learning task (Biggs, 1996; Mishra & Koehler, 2006). Institutions typically draw on their own established repertoires of learning theories and instructional design models, whether explicitly codified or implicitly embedded in local teaching cultures, and these provide the conceptual background against which instructional practices are interpreted (Merrill, 2002; Reiser, 2001a, 2001b).

Finally, every institution operates within an overarching educational model that articulates what it counts as good teaching and meaningful learning, for example prioritising structured explanation and guided practice, inquiry-oriented learning with scaffolding, collaborative knowledge building, or competency-based progression (Biesta, 2009; Biggs, 1996; Kirschner et al., 2006). Such an institutional model is never arbitrary: it rests on a usually implicit combination of learning theories and instructional or educational design models that shape how courses are structured, how feedback and assessment work, and how responsibilities are distributed between teachers, students, and support staff (Biesta, 2009; Biggs, 1996; Merrill, 2002; Reiser, 2001a). Yet these theoretical and design choices are rarely made explicit, and the underlying rationale – why certain approaches were chosen, how they are expected to work, and what kinds of outcomes they privilege – often remains taken for granted and may remain tacit when practices are sustained through local teaching cultures and informal professional exchange (Roxå & Mårtensson, 2009). Making this rationale visible is crucial so that all stakeholders share a common understanding of how the institution “does” teaching and learning, and so that technology integration can be woven into existing practices and methods rather than being pushed onto them as a separate or siloed layer. In the HITE Framework, the Context dimension therefore calls for institutions to articulate the learning theories and instructional design models that underpin their educational model and to connect this analysis with the Pedagogy dimension, where these theoretical and design repertoires are examined more explicitly as inputs into technology-related decision-making (Biggs, 1996; Merrill, 2002; Mishra & Koehler, 2006).

3.1.3. Existing Infrastructure

When discussing technology integration, institutional infrastructure is often treated as a self-evident backdrop. Yet what appears obvious to those working within an organization may remain invisible to external stakeholders or technology providers. A head teacher or university rector operates within an established ecosystem of practices, facilities, and regulatory boundaries, whereas a technology provider typically presents a generic, decontextualized solution. For any educational technology to function meaningfully, this contextual gap must first be made explicit. Explicating the existing infrastructure is therefore an essential step in aligning technological possibilities with institutional realities. Without such alignment, even promising tools risk becoming ineffective, costly, or ethically problematic once embedded in everyday operations.

The third subdimension of the Context Dimension concerns the existing infrastructure that supports teaching and learning across the organization. Infrastructure determines the material and procedural feasibility of any educational innovation and reflects the degree to which technological and human systems are aligned. It encompasses three interrelated elements: hardware and facilities, software ecosystem and integration processes, and staff expertise.

Hardware and facilities constitute the most tangible layer of the institutional environment. These include physical learning spaces, network capacities, and digital or analog equipment ranging from low-technology classrooms to advanced laboratory or simulation settings. Infrastructure should be understood along a continuum – from minimal, low-tech configurations that rely on general-purpose devices to highly specialized environments that require dedicated maintenance and investment. Mapping this continuum helps identify not only the technical readiness of an institution but also its resilience and adaptability, clarifying whether new initiatives can be sustained within existing resources or demand infrastructural expansion.

The software ecosystem defines the digital architecture through which educational activities are organized. This ecosystem may comprise learning management systems, communication platforms, assessment tools, and various discipline-specific applications. Equally important are the institution's integration and governance policies, which regulate interoperability, data management, and external software approval. Some institutions maintain tightly coupled systems that require formal integration and institutional approval before use; others permit more decentralized experimentation with third-party tools. Understanding these integration practices is crucial, as they reveal the balance between institutional control, security, and pedagogical flexibility. The organization's stance on data protection, accessibility compliance, and interoperability standards determines the extent to which new technologies can be meaningfully embedded without disrupting existing workflows.

Finally, staff expertise represents the human dimension of infrastructure. The availability of in-house competence, for example, in instructional design, media production, accessibility assurance, or learning analytics, defines how effectively hardware and software can be utilized for pedagogical purposes. Expertise mapping

involves identifying both specialized technical roles and pedagogical design capacities distributed across departments. Institutions with strong internal support networks and professional development structures can adapt more readily to innovation, while those with fragmented or under-resourced expertise often face implementation bottlenecks even when hardware and software are available. In this respect, human capability is not merely a supplement to infrastructure but an essential component of it.

3.2. Pedagogy Dimension

The Pedagogy dimension of the HITE Framework provides the *static theoretical and evidence base* that informs all design and implementation decisions. It constitutes a reservoir of accumulated knowledge on how learning occurs, how cognition interacts with media, and how learning experiences can be intentionally structured. Within the framework, pedagogy functions as the theoretical backbone connecting technology and context: it guides how digital tools are used to achieve epistemic, cognitive, and social learning goals (Biesta, 2009). As such, pedagogy represents not a set of prescriptive methods but an evolving repertoire of learning theories and instructional design models from which appropriate combinations are drawn for specific institutional or technological contexts (Dron, 2022; Fawns, 2022).

Pedagogy is also inherently value-laden. Each theoretical position implies particular assumptions about the nature of knowledge, the role of the learner and teacher, and the purposes of education (Biesta, 2010). Behaviourist approaches, for instance, emphasise control and efficiency, reflecting instrumental values of measurement and standardisation; constructivist and sociocultural perspectives, in contrast, privilege autonomy, collaboration, and meaning-making, expressing democratic or emancipatory orientations (Freire, 1970; Dewey, 1938). Hence, while the Values dimension of the framework treats ethical and institutional values explicitly, pedagogical orientations already carry implicit normative commitments that must be recognised and negotiated during design.

In the HITE Framework, the role of the Pedagogy dimension is therefore not to teach, compare, or prescribe particular learning theories or instructional design models, but to make explicit that theoretically informed work is indispensable for meaningful technology integration. The framework highlights that expert consideration of how learning is expected to happen – and how outcomes, activities, assessment, and technological affordances can be constructively aligned – must precede major integration decisions (Biggs & Tang, 2011). It does not replace specialised training in instructional design or learning sciences; instead, it ensures that this existing body of knowledge is systematically brought into institutional decision-making about technology, and that such analysis is carried out by qualified experts before tools, platforms, or configurations are selected. To support this process, the Pedagogy dimension points users to two non-exhaustive knowledge reservoirs: families of learning theories and families of instructional and educational design models, which serve as reference points for aligning pedagogical intent, technological affordances, and contextual conditions.

3.2.1. Learning Theories

Learning theories provide the foundational grammar of pedagogy – the conceptual explanations of how people acquire, process, and apply knowledge. Below we list several influential families of learning theories, offered as a non-exhaustive overview intended to support further deepening rather than to prescribe or limit theoretical choices.

Behaviourism (Thorndike, 1913; Skinner, 1953) views learning as the acquisition of new behaviours through reinforcement and conditioning. Its value stance emphasises control, predictability, and efficiency—principles that remain relevant for procedural learning or adaptive practice sequences.

Cognitivism (Atkinson & Shiffrin, 1968) shifted attention to internal processes such as attention, memory, and schema formation. Building on this, the Cognitive Load Theory (Sweller, 1988) and the Cognitive Theory of Multimedia Learning (Mayer, 2001; Clark & Mayer, 2016) specify how instructional materials should manage intrinsic, extraneous, and germane load through design principles such as signalling, segmentation, and contiguity.

Constructivist and complexivist perspectives (Piaget, 1970; Davis & Sumara, 2006) regard learning as active sense-making within emergent systems; they inform learner-centred and exploratory designs.

Sociocultural and activity-theoretical accounts (Vygotsky, 1978; Engeström & Sannino, 2010) frame learning as participation in culturally mediated practices, with emphasis on collaboration, dialogue, and tool mediation.

In parallel, *ecological* and *distributed-cognition* perspectives (Gibson, 1979; Clark, 2008; Norman, 1993) conceptualise knowledge as extended across minds, artefacts, and environments, introducing the notion of affordances—the action possibilities a setting offers to particular learners.

Finally, *critical-pedagogical* and *pragmatist* traditions (Freire, 1970; Dewey, 1938) highlight reflection, agency, and the social purposes of education. Together, these theories constitute a multi-layered foundation that allows designers to articulate why specific technological and pedagogical configurations are meaningful in a given context.

3.2.2. Instructional and Educational Design Models

While learning theories explain *how* learning occurs, instructional design models provide structured approaches for *organising* and *orchestrating* learning experiences. They translate theoretical assumptions into sequenced activities, roles, and feedback mechanisms. Within the HITE Framework, these models form the methodological repertoire from which educators and designers can select when aligning pedagogical intent with technological affordances and contextual conditions (Laurillard, 1993; Goodyear & Carvalho, 2014).

Behaviourist-inspired models such as *Programmed Instruction* and *Mastery Learning* emerged in the mid-twentieth century from the work of Thorndike (1913), Skinner (1954, 1958), and Bloom (1968). Both emphasise clearly defined objectives, sequenced tasks, and continuous feedback to shape desired behaviours.

Programmed instruction relies on immediate reinforcement through stepwise progress, while mastery learning introduces corrective loops and formative assessments to ensure each learner achieves competency before moving forward (Guskey, 2007). These models remain valuable for procedural or skills-based learning where precision and practice are central, and they underpin later design frameworks such as *Gagné's Nine Events of Instruction* (Gagné, 1985).

Cognitivist models built on information-processing views of learning by emphasising internal structures and cognitive efficiency. *Gagné's Conditions of Learning* established the link between different learning outcomes and instructional events (e.g., gaining attention, providing feedback). Later developments such as *Cognitive Load Theory* (Sweller, 1988) and the *Cognitive Theory of Multimedia Learning* (Mayer, 2001; Clark & Mayer, 2016) expanded this logic to digital media, highlighting how signalling, segmentation, and modality can reduce extraneous load and enhance schema construction. In instructional practice, these principles inform tutorial design, e-learning modules, and other structured learning sequences where clarity and efficiency are valued.

Constructivist and complexivist approaches shifted focus from transmission to learner agency. Rooted in Piagetian and Deweyan traditions, *Inquiry-based*, *Problem-based*, and *Project-based Learning* situate knowledge construction within authentic contexts and collaborative exploration (Barrows & Tamblyn, 1980; Blumenfeld et al., 1991; Hmelo-Silver, Duncan, & Chinn, 2007). These models value iterative experimentation, reflection, and the co-construction of meaning, often supported by scaffolding to prevent cognitive overload (Kirschner, Sweller, & Clark, 2006). They align particularly well with complex, ill-structured domains and with learning designs emphasising autonomy and transfer.

Sociocultural and activity-theoretical models such as *Cognitive Apprenticeship* (Collins, Brown, & Newman, 1989) and *Expansive Learning* (Engeström & Sannino, 2010) interpret learning as participation in culturally mediated practices. The teacher's role shifts toward guiding participation, modelling expert behaviour, and facilitating reflection within communities of practice. Such models have informed design-for-learning methodologies that configure tasks, social structures, and tools into coherent "learning architectures" (Goodyear & Carvalho, 2014).

Ecological and distributed-cognition perspectives highlight how cognition extends across people, artefacts, and environments (Gibson, 1979; Norman, 1993; Clark, 2008). Instructional designs grounded in these perspectives emphasise affordance-rich environments and tool configurations that support perception–action coupling and shared problem-solving. They inform learning spaces, simulations, and mixed-reality environments that leverage contextual cues and multimodal interaction.

Critical-pedagogical and pragmatist traditions, drawing on Freire (1970) and Dewey (1938), foreground the ethical and social dimensions of design. *Dialogic pedagogy* and *praxis-based inquiry* engage learners in questioning, reflection, and transformative action within authentic social contexts. Here, instructional design involves cultivating participatory, democratic processes rather than prescribing fixed sequences.

Finally, integrative models such as Laurillard's Conversational Framework (1993) and Teaching-as-Design / Design-for-Learning (Goodyear & Ellis, 2008; Goodyear & Carvalho, 2014) cut across paradigms. They view teaching as iterative dialogue or design configuration, aligning conceptual understanding with experiential activity. Complementary to these are evidence-based media and message design principles from multimedia learning (Mayer, 2001; Clark & Mayer, 2016), which ensure cognitive and technological alignment.

Pedagogical design is strongest when the instructional approaches and learning activities used are consistent with the learning theories that underpin them, so that intended learning outcomes, teaching methods, assessment, and feedback are constructively aligned (Biggs, 1996; Laurillard, 2013; Shulman, 1986). Familiarity with these theoretical and methodological traditions enables educators, instructional designers, institutional leaders, and technology developers to select and adapt models such as mastery learning, worked-example instruction, problem- and project-based learning, and cognitive apprenticeship in ways that are appropriate to their disciplinary aims and local conditions (Barrows & Tamblyn, 1980; Bloom, 1968; Collins et al., 1989; Goodyear & Carvalho, 2019; Sweller & Cooper, 1985). The examples provided are therefore illustrative rather than exhaustive, but they underscore a central point: pedagogical configurations should be grounded in a clearly articulated theoretical rationale, rather than assembled from methods that are only loosely connected to assumptions about how learning takes place.

3.3. Technology Dimension

The technology dimension of the HITE Framework concerns how educational technologies afford particular actions and experiences that may, within a specific pedagogical and contextual configuration, become *hypothesised learning benefits*. Technology is therefore not an autonomous driver of learning but a set of material, digital, and procedural arrangements that offer possibilities for action within specific institutional and pedagogical systems. The analysis of technology thus begins not with what a tool *is*, but with what it *enables* teachers and learners to do in situated practice (Fawns, 2022; Salomon, 2000). In this framework, meaningful integration requires that technological opportunities are interpreted through educational purposes rather than through functional novelty.

3.3.1. Technological Affordances

In the HITE Framework, technological affordances refer to the action possibilities that educational technologies make available to teachers and learners as they enact specific tasks within contexts. The term builds on Gibson's ecological view of affordances as the opportunities for action that arise from the relationship between an actor and the environment (Bornstein & Gibson, 1980; Gibson, 1979), and it aligns with later work that clarifies how affordance language is used to explain technology-enabled action (Evans et al., 2017). In software design, the functions that users can actually invoke represent the affordances of the technology, while perceived affordances concern how clearly those possibilities are communicated through the interface (McGrenere & Ho, 2000) and how interfaces support users in noticing and

interpreting what can be done (Hartson, 2003). In educational technology research, this idea has been extended to describe the match between the affordance requirements of learning tasks and the technological affordances of ICT tools (Dalgarno & Lee, 2010, building on Bower, 2008). The focus is therefore not on listing system features, but on understanding what a technology enables its users to do that is educationally meaningful. Fowler (2015) emphasises that these technical possibilities only gain pedagogical value when they are aligned with clear learning objectives, while Fawns (2022) reminds us that such possibilities are always shaped by social and contextual factors. Taken together, these perspectives position technological affordances as meaningful opportunities for action that emerge within particular pedagogical, institutional, and cultural settings.

Building on this line of scholarship, earlier work has proposed conceptual taxonomies to describe the types of possibilities that ICTs tend to make available in educational settings. Conole and Dyke (2004), for example, identified a series of characteristic affordances through which ICTs can expand, reshape, or constrain learning opportunities. Their taxonomy highlighted the ways in which technologies mediate access to information, support communication and collaboration, enable new representational forms, and structure knowledge-building practices. Importantly, they emphasised that these affordances operate as both opportunities and constraints, and that their educational value depends on how they are situated within pedagogical, institutional, and cultural contexts. Incorporating such perspectives reinforces the idea that affordances are relational and socio-historically situated, rather than inherent properties of technological artefacts. Taken together, this body of work positions technological affordances as context-dependent possibilities for action whose relevance emerges from the interplay between technological design, pedagogical purpose, and institutional conditions.

3.3.2. Hypothesised Learning Benefits

Moving from technological affordances to hypothesised learning benefits involves linking what a technology makes possible with what a learning design aims to achieve. Prior research shows that this link is not linear but relational, depending on how technological, pedagogical, and contextual factors interact. Fawns (2022) describes educational activity as *entangled*: technologies, teaching methods, institutional structures, and values continually shape one another. Any benefit attributed to technology therefore emerges from how these elements are combined and enacted in practice, not from the tool alone. The analysis of learning benefits should thus focus on how technologies and pedagogical strategies *work together* to create opportunities for meaningful learning.

This view echoes Salomon's (2000) argument that the educational value of technology depends less on its technical capacity than on how teachers and institutions choose to employ it. Each proposed benefit should therefore begin as a pedagogical hypothesis: given specific learning goals and conditions, certain technological affordances are *expected* to enhance engagement, understanding, or collaboration. Formulating such hypotheses makes explicit the reasoning that

connects technological potential to educational purpose and allows those expectations to be tested and refined through evidence.

3.3.3. Risks, Constraints, and Unintended Consequences

Analysing technological affordances also requires recognising the constraints and unintended consequences that accompany their educational use. As Dron (2021) observes, educational technologies often function as *Faustian bargains*: every new capability introduces new dependencies, trade-offs, and constraints. Technologies are never neutral – they embody particular assumptions, priorities, and power relations that shape how teaching and learning are organised (p. 160). For example, systems that promise efficiency or surveillance may simultaneously reduce autonomy, trust, or opportunities for dialogue (Fawns, 2022). Salomon (2000) likewise cautioned against *technocentrism*, urging that technological choices be guided by educational values rather than by the lure of technical possibility. These perspectives collectively invite a reflective stance that treats technological integration not only as a process of enabling new forms of learning but also as one of negotiating compromises and ethical tensions.

Within the HITE Framework, this tension is addressed by conceptualising technology integration as an iterative, research-informed process that distinguishes exploratory piloting from wider institutional uptake. Rather than treating integration as a one-off decision, the framework assumes that potential learning benefits are first articulated as theoretically grounded hypotheses, informed by existing learning theories, evidence from comparable contexts, and an analysis of the relevant technological affordances. These hypotheses are then examined through small-scale pilots or design-based research cycles in authentic settings, allowing systematic investigation not only of targeted learning outcomes but also of side effects for workload, equity, and organisational processes (McKenney & Reeves, 2018; Wang & Hannafin, 2005). On this basis, decisions about scaling up, redesign, or discontinuation can be made with reference to converging theoretical and empirical indications rather than to fragmented short-term outcomes alone. In this way, the HITE Framework does not prescribe whether a given technology should be adopted, but offers a structure for auditing hypothesised benefits and risks before large-scale investment, framing integration as a negotiated and evidence-informed process rather than a deterministic response to innovation.

Because technological affordances operate within institutional, cultural, and cognitive ecologies, their analysis must extend beyond the benefits they promise to the constraints and potential risks they entail. The same relational complexity that makes technologies educationally valuable also renders their effects unpredictable: when affordances interact with cognitive processes, social dynamics, or institutional structures, they can generate both productive and problematic outcomes. Empirical and conceptual studies across diverse educational technologies have demonstrated this duality, showing that the same affordances that enable learning can also introduce unintended challenges. For instance, immersive or high-fidelity environments may impose excessive cognitive load, leading to distraction or superficial engagement when realism exceeds instructional need (Fowler, 2015;

Dalgarno & Lee, 2010). Similarly, poorly specified or false affordances – when users misinterpret interface cues – can increase extraneous processing and hinder task performance (McGrenere & Ho, 2000). Motivational affordances can also backfire: the pursuit of engagement or novelty may prioritise entertainment over learning, producing short-term interest without deeper understanding (Salomon, 2000; Fawns, 2022). Collaborative platforms introduce further tensions, as coordination demands, unequal participation, or poorly aligned assessment can diminish the intended benefits of social interaction (Strijbos, Martens, & Jochems, 2004; De Hei, Donche, & Van Petegem, 2016). At a systemic level, Dron (2021) reminds us that technologies act as *Faustian bargains*: each new capability introduces dependencies on infrastructure, data governance, and technical support. Without adequate organisational capacity and professional development, even promising tools can generate inequities or institutional fragility. These examples underscore the need for analyses that bridge micro-level pedagogical design and meso-level organisational readiness, recognising that technological outcomes emerge from the ongoing interplay of cognitive, social, and institutional factors (Reiser, 2001; Fawns, 2022).

3.4. Values Dimension

The Values dimension articulates the normative commitments that underlie meaningful integration. Values capture the *why* of educational practice – why teaching and learning are conducted the way they are believed they should be. As early as 1951, Kluckhohn defined a value as a belief, whether implicit or explicit, that guides the selection among available modes, means, and ends of action. Within education, values can therefore be understood as beliefs about what matters in learning and teaching, encompassing ideals, standards, and principles of intrinsic worth (Collinson, 2012; Fawns, 2022). While such commitments are inherent to education, they are often implicit, particularly in systems that privilege measurement and standardisation (Harland & Pickering, 2010). Making them explicit is therefore essential for maintaining the capacity to interpret, adapt, and steer educational practice in purposeful ways (Biesta, 2009).

Values operate dynamically across societal, institutional, and personal levels (Swanson, 1999; Garst et al., 2021). They inform decisions, shape organisational cultures, and influence the design and use of educational technologies, yet they are also reciprocally shaped by these same technologies. To capture this interplay, the HITE Framework adopts Value Sensitive Design (VSD) as a guiding orientation (Friedman & Hendry, 2019; Winkler & Spiekermann, 2018). VSD treats values not as abstract ideals but as design requirements, investigated conceptually (clarifying relevant values), empirically (understanding stakeholder priorities), and technically (translating values into system features and governance mechanisms). This approach aligns with the framework's multi-level structure, where values guide action across macro, meso, and micro layers. Across these levels, values serve as the connective tissue of meaningful integration. They provide normative orientation at the societal or macro level, institutional coherence at the meso level, and personal authenticity at the micro level. Guided by VSD, the Values dimension ensures that decisions about technology, pedagogy, context, and management remain anchored

in explicitly deliberated commitments, allowing educational organisations to steer digital transformation not only by efficiency or novelty but by what they collectively deem to be educationally and ethically *good*.

3.4.1. Embeddedness of Values Across Technology, Pedagogy and Context Dimensions

Although the *Values* dimension provides a conceptual foundation for meaningful integration, values cannot be separated from the other dimensions of the HITE Framework. They are inherently embedded within the processes, practices, and artefacts that constitute the other dimensions of the framework – Technology, Pedagogy, and Context. Each of these dimensions carries its own value assumptions and enacts particular priorities, often implicitly. Examining these assumptions is essential for understanding how educational technologies and organisational systems can support, distort, or transform the purposes of education.

From the perspective of VSD (Friedman & Hendry, 2019; Winkler & Spiekermann, 2018), values are realised through design choices, institutional policies, and pedagogical practices that privilege certain aims and constrain others. This means that values are not abstract ideals to be applied after technological or pedagogical decisions have been made; they are integral to how such decisions are conceived and implemented. Educational technology scholarship similarly cautions against treating technology as value-neutral and instead foregrounds how educational practices are shaped by social, cultural, and political conditions (Selwyn, 2010). Fawns (2022) similarly argues that pedagogy, technology, and context form an *entangled* relationship, in which values are continuously enacted and interpreted. Recognising this interdependence helps to move beyond instrumental or sequential models of integration toward a more relational understanding of educational change.

The embeddedness of values can also be understood through socio-technical and institutional theories. Socio-technical systems theory (Trist & Bamforth, 1951; Mumford, 2006) emphasises the need for alignment between social and technical subsystems, suggesting that any modification of technological structures entails a corresponding adjustment in human roles and organisational norms. Institutional theory further explains how norms, rules, and cultural expectations shape organisational behaviour and legitimise particular forms of practice (Scott, 2014). Together, these perspectives illuminate how educational institutions mediate between societal expectations and pedagogical realities, translating collective values into the concrete mechanisms of teaching and technology use.

3.4.2. Embeddedness of Values in the Context Dimension

Values do not operate in a vacuum; they are shaped and enacted across multiple layers of the educational ecosystem. Understanding how values emerge and interact at the societal, institutional, and individual levels is essential for a context-sensitive account of any meaningful integration. As Biesta argues, educational decisions are never merely technical but always normative, embedded in wider cultural and political assumptions about what education is for and what constitutes a good or worthwhile outcome (Biesta, 2009, 2010). Values are embedded in every subdimension of the educational context: within stakeholder profiles, institutional

processes, and infrastructural arrangements, and they shape what an institution perceives as legitimate, desirable, or possible. Below, we situate values within their contextual layers and review how each layer conditions the process of technology integration.

Societal Level. Societies differ in their cultural, historical, political, economic, and religious trajectories, and therefore carry distinct normative commitments that shape what is perceived as "right," "good," or "desirable" in education. These societal orientations influence expectations of schooling, conceptions of citizenship, and the purposes technology should serve. Cross-cultural research shows that collectivist societies often emphasise social cohesion, relationality, and interdependence in educational design, whereas individualistic societies prioritise autonomy, personal achievement, and individual rights (Schwartz, 2007, 2011) (Hofstede, 2001; Markus & Kitayama, 1991; Triandis, 1995; Schwartz, 2006; House et al., 2004). Similarly, democratic political cultures may emphasise critical inquiry, deliberation, and participatory agency, while more authoritarian political contexts may frame education as socialisation into conformity, loyalty, or national ideology (Torney-Purta et al., 2010; Banks, 2008; Osler & Starkey, 2010; Davies, 2008). These differences influence how societies define educational purpose – as economic competitiveness, nation-building, democratic citizenship, moral formation – and therefore which values guide technology selection and use. Societal values also affect public tolerance for surveillance, datafication, commercialisation, and AI-mediated decision-making (Selwyn, 2019; Williamson, 2017; Zuboff, 2019). Values shape not only *what* technologies are chosen but *why* they are integrated: to expand participation, increase oversight, promote competitiveness, preserve cultural identity, or safeguard vulnerable groups. Technology integration is thus inseparable from broader societal debates about public purpose, equity, identity, and the long-term horizon of what kind of society education is meant to shape.

Responsible Innovation scholarship argues that these societal value frameworks are not peripheral but central to evaluating the desirability and legitimacy of technological futures. Stilgoe, Owen, and Macnaghten conceptualise *Responsible Innovation* as collective "care for the future," requiring anticipation, reflexivity, inclusion, and responsiveness as mechanisms for aligning innovation trajectories with societal values and expectations (Stilgoe et al., 2013). These values are not static; they evolve in response to crises, demographic shifts, and public debates, requiring institutions to maintain openness to value contestation and change.

In parallel, VSD and responsible innovation studies show that societal values often give rise to value conflicts – both inter-value (e.g., equity vs. efficiency) and intra-value (different interpretations of how a single value should be realised) – which must be explicitly navigated rather than assumed away (Garst et al., 2021). Educational technologies thus carry social constitutions: implicit assumptions about what students should become, how teachers should act, and what educational systems are for.

At the **institutional level**, values shape organisational identity, governance logics, stakeholder relations, and the configuration of pedagogical and technological ecosystems. New institutions, such as recently founded private universities, often

begin with a blank slate, allowing them to articulate their values explicitly while designing programmes, workflows, and infrastructures from the ground up. In such contexts, the values guiding pedagogical design, data governance, digital ecosystems, and staffing structures are deliberately selected rather than inherited. This clarity facilitates a more transparent alignment between organisational purpose, stakeholder representation, and technological choices.

In contrast, long-established universities carry centuries-old traditions, rituals, and implicit norms that evolved under historical societal conditions. Many of these values remain embedded in organisational structures, curricular patterns, governance processes, and infrastructural arrangements. Because they appear "natural," they are harder to surface, question, or change. Biesta (2009) warns that institutions risk drifting toward what is administratively convenient or measurable unless they reconnect organisational decisions to explicit questions of educational purpose.

Institutions also perform a representational function: they embody societal expectations and act as stewards of public futures. This includes balancing the often competing values of different stakeholder groups. Hernández-Leo et al. (2025) demonstrate how teachers, when supported by structured reflective tools, articulate nuanced and sometimes conflicting value positions (e.g., balancing innovation with workload, privacy with analytics, equity with personalisation). Responsible Innovation research likewise emphasises that organisational reflexivity and inclusivity are essential for navigating these tensions (Stilgoe et al., 2013).

Critically, institutions must differentiate between aspirational values (what they claim to stand for) and actual values (what their processes reveal). Analysing assessment practices, digital workflows, hiring patterns, recognition systems, and infrastructural choices helps surface the values truly embodied in practice. Garst et al. (2021) show that organisations require value-sensitive capacities to detect, interpret, and adapt to societal expectations – a principle equally relevant for educational institutions.

At the **individual level**, values are shaped by personal histories, professional traditions, and lived experiences. Bourdieu's concept of *habitus* explains how individuals develop durable dispositions that influence what they perceive as legitimate knowledge, appropriate behaviour, or meaningful learning (Bourdieu, 1977, 1990). Teachers' and students' habitus affects how they interpret institutional values, respond to technological change, internalise pedagogical expectations, or resist certain practices.

Biesta's (2020) emphasis on subjectification highlights the moral and existential dimension of teaching and learning: education involves risk, judgment, and personal encounter, which cannot be reduced to procedural models or technical optimisation. Individuals thus act as interpreters and carriers of values. Hernández-Leo et al. (2025) show that teachers' responses to technologies cannot be understood without acknowledging the ethical and emotional dimensions of their work. Making individual-level values explicit supports alignment between personal professional identities and institutional aspirations.

Overall, explicating values across the societal, institutional, and individual levels within the Context Dimension is essential for understanding how the educational environment is shaped and how it shapes practice in return. Uncovering these embedded values clarifies how historical legacies and societal expectations inform current organisational arrangements, reveals how institutional routines and infrastructures enact particular priorities, and illuminates how individual dispositions shape everyday pedagogical and technological choices. Making these multi-layered values visible strengthens the diagnostic function of the Context Dimension, supports alignment between institutional purpose and real-world practices, and enables responsible negotiation of tensions between stakeholder groups. Most importantly, it allows institutions to plan their development trajectories deliberately, ensuring that the evolution of their pedagogical and technological ecosystems remains coherent, future-oriented, and aligned with their mandate to educate the citizens of tomorrow.

3.4.3. Embeddedness of Values in the Pedagogy Dimension

In every pedagogical tradition, it is not only *how* teaching and learning are organised that matters, but *why* certain approaches are regarded as the "right" way of doing things. Underlying every teaching method are assumptions about what teachers should do, what learners are capable of, and what learning itself means. These assumptions reveal the deeper purposes of education – whether the goal is to cultivate specific skills (*qualification*), to induct learners into existing norms and practices (*socialisation*), or to support their personal and ethical development as autonomous subjects (*subjectification*) (Biesta, 2010). As Packer and Goicoechea (2000) argue, "debates in learning theory concern not just conceptions of knowledge (epistemological assumptions) but also assumptions about the known world and the knowing human (ontological assumptions)" (p. 227). Ontology refers to beliefs about what exists – what learners and knowledge *are* – while epistemology concerns how knowledge can be acquired or justified. These philosophical orientations determine what teachers and learners are expected to do, how authority and agency are distributed, and what counts as legitimate evidence of learning.

Learning theories make these orientations explicit. Each theory embodies a particular worldview about what counts as knowledge and how learning takes place. In behaviourism, knowledge is seen as an objective entity existing outside the learner, and learning is defined as a measurable change in behaviour caused by external reinforcement (Cooper, 1993). Teaching, from this perspective, is about shaping responses through controlled stimuli, and the learner's role is to master pre-specified skills. By contrast, constructivism assumes that knowledge does not exist independently of the learner but is actively built through engagement with experience. Learning therefore involves organising and interpreting one's own experiences to construct meaning (Olssen, 1995). In this worldview, the teacher facilitates rather than transmits, and learning is judged by understanding and transfer rather than by replication.

These two perspectives illustrate that what a theory *believes* to be "right" profoundly influences both pedagogy and design. Behaviourism values precision,

efficiency, and control; constructivism values autonomy, reflection, and authenticity. As Cooper (1993) demonstrated, paradigm shifts from behaviourism to cognitivism and constructivism transformed not only theoretical explanations of learning but also how classrooms were organised, how technologies were used, and how feedback and assessment were conceived. Each shift reflects a revaluation of what learning is ultimately *for* – whether to condition, to process, or to construct knowledge—and thus enacts a different moral and epistemic stance toward the learner. These value orientations can, in fact, be explicated for every learning theory; a brief comparative overview is provided in Appendix F, Table 1F, although the authors refrain from simplistic generalisations and encourage readers to explore these relations in greater depth within their own contexts.

Overall, recognising the Values Dimension within pedagogy means acknowledging that theories of learning are not neutral tools but vehicles of worldview and purpose. Each theory also informs specific instructional design models and teaching approaches. For example, programmed instruction (Skinner, 1959, 1970) and mastery learning (Bloom, 1968; Guskey, 2007) emerging from behaviourism, cognitive apprenticeship (J. S. Brown et al., 1989; Collins et al., 1989) and worked-example design (Sweller et al., 1998a; Sweller & Cooper, 1985) from cognitivism, or inquiry-(Dewey, 1981, 2018; Hmelo-Silver et al., 2007), problem-(Barrows, 1986; Barrows & Tamblyn, 1980), and project-based learning (Blumenfeld et al., 1991; Kilpatrick, 1918) from constructivist traditions, each carrying forward its characteristic values into design practice. When educators clarify their values, particularly their ontological and epistemological commitments, or what they believe knowledge, learning, and the learner to be, they can align instructional design, assessment, and institutional practices with coherent educational aims. Equally, these pedagogical commitments must be linked to the technical affordances of learning environments and to the hypothesised learning benefits and risks associated with particular technologies, ensuring that technological, instructional, and ethical decisions work in concert rather than at cross purposes. Making these commitments explicit keeps pedagogy accountable to its broader ethical and societal purposes, ensuring that what is taught and how it is taught remains grounded in what is *educationally desirable*, not merely what is procedurally efficient or easily measured.

3.4.4. Embeddedness of Values in the Technology Dimension

From the perspective of value-sensitive design (VSD), values are operationalised through design decisions and through the socio–technical arrangements that shape how technologies are taken up in practice (Friedman et al., 2013; Gerdes & Frandsen, 2023; Hendry et al., 2021; Winkler & Spiekermann, 2021). Values are therefore integral to how technology-related and pedagogical decisions are conceived, governed, and enacted, not abstract ideals that can be appended after the fact (Friedman & Hendry, 2019; Winkler & Spiekermann, 2021). At the level of the technology artefact, architectures, algorithms, and interfaces afford and constrain particular forms of action, interpretation, and accountability, thereby shaping what becomes practicable and salient for users (Hutchby, 2001; Leonardi, 2011; Nissenbaum, 2001). Technologies are developed within particular cultural and

economic environments and may reflect associated priorities, including efficiency, standardisation, and data driven optimisation, which can become naturalised as "features" in educational settings through procurement decisions, institutional policies, and routine pedagogical use (Jarke & Breiter, 2019; Williamson et al., 2020). This dynamic illustrates how values are not only designed into technologies but also enacted through their institutional and pedagogical use (Friedman & Nissenbaum, 1996; Nissenbaum, 2001)(Feenberg, 1999; Nissenbaum, 2001).

At the **societal level**, technologies emerge within broader value systems that define legitimate innovation and acceptable risk. For example, North American technology companies often operate within a commercial logic prioritising growth, user engagement, and data monetisation, whereas European regulatory traditions tend to foreground privacy, human dignity, and public accountability (Floridi, 2014; Stahl, 2011). These contrasting frameworks result in artefacts shaped by different normative architectures: data-driven personalisation systems, for instance, may align with market efficiency but conflict with European expectations of transparency and proportionality. When such technologies enter educational contexts, they import these external value logics, which may reinforce or disrupt the host institution's ethical and pedagogical commitments. The question "who the technology was developed for and why" therefore becomes a central part of any evaluation of its appropriateness for learning.

At the **institutional level**, educational technologies are shaped by the value commitments of the firms that design, develop and commercialise them. These value architectures influence product features, business models, data practices and the relationships established with schools. For instance, studies of Google LLC's deployment of Chrome OS and Workspace for Education show how commercial logics, such as user growth and data monetisation, may sit uneasily alongside educational aims of privacy, autonomy and public-good value (Lindh & Nolin, 2016; Liu et al., 2023).

When a company's priority lies primarily with market expansion rather than pedagogical integrity, institutional adoption risks misalignment with the educational organisation's values. The decision to deploy a technology should therefore go beyond functionality: institutions must evaluate the vendor's value orientation, contractual governance and accountability structures. Without such scrutiny, there is a danger of ethics-washing, where product claims of "student-centred learning" mask embedded logics of surveillance or dependency (Livingstone, 2024).

Because institutions act as intermediaries between commercial vendors and pedagogical practice, they bear responsibility for value stewardship. This means vetting how an educational technology encodes values into its architecture, such as data-collection defaults, algorithmic profiling or scalability over transparency, and ensuring its alignment with the institution's mission, privacy commitments and pedagogical ambitions. In effect, institutions must not simply adopt technologies, but intentionally govern them in ways that sustain the normative commitments of meaningful integration.

At the **individual level**, the values embedded in educational technologies arise from the priorities and judgments of those who design and lead their development. Developers, engineers, and product managers, among others, translate competing institutional and societal priorities into technical artefacts through their personal beliefs into decisions about e.g., interface defaults, data collection, algorithmic transparency, and accessibility. In this sense, they act as moral intermediaries between abstract principles and operational systems. As Nissenbaum (2001) noted, computer systems *embody values*, and individual design choices determine which values are realised in practice. Each decision – e.g., what to automate, how to visualise data, which defaults to set, or what options to hide – represents a *mode of value negotiation* rather than a neutral optimisation step. In this sense, designers act as mediators between conflicting beliefs about what constitutes efficiency, transparency, autonomy, or care (Nissenbaum, 2001; Winkler & Spiekermann, 2018).

Empirical research on design processes shows that individual actors navigate tensions between the commercial, educational, and ethical logics of their organisations. Developers within large corporations may be driven by performance metrics such as engagement, scalability, or data yield, while educators and policymakers emphasise human agency, learning quality, and social well-being (Komljenovic, 2020; Williamson, 2022). Value Sensitive Design interprets such tensions not as deviations but as opportunities for *iterative negotiation*, requiring conceptual clarification of the values at stake, empirical engagement with stakeholders, and technical translation into artefact properties (Friedman & Hendry, 2019). When these negotiations occur transparently, technologies are more likely to reflect plural and contextually grounded priorities; when they are opaque, dominant organisational or cultural values such as efficiency or control may become default design logics.

The distinction between design orientations is often visible in how feedback and agency are distributed. In some development cultures, iterative loops actively include users and educational partners in prototype testing and requirement definition, creating mechanisms for shared deliberation. In others, decisions are centralised and guided by internal assumptions about user behaviour or by commercial convenience, with limited opportunity for negotiation once systems are deployed. These orientations carry distinct implications for learning: closed design loops tend to normalise standardised, top-down control of learning processes, while open feedback architectures permit adaptation, critique, and user agency (Suchman, 2007; Oudshoorn & Pinch, 2003).

The neutrality of design therefore cannot be assumed. What appears as a technical optimisation – automating grading, ranking contributions, or recommending content – embodies specific beliefs about the learner and about the purpose of education. The individual designer's task is not to decide which values are inherently right, but to make explicit which beliefs inform their design, whose interests are prioritised, and whose voices are absent. Responsible design thus entails reflexivity about the social consequences of seemingly pragmatic choices. The effectiveness of Value Sensitive Design or any other ethical framework ultimately depends on

whether individuals at the micro level are empowered and incentivised to question defaults, surface trade-offs, and reopen negotiation when technologies begin to shape educational practice in unintended ways.

3.5. Management Dimension

So far, the HITE framework has organised what is relatively well established in the literature into four analytic dimensions that clarify Context, Pedagogy, Technology, and Values as distinct but interrelated domains. Taken on their own, however, these lenses remain largely descriptive: they illuminate what matters, but not how institutions actually connect these elements and move from fragmented insights to coherent, meaningful integration in practice. Within the HITE framework, the Management Dimension addresses this gap. It represents the dynamic, process-oriented capacity of an educational organization to steer the meaningful integration process over time (Damschroder et al., 2009; May et al., 2009; Weiner et al., 2008). It functions as the alignment dimension of the framework, bringing together intervention characteristics, inner and outer settings, characteristics of individuals, and implementation processes in a coherent way, rather than treating them as isolated levers (Damschroder et al., 2009; McEvoy et al., 2014). Management dimension encompasses institutional agency, the ability to translate strategic purpose and values into coordinated action through staged process facilitation, continuous and iterative evaluation, and vision-oriented planning (Alvarez et al., 2004; Weiner et al., 2008). Within this capacity, Management dimension ensures that technological affordances are purposefully aligned with pedagogical aims and content (Koehler & Mishra, 2009), that implementation remains responsive to evolving stakeholder profiles, infrastructures, and learning arrangements (Kyndt & Baert, 2013; Maurer et al., 2003), and that participation and self-directed development are supported through attention to both individual and situational factors (Garavan et al., 2010; Zia et al., 2020). In doing so, the Management Dimension provides the organizational mechanisms through which alignment among the other dimensions can be maintained, monitored, and adapted over time, supporting the embedding, normalization, and sustainability of technology-supported practices in everyday work (Damschroder et al., 2009; May et al., 2009; McEvoy et al., 2014).

Crucially, the Management Dimension is not intended as a prescriptive checklist or an exhaustive catalogue of theories and procedures. Consistent with the role of conceptual frameworks in educational technology as theory-based and evidence-informed instruments for organising inquiry rather than ready-made recipes (Antonenko, 2015; Ely, 2008), the HITE framework does not specify a single correct way in which integration must be organised. Instead, the *Management Dimension* makes visible a set of sub-dimensions that institutions can use to reflect on whether and how alignment work would need to be implemented.

This reflection explicitly accommodates different organisational configurations. Management may be exercised through formal leadership, distributed across middle management and professional communities, or emerge from bottom-up initiatives and horizontal networks (Marshall, 2010; Rikkerink et al., 2016). The framework does

not prescribe whether integration should be led top-down, bottom-up, or through hybrid arrangements. Rather, it foregrounds the expectation that some form of agency and responsibility must be assumed if alignment is to be purposeful and ethically defensible, and that these arrangements should be monitored, discussed, and adapted in light of evidence and values. In line with implementation frameworks that emphasise contextual adaptation and reflexive monitoring (Damschroder et al., 2009; May et al., 2009; McEvoy et al., 2014), the Management Dimension therefore invites institutions to treat alignment as an ongoing, collectively owned process: one that is actively shaped by stakeholders, tracked and learned from, and continually related back to the values that the institution seeks to uphold.

3.5.1. Step 1: Mapping and aligning Context and Technology

The first step in the management workflow is to determine whether the Context and Technology Dimensions are sufficiently aligned to support meaningful integration, and to identify where deliberate management action would be required. This step consists of a structured characterisation of the relevant context and of the proposed technology, followed by an analysis of their alignment.

On the side of context, the focus is on a concise characterisation of the setting in which the technology would be embedded. In line with the Context Dimension described above, this mapping draws on its sub-dimensions and treats them as elements that need to be explicated, reflected upon, and made visible, rather than taken for granted. This includes the main stakeholder groups and their roles, capabilities, constraints, and needs; existing teaching–learning arrangements and dominant content repertoires (for example, programmes that are largely text-based versus those already using visual, spatial, or data-intensive materials); and the available hardware facilities, software integration requirements that are already in place or planned, and expertise in operation (such as educational design, media production, software development, or data and ethics expertise). In addition, values that shape educational practice at societal, institutional, and personal levels are made explicit, encompassing policy expectations, institutional missions and strategies, and the professional and personal commitments of stakeholders. No single theoretical lens is prescribed for this analysis; the emphasis is on rendering the material and normative conditions specified in the Context Dimension sufficiently visible to allow reasoned judgements about integration.

In parallel, the Technology Dimension is characterised in corresponding terms, assuming that its sub-dimensions are likewise explicated and reflected upon rather than treated as self-evident. Core functionalities and envisaged educational affordances are specified, together with the hardware facilities required for implementation (e.g., device types, peripheral equipment, network capacity), the software integration requirements in relation to existing systems (such as learning management systems, identity management, or data pipelines), and the expertise in operation needed for technical maintenance and pedagogically meaningful use. In addition, the values, priorities, and risks associated with the technology's design and intended use are considered: whose interests it primarily serves, under which assumptions it was developed, why it is being proposed for this context, and what

forms of datafication or commodification it may entail. For data-intensive tools in particular, this includes recognising the potential hidden costs of apparently low-cost or "free" products, where value is extracted from learners' data through profiling and platform revenue models rather than through visible licensing or hardware expenditures (Hakimi et al., 2021; Komljenovic, 2022; Williamson et al., 2020).

The alignment analysis then considers, for each of the three core aspects – hardware facilities, software integration requirements, and expertise in operation – the extent to which contextual conditions and technological demands are aligned. Close alignment suggests that meaningful integration is feasible without major restructuring; pronounced gaps indicate areas in which management intervention would be required, whether through targeted investment, capacity building, re-scoping of ambitions, or, where justified, a decision not to proceed. Importantly, this assessment includes both visible costs (e.g., equipment, licences, staffing) and less visible implications such as long-term dependence on external platforms, data governance burdens, or value conflicts around surveillance and autonomy.

Two contrasting technologies illustrate how these alignments can differ. Fully immersive VR for teaching typically occupies the higher end of the spectrum with respect to hardware facilities and expertise in operation: head-mounted displays, suitable physical spaces, robust networks, and specialised design and operational skills are often required if its educational affordances are to be realised at scale. A context characterised by modest hardware provision and limited media expertise would thus exhibit clear gaps on these dimensions, implying substantial management effort before integration becomes realistic. Large language models and generative AI–based chatbots for personalised learning, by contrast, may place relatively modest demands on hardware facilities, since they can usually run on standard devices and operating systems. However, they often introduce more complex software integration requirements and regulatory questions. This is especially the case in contexts with strict data protection rules, where the use of external AI services raises concerns about data transfer, storage, and profiling. In such situations, alignment work shifts away from hardware and towards designing compliant integration architectures, establishing clear data-governance arrangements, and ensuring sufficient expertise in operation for data protection and pedagogically responsible use (Hakimi et al., 2021; Komljenovic, 2022).

3.5.2. Step 2: Align Context-Specific with Technology-Specific Pedagogy

The second step in the workflow concerns the Pedagogy Dimension and explicates the way that the learning process is currently configured within the organisation, as well as the way the learning process *should* be configured if the chosen technology is to contribute to educational benefit. Pedagogy is treated here as a linking pin between context and technology rather than an isolated bubble or layer, acknowledging the entanglement of teaching practices, tools, and institutional arrangements (Fawns, 2022).

This step consists of three analytic moves. First, pedagogy as it is currently practiced in the institution is made explicit. This includes identifying the pedagogical theories and models that shape everyday work, the prevailing teaching–learning

formats (e.g., synchronous/asynchronous, face-to-face/distance/blended), and the dominant types of content. It also requires articulating the pedagogical values that orient practice and identifying existing tensions, such as misalignments between stated learner-centred intentions and lecture-dominated practice, or between institutional aspirations and structural constraints. The aim is to produce a concise picture of *Pedagogy in Context* that is sufficiently explicit to reason about technology integration.

Second, a pedagogy for the technology is formulated. Rather than assuming that teachers will independently infer optimal use cases or theoretical underpinnings for a new tool, this step begins with the technology's functionalities and derives its educational affordances. These affordances are then linked to relevant learning theories or instructional design models to specify how the tool could support learning in principled ways. In many cases, this requires developing technology-specific pedagogical scenarios—for example, instructional templates or use-case patterns that articulate plausible didactic configurations for the tool. Such scenarios can be co-developed by pedagogical experts, instructional designers, technology specialists, and practitioners, acknowledging that it is rarely feasible for individual teachers to be simultaneously expert operators of the tool, expert instructional designers for that tool, and experts in aligning it seamlessly with their local pedagogical constraints. These scenarios provide theory-informed, context-relevant exemplars from which teachers can choose pedagogical aims and select or adapt appropriate uses of the technology.

Third, context-specific and technology-specific pedagogies are aligned. This involves examining where the pedagogical principles, values, and practices identified in the first sub-step converge with those articulated for the technology, and where they diverge. Areas of convergence indicate pedagogical coherence, while areas of divergence signal tensions that require managerial attention. Some tensions may represent make-or-break points, where fundamental differences in values or structures hinder integration; others may serve as sites of potential development, where technology could support pedagogical evolution if the change is explicitly recognised and deliberately managed. This analytic alignment does not prescribe how tensions must be resolved; instead, it clarifies whether meaningful integration is pedagogically viable under current conditions or whether further pedagogical re-design and value work fall within the remit of the Management Dimension.

3.5.3. Step 3: Process Management

The third step of the workflow concerns the ongoing governance of the integration process. Whereas Steps 1 and 2 establish the analytical groundwork for alignment, Step 3 addresses how the integration is planned from the outset, how it unfolds over time, and how its future trajectories are decided.

Before implementation begins, the envisaged workflow is articulated in outline, including major phases, expected decision points, and possible outcomes. This involves conceptual and counterfactual reasoning with relevant stakeholders: systematically exploring not only the intended pathway, but also plausible scenarios in which the first phase of integration yields weak, ambiguous, or negative results.

At this stage, it is agreed under which conditions the institution would (a) refine and iterate, (b) pause and redesign, or (c) wrap up the initiative. Making such decision paths explicit from the outset reduces the risk that later choices become primarily political or driven by sunk costs rather than by evidence and values.

In parallel, roles and responsibilities are defined. Research on school-wide capacity for improvement and teacher professional learning has shown that leadership practices and school organisational conditions, such as vision building, teacher collaboration, and participative decision-making, are central for developing and sustaining improvement capacity, and that this capacity is difficult to maintain without coherent coordination (Geijsel et al., 2009, 2010; Sleegers & Leithwood, 2010; Thoonen et al., 2012). These studies suggest that large-scale innovation is less likely to succeed when responsibility remains diffuse and unstructured. For the purposes of the HITE framework, this implies that dedicated project management expertise is needed to coordinate the integration process, particularly when scaling up, while clear lines of accountability are established for strategic decisions, pedagogical and technical support, and monitoring of effects. Such arrangements do not predetermine outcomes, but they provide a transparent organisational structure within which adaptation, negotiation, and evidence-informed decision-making can occur.

Against this pre-agreed workflow, the integration is then evaluated before, during, and after implementation. Before implementation, expected learning benefits and anticipated practical implications, such as workload, support needs, and risk areas, are specified as part of the initial decision logic. During implementation, indicators of how the process is unfolding are monitored, including participation patterns, usability issues, emergent workarounds, and signs of overload or frustration. After implementation, both learning impact (for example, knowledge development, skills, participation, inclusion) and practical outcomes (such as teacher and student well-being, workload, time investment, perceived fairness, and sustainability of routines) are examined. The purpose is not only to judge whether the technology “works,” but to understand how it reshapes learning processes, working conditions, and institutional priorities, and whether these effects remain acceptable in light of the values articulated earlier in the framework.

Finally, Step 3 encompasses the ongoing management and future orientation of the integration. Process management includes revisiting the purpose and strategic fit of the technology, maintaining clarity about responsibilities across instructional, technical, and administrative roles, and sustaining communication channels through which interim findings, difficulties, and adjustments are shared. Evaluation findings are fed back into the pre-defined decision workflow: they inform whether the initiative should be continued and scaled, stabilised at a given level, substantially redesigned, or phased out.

Planning for future development and sustainability involves considering what additional forms of support (training, time, infrastructure, recognition) may be required; how resources should be allocated over time (licences, maintenance, upgrades, staff capacity); and how data governance and ethical commitments will be maintained as the integration matures. This way, technology integration is

considered as part of a longer organisational trajectory rather than an isolated project, emphasising that sustainability depends not only on initial alignment but also on the clarity of decision paths, the presence of dedicated project management and accountability.

4. Discussion

This paper has introduced the Holistic Integration of Technology in Education (HITE) Framework as a first conceptualisation of organisational-level conditions that shape meaningful context-sensitive integration of technology in education.

The framework was developed iteratively by integrating empirical insights from two studies, an interview-based single-institution case study and a Group Concept Mapping study conducted across two institutions. The empirical base was integrated with a theoretical synthesis of research on technology-enhanced learning and organisational change, and with expert review. This development approach is consistent with conceptual framework analysis as the construction of a network or plane of linked concepts across multiple sources (Jabareen, 2009). Building on the argument that conceptual frameworks can organise inquiry and connect theory with practice in educational technology research, HITE functions as a sensemaking scaffold for mapping how Technology, Pedagogy, Context, Values, and Management co-constitute integration processes (Antonenko, 2015). This mapping helps make visible where tensions, misalignments, or enabling conditions may arise, with implications for mindful, sustainable, and scalable integration.

A key contribution of the Holistic Integration of Technology in Education (HITE) Framework is that it brings the drivers of meaningful integration into a single conceptual plane, treating integration as an entangled educational process shaped by Technology, Pedagogy, Context, Management, and Values (Biesta, 2009; Fawns, 2022). Within this five-dimensional view, Management is conceptualised as the coordinating work through which the other dimensions are aligned over time, including planning, resourcing, governance, evaluation, and sustainment, rather than as a purely administrative layer (Chambers et al., 2013; May et al., 2009). This is consequential because existing strands of research typically address only a subset of the conditions that shape meaningful integration. Teacher-centred frameworks such as Technological Pedagogical and Content Knowledge (TPACK) foreground classroom-level knowledge demands (Koehler & Mishra, 2009; Voogt et al., 2013), while user-acceptance models such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) emphasise perceived usefulness and ease of use (Davis, 1989; Venkatesh et al., 2003). Organisational implementation frameworks, including Diffusion of Innovations (DOI), the Promoting Action on Research Implementation in Health Services framework (PARIHS), the Consolidated Framework for Implementation Research (CFIR), and Normalization Process Theory (NPT), add attention to organisational determinants and embedding work (Damschroder et al., 2009; Greenhalgh et al., 2004; May et al., 2009; Rycroft-Malone, 2004), and education-specific models such as the e-capacity model specify school-level capacity conditions (Vanderlinde & van Braak, 2010).

However, these lenses can still be applied without making explicit the education-specific “whether” question, or without treating sustainability as depth, ownership, and adaptive fit rather than continued use (Coburn, 2003; Moore et al., 2017; Wiltsey Stirman et al., 2012). HITE framework foregrounds these interdependencies and renders visible how governance dynamics, including platformisation and datafication, can constrain pedagogical autonomy and redistribute work in ways that shape what integration can become (Komljenovic, 2022; Kerssens & van Dijck, 2022; Selwyn, 2021; Williamson, 2018).

HITE’s potential practical value follows from this conceptual contribution. It can serve as a shared analytic language to support cross-role deliberation, helping stakeholders surface assumptions, locate constraints (e.g., infrastructure, workload, governance routines), and specify what would need to align for an initiative to be feasible and sustainable in a given institutional context. These interdependencies are consistent with implementation scholarship emphasising that embedding new practices depends on alignment work across organisational arrangements, roles, and routines (Chambers et al., 2013; May & Finch, 2009; Vanderlinde & van Braak, 2010).

A further implication, aligned with feedback from institutional practice, is that integration work often becomes clearer when Values are made explicit early. Many institutions articulate aims such as inclusion, learner flexibility, or democratic educational purposes, and these aims shape curriculum, support structures, and governance routines before any specific technology is selected. When Values are treated as an explicit dimension, HITE supports questions about educational warrant – including whether an initiative coheres with declared purposes and the educational goods the institution seeks to realise (Biesta, 2009, 2020a). In contexts of platformisation and datafication, this Values lens is also relevant because infrastructural and governance decisions can reshape pedagogical autonomy, professional judgement, and the organisation of educational work (Kerssens & Dijck, 2022; Komljenovic, 2022; Selwyn, 2021; Williamson, 2016).

It must be noted that HITE framework should was not intended as a ready-to-use implementation manual. Its immediate utility lies in structuring inquiry and deliberation. Translating the framework into use-oriented supports, such as facilitation prompts, decision-oriented reflection questions, and case-based guidance, requires additional design and prospective evaluation to examine whether these supports improve coordination, sustainment, and value alignment across stakeholder groups (Antonenko, 2015; Chambers et al., 2013; May et al., 2009)

4.1. Limitations

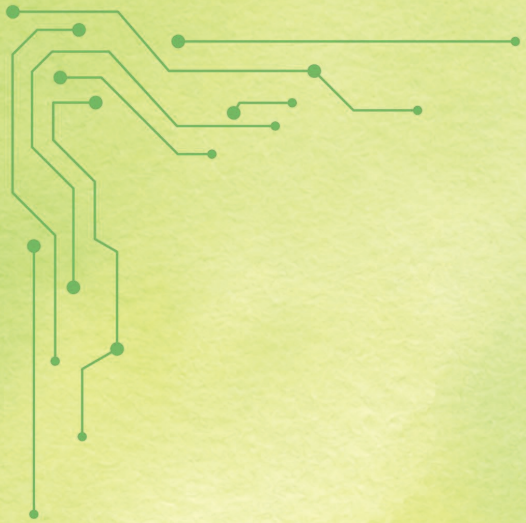
Several limitations of this work should be acknowledged. First, the empirical grounding of the framework was based on a single institutional case, albeit one investigated with multiple methods. This provided rich insights but inevitably reflects the particular history, culture, and structures of that setting. Second, although expert review contributed to the refinement of the framework, the number and profile of experts remain limited, and their perspectives may not capture the full diversity of

educational systems and stakeholder groups. Third, the five dimensions necessarily simplify complex institutional realities, and some phenomena, such as power relations, external policy pressures, or rapidly changing market conditions, may cut across multiple dimensions in ways that are not yet fully articulated. Finally, while the Management dimension is conceived as an agile integrator, the present paper does not yet offer detailed process models or tools for enactment; how this dimension is taken up will depend strongly on local governance, leadership practices, and existing routines and capacities (Chambers et al., 2013; May et al., 2009; C. R. May et al., 2016).

4.2. Future directions

Future research can extend and test the HITE Framework in several directions. Empirically, studies across different sectors and countries could explore how stakeholders use the framework to analyse ongoing or planned integrations, and whether it supports clearer decision-making, more transparent trade-offs, or more sustainable outcomes. Design-based or participatory research could involve stakeholders in adapting the framework to their own contexts and developing concrete artefacts, such as decision templates, diagnostic checklists, or evaluation rubrics, derived from the five dimensions. Conceptually, further work may refine the internal structure of each dimension, examine how they interact under different conditions (for example, in low-resource versus high-resource settings), and relate HITE more explicitly to theoretical perspectives such as entangled pedagogy or postdigital critiques. Finally, comparative studies could investigate how HITE can be used alongside existing frameworks (e.g., TPACK, TAM/UTAUT, WST, CFIR) in professional development, institutional strategy processes, or policy dialogues, clarifying where it adds value and where other approaches remain more appropriate (M. C. Davis et al., 2014; Koehler & Mishra, 2009; Venkatesh et al., 2016; Xue et al., 2024).

In sum, the HITE Framework contributes to ongoing efforts to explore technology integration in education in systemic, context-sensitive, and value-aware terms. By offering a coherent structure that connects pedagogical and technological considerations with contextual, managerial, and ethical ones, it aims to support institutions and educators in making more informed and transparent decisions about when, how, and why digital technologies should be integrated into educational practice. The framework is proposed not as a definitive answer, but as a starting point for further inquiry, adaptation, and dialogue among those concerned with the meaningful, context-sensitive, and sustainable integration of technology in education.





General Discussion

General Discussion

The research in this thesis explored design requirements for meaningful, sustainable and scalable integration of DVR-enhanced presentations in higher education. It was also examined how a DVR technology can be meaningfully, sustainably, and scalably integrated into university teaching practice of universities. Across iterative design-based research (DBR) cycles, the investigation moved from stakeholder exploration of enabling conditions and constraints, to the design of Technology-Specific Instructional Templates that specify several pedagogical ways of using DVR-enhanced presentations, to an initial evaluation and reflective synthesis that considered how different configurations redistribute work and support requirements at institutional level (McKenney & Reeves, 2019; Murray et al., 2010). Finally, the findings are interpreted in relation to existing theory, supporting the argument that classroom-level instructional embedding and organisational-level integration should be bridged within the proposed Holistic Integration of Technology in Education (HITE) Framework.

The aim of this General Discussion is to synthesise how the individual studies, taken together, advance understanding of DVR-enhanced presentation technology from the perspective of (a) instructional embedding in the didactic workflow and (b) sustainable technology integration. This chapter is organised in three parts. First, evidence is synthesised across the DBR cycles to address the two research questions at thesis level. Second, contributions and implications for technology-enhanced learning research and teaching practice are discussed. Finally, limitations and directions for future research are outlined.

1. Synthesis of findings

This section presents thesis-level answers to the two overarching research questions.

RQ1: *What design requirements support meaningful, sustainable and scalable integration of DVR-enhanced presentations in higher education?*

RQ1 is addressed by synthesising findings across Chapters 1–4, which together follow the design-based research (DBR) workflow (Anderson & Shattuck, 2012; Euler & Sloane, 2014; McKenney & Reeves, 2019; Sandoval, 2014). Chapters 1–2 provide exploratory, stakeholder-driven evidence about requirements and constraints likely to enable or hinder meaningful integration of a DVR tool in university teaching practice (Anderson & Shattuck, 2012; Sandoval, 2014). Chapter 3 translates these requirements into Technology-Specific Instructional Templates (TSI templates) and cross-cycle design guidelines, representing design conjectures grounded in theory and stakeholder appraisal. Chapter 4 provides exploratory student-facing evaluation evidence in piloting one of the TSI templates in authentic synchronous online lectures to examine knowledge gain, cognitive load, and intrinsic motivation (Deci & Ryan, 1985; Ryan & Deci, 2000a; Sweller, 1988, 2010).

Synthesising the findings, it is argued that DVR-enhanced presentations can be designed and implemented as template-guided instructional formats in which pedagogical purpose drives affordance selection, cognitive load management constrains visual orchestration, teacher presence is calibrated to segment goals, and operational arrangements support reliable enactment and reuse. The student pilots provide exploratory evidence that such implementations can be enacted without detectable detriment on knowledge gain, cognitive load, or intrinsic motivation under the tested conditions (Deci & Ryan, 1985; Ryan & Deci, 2000a; Sweller, 1988, 2010). The design requirements presented below synthesise the cross-chapter evidence.

Design requirement 1 – Making pedagogical purpose explicit and translating it into teacher-usable templates.

DVR-enhanced presentations should begin from a clearly stated pedagogical purpose and express that purpose in a TSI template that teachers can recognise and enact within their existing instructional workflow. This principle is grounded in Chapter 3's definition of TSI templates as purpose–technique–configuration–guidance linkages, and in Chapters 1–2 stakeholders' repeated emphasis that teachers need clarity about why, when, and how the tool supports teaching practice rather than "using VR" as an end in itself. Theoretically, this aligns with evidence that educational value follows from purposeful orchestration of affordances through instructional design rather than from media features alone, and with DBR accounts of design knowledge as conjecture-based and iteratively refined in context (Dalgarno & Lee, 2010a; Edelson, 2002; Fowler, 2015; Kirkwood & Price, 2014; Sandoval, 2014).

Design requirement 2 – Alignment of affective and cognitive goals through theory-informed design configurations

Designing DVR-enhanced presentations requires an explicit distinction between knowledge-oriented goals and affective goals (like motivation, situational interest), because these goal types imply different trade-offs in how visual information and teacher presence should be orchestrated. In this thesis, the decision logic combines multimedia learning and cognitive load theory to guide coherence, signalling, and segmentation so that DVR configurations minimise extraneous processing (R. E. Mayer, 2005; R. E. Mayer & Moreno, 2003; Paas et al., 2003; Sweller, 1994, 2010). At the same time, self-determination theory provides a rationale for when design choices that foster relatedness, autonomy, and competence are pedagogically relevant in synchronous online teaching (Deci & Ryan, 1985; Ryan & Deci, 2000a).

Design requirement 3 – Designing for routinised use by managing the operational workload

DVR-enhanced presentations should specify and constrain the operational work expected from teachers. This keeps the added demands of camera logic, cueing, and scene management feasible within authentic teaching conditions. This principle is grounded in Chapter 1, where stakeholders prioritise *Maintenance and Training* and highlight *Affordances and Infrastructure* as prerequisites for ease of meaningful use and support mechanisms. It is reinforced in Chapter 2 through the emphasis on institutional capacity and facilitation, and made concrete in Chapter 3, where

feasibility constraints are addressed through practical enactment guidance and workload-reducing support arrangements. Theoretically, this aligns with implementation research showing that embedding at scale depends on whether a practice can be enacted reliably as routine work, supported by organisational arrangements that shift responsibility from individual teachers to collectively maintained routines (Coburn, 2003; C. May, 2013; May & Finch, 2009; Murray et al., 2010).

RQ2: *How can a DVR technology be meaningfully, sustainably, and scalably integrated into the teaching practice of universities?*

RQ2 is addressed through cumulative, cross-phase evidence across the research line, moving from stakeholder-based problem exploration (Chapters 1, 2) to cross-context appraisal (Chapter 5) and thesis-level conceptual synthesis (Chapter 6). In the analysis and exploration phase, Chapter 1 identifies implementation requirements organised into five clusters – Maintenance and Training, Institutional Requirements, Evaluation, Affordances and Infrastructure, and Student Requirements – and highlights that these requirements are jointly relevant for the prospective sustainable technology integration. Chapter 2 supports and deepens the identified requirements by showing how integration is shaped by the interdependence of Context, Technology, Pedagogy, Values, and Management, and by translating stakeholder accounts into two practical mechanisms – a three-point audit (hardware, software, staff expertise) and a value-aligned design workflow. In the evaluation and reflection phase, Chapter 5 extends the institutional lens by comparing stakeholder appraisals of pilots across three universities and three setup levels (minimal, medium, advanced) using Normalization Process Theory (NPT), treating integration as the work through which practices become meaningful and workable in routine institutional settings (May & Finch, 2009; May et al., 2009; Murray et al., 2010). Finally, Chapter 6 synthesises the cross-stage implications by proposing the HITE Framework as an alignment-oriented conceptual framework that connects Technology, Pedagogy, Context, and Values, coordinated through Management as the dimension responsible for planning, resourcing, implementation support, and sustained alignment (Antonenko, 2015; Jabareen, 2009).

Bringing together the findings of Chapters 1, 2, 5, and 6, the thesis indicates that meaningful, sustainable, and scalable integration of a DVR technology is most likely when universities organise it as an institution-level coordination challenge in which pedagogical use-cases, role distributions, support arrangements, quality thresholds, and evaluation routines are aligned from the outset and maintained over time through governance and resourcing. To make these cross-chapter implications explicit, the thesis formulates a set of synthesis propositions as the structured answer to RQ2. In line with the DBR logic of the thesis, each proposition distils cross-phase evidence into a transferable statement about what appears to support meaningful integration at scale under the studied conditions.

Proposition 1: Define the pedagogically purposeful use of the tool with stakeholders early on

Across Chapters 1 and 2 it is argued that meaningful integration starts when stakeholders make the technology's purpose explicit in relation to the institution's teaching practice, and when this purpose is specified as educational aims rather than technologically novel use per se. Chapter 2 sharpens this into a value-driven workflow in which technical affordances are only legitimised when mapped to explicit pedagogical purposes and screened for risks that would undermine institutional priorities. Chapter 5 provides a comparative mechanism: across three complexity configurations (Set 1–Set 3), stakeholders reject technical sophistication without explicit pedagogical function and treat goal alignment and scenario-fit as the gatekeepers of coherence and internalisation (May & Finch, 2009; Murray et al., 2010). This is consistent with organisational research showing that perceived usefulness and facilitating conditions drive sustained use intentions, while shared organisational meaning-making stabilises collective expectations for what the tool and practice is for and how it should be supported (Davis, 1989; Proctor et al., 2011; Venkatesh et al., 2003, 2016; Weiner et al., 2008; Weiner, 2020).

Proposition 2: Coordinate technology integration as an interdependent institutional process

Across Chapter 1 (five requirement clusters) and Chapter 2 (e.g. Context–Technology alignment via Management), integration is framed as a coupled arrangement of infrastructure, tool–ecosystem fit, curricular embedding and teacher workflow support, going beyond teacher uptake alone. This interdependence perspective is further sharpened in Chapter 5 by showing that as technical setups become more complex, stakeholders raise their expectations for workload and role (re-)distribution that need to be facilitated. This perspective is consolidated in Chapter 6, where Management is positioned as the coordinating dimension that maintains alignment across Context, Technology, Pedagogy, and Values over time. This system view aligns with practice-oriented and implementation research in which integration depends on the organisation of work, roles, and resources across levels rather than on the technological artefact's presence alone (Fawns, 2022; Fowler, 2015; May & Finch, 2009; May et al., 2016).

Proposition 3: Build a scalable *support plus autonomy* operational model differentiated by a technical setup level

Chapter 1 ranks "Maintenance and Training" as highly important, foregrounding the need for layered training (self-study materials plus workshops), readily available expert support, and ongoing maintenance. Chapter 2 adds operational detail: scalability in a distance setting is constrained by home-based teaching, limited studio access, and the need for seamless learning management system integration and device compatibility, implying that institutions must decide where to raise capacity (equipment access, specialist support) and where to lower the threshold (templates, reusable assets, simplified pathways). Chapter 5 turns this into a core scalability rule: full support for every instance does not scale, but no support undermines quality and trust; therefore, institutions need explicit boundaries for what teachers produce

independently, what requires specialist production, and what minimum quality standards apply before release. This logic directly reflects NPT's emphasis on collective action and contextual integration as conditions for enactment becoming routine (May & Finch, 2009; May et al., 2009; McEvoy et al., 2014; Murray et al., 2010; Vanderlinde & van Braak, 2010).

Proposition 4: Treat evaluation as a continuous cycle facilitating effectiveness, efficiency, equity and long-term viability.

Chapter 1 features *Evaluation* as the cluster with a clear importance–feasibility gap, signalling that stakeholders see evaluation as urgent but organisationally demanding. Chapter 2 specifies what evaluation must include to support scale: (a) academic evaluation of learning effectiveness (including novelty fade and discipline-fit), (b) practical evaluation of usability and workflow burden, and (c) cost–value appraisal as an explicit business-case constraint. Chapter 5 explains why this is decisive: internalisation strengthens only when stakeholders can articulate a credible return on investment, and the required return changes as the setup redistributes work and raises production expectations. Operationally, this implies an iterative evaluation loop that does not only ask if the technology works, but for whom, under which scenarios, at what workload cost, and with what institutional consequences, which is consistent with implementation research that treats ongoing appraisal and adaptation as central to sustaining complex interventions (May & Finch, 2009; May et al., 2009; McEvoy et al., 2014; Murray et al., 2010; Orlikowski, 2000).

Proposition 5: Treat Values as binding constraints that shape sustainability.

Across the thesis, values operate as non-negotiable contextual conditions that determine whether DVR technology can be meaningfully integrated and sustained in university teaching practice. Chapter 2 frames equity, accessibility, privacy, and related institutional commitments as decision constraints that must be applied before DVR configurations are selected and resourced, so that pedagogical purpose is pursued within boundaries that protect what the institution is trying to uphold. Chapter 5 shows why this matters for sustainability: as technical setup levels increase, legitimacy and return expectations shift, and stakeholders scrutinise whether the redistributed workload, data practices, and production arrangements remain acceptable relative to institutional commitments. Chapter 6 consolidates this into an alignment logic in which values filter trade-offs before investment decisions are made, preventing technically attractive solutions that later fail because they conflict with institutional priorities or stakeholder acceptability. This synthesis aligns with both socio-technical research and critical educational technology scholarship emphasising that technology decisions are inherently normative and therefore require explicit governance rather than implicit assumptions (Bayne, 2015; Fawns, 2022; Orlikowski, 2000, 2007; Selwyn, 2010, 2025; Williamson et al., 2020).

2. Contributions and implications

This section consolidates the thesis contributions and derives implications that follow from them.

The main contribution to practice of this thesis is the concept of Technology-Specific Instructional Templates (TSI templates) as a design representation for DVR-enhanced presentation technology. A TSI template specifies a tool configuration in didactic terms by making explicit links between pedagogical purpose, instructional techniques, technical configuration, and practical enactment guidance, including prerequisites for embedding. Within the DBR research line, TSI templates formalise the translation from stakeholder requirements into reusable instructional formats and provide a stable reference for aligning design decisions, teacher learning, and institutional support.

The contribution has three implications. For technology development, TSI templates position pedagogical specification as part of the product boundary, rather than an optional local translation, which supports alignment between intended use and feasible enactment (Kirkwood & Price, 2014; Penuel et al., 2011). For teacher involvement, TSI template development requires early elicitation of routine constraints and enactment requirements, and this ensures that teachers' practices are addressed. This is consistent with the DBR lens treating design knowledge as refined through stakeholder-grounded evidence (Anderson & Shattuck, 2012; Sandoval, 2014). For institutional coordination, templates provide a concrete basis for aligning training, support capacity, and quality expectations. This is consistent with implementation theory emphasising that embedding depends on organised roles and routines rather than sustained individual effort (May & Finch, 2009; Orlikowski, 2000).

A theoretical contribution is the HITE framework as an empirically grounded way to extend technology-enhanced learning (TEL) research beyond classroom-level instructional embedding to include the institution-level conditions that shape whether technology use becomes routine, supportable, and sustainable. This framing occupies a methodological and conceptual niche between TEL research that foregrounds instructional design and didactic practices and research on sustainability and scale that emphasises organisational capacity and infrastructure (Coburn, 2003; Fawns, 2022; Fowler, 2015; Kirkwood & Price, 2014; Penuel et al., 2011).

The HITE framework has implications at four levels: society, institutions, technology providers, and research. It extends TEL research by treating meaningful, sustainable and scalable technology use as dependent on institution-level coordination across Technology, Pedagogy, Context, Values, and Management, rather than on classroom-level instructional design and teacher agency alone (Kirkwood & Price, 2014; Penuel et al., 2011).

Societal implications. At the societal level, the framework foregrounds that decisions about educational technology contribute to shaping future learning practices and, by extension, the kinds of social participation and capability development that education makes possible. The implication is that technology

choices should be treated as deliberate, values-informed judgements, supported by systematic scrutiny of likely benefits, risks, and exclusions, rather than as neutral upgrades driven by novelty or convenience. This broadens the explanatory focus in TEL from classroom enactment and teacher agency to include the institution's role as a public actor whose priorities, constraints, and governance decisions channel educational trajectories and their social consequences (Biesta, 2020b; Fawns, 2022; Kirkwood & Price, 2014).

Institutional implications. Institutional decision-making on educational technology can be treated as an alignment task across Technology, Pedagogy, Context, Values, and Management, rather than as a sequence of isolated choices. This implies governance routines that make purpose and scenario-fit explicit, define responsibilities and support capacity, and maintain evaluation and revision over time. Values delimit acceptable trade-offs, and Management coordinates alignment across dimensions as conditions change. Sustainability depends on maintaining this alignment under routine teaching constraints, rather than expecting teachers to compensate for missing infrastructure or support (Coburn, 2003; Penuel et al., 2011).

Implications for technology providers. Technology development can incorporate a didactic articulation of intended use as part of what the product delivers. This includes configuration-specific pedagogical scenarios, clear guidance on what teachers need to do during teaching, and transparent requirements for training, support, and setup. Such specification helps institutions judge fit and reduces the need to invent pedagogical rationales and operational arrangements after deployment (Kirkwood & Price, 2014; Orlikowski, 2000; Penuel et al., 2011).

Implications for research. The framework motivates TEL research that bridges instructional embedding and institutional conditions. This implies research designs that connect classroom-level processes with governance, resourcing, support structures, and Values-based justification, preferably using longitudinal and mixed-method approaches that capture change across time rather than short pilots alone (Coburn, 2003; Fawns, 2022; Fowler, 2015; Kirkwood & Price, 2014; Penuel et al., 2011).

3. Limitations and future research directions

This section identifies the limitations of the thesis evidence base and outlines directions for future research.

The first limitation concerns the prospective orientation of the problem exploration. Chapters 1–2 derive stakeholder-driven requirements and constraints for meaningful integration, but much of this evidence reflects anticipated conditions for use rather than documented patterns of sustained, routine use over time. Chapter 5 adds a cross-institutional perspective by synthesising stakeholder views on pilots across different technical setups, yet this evidence remains centred on early-stage integration and combines retrospective reflection with prospective expectations, rather than tracing how practices stabilise or change once the technology becomes part of standard teaching workflows. Future research should therefore extend the evidence base in two complementary ways. First, longitudinal within-case studies

are needed to examine how purpose specification, support arrangements, and decision routines develop after initial design and piloting, and to determine which integration processes persist, degrade, or are reconfigured as routine constraints become salient (Anderson & Shattuck, 2012; Edelson, 2002; C. R. May et al., 2016; Murray et al., 2010; Sandoval, 2014).

Second, comparative multi-case studies are needed to test which conditions generalise across contexts and which remain context-dependent, including how variation in organisational setting and technology configuration alters the coordination work required for sustainability and scale. In this regard, implementation research on complex interventions seems directly relevant, because it conceptualises sustainability as dependent on the interaction between intervention complexity, local context, and the organisational work required to embed practices beyond time-limited trials (Damschroder et al., 2009; Greenhalgh et al., 2004; C. R. May et al., 2016; May & Finch, 2009; Murray et al., 2010). This research focus would support more nuanced investigation of how integration processes develop across time within a setting and how contextual variation shapes the conditions under which meaningful and sustainable integration can be maintained.

Another limitation concerns the validation scope for the TSI templates. Chapter 3 establishes the template concept and supports it through design, development and expert appraisal of three DVR templates. However, student-facing evaluation is only available as an exploratory pilot for one of the templates in Chapter 4, and was conducted in a single lecture, which limits inferences about sustained effects and leaves the possibility of short-term novelty effects. Future research could therefore evaluate the other templates in authentic teaching settings over longer instructional sequences (e.g., repeated sessions within a course)and examine whether the template concept functions reliably as a teacher-facing design representation that supports instructional planning and delivery across repeated use in multiple settings. In addition, future work should extend beyond teacher-led DVR-enhanced presentations to interactive activities for students, as well as creative and collaborative formats. This extension should include explicit comparisons of how different forms of interaction enabled by technical affordances align with instructional goals, pedagogical purposes, and learning processes, including knowledge gain, cognitive load, situational interest and intrinsic motivation, among others (Deci & Ryan, 1985; Mayer, 2005; Ryan & Deci, 2000; Sweller, 1994). This research direction is consistent with broader VR evidence showing heterogeneous effects that depend on design features and instructional conditions (Merchant et al., 2014; Radianti et al., 2020) and with theoretical work suggesting that immersive features can influence learning through cognitive and affective pathways, including the possibility that increased presence and agency may raise extraneous cognitive load if instructional design is not carefully managed (Makransky & Petersen, 2021; Parong & Mayer, 2018).

A further research direction could be to develop empirically grounded selection criteria for when specific VR formats and technical setups are instructionally warranted, rather than treating VR as a generally beneficial umbrella technology. Reviews and meta–analyses show that VR effects are heterogeneous and vary

across setups, by learning content, design features, and instructional conditions. Several literature reviews of iVR suggest that its use is most defensible when learning goals depend on spatial relations, navigation and manipulation, or simulations of otherwise costly, hazardous, or inaccessible environments, while offering fewer benefits when equivalent learning goals can be met through simpler representations (Merchant et al., 2014; Radianti et al., 2020). Future research could therefore develop and test explicit selection criteria that link technical setups and affordances, content characteristics, activity formats, and learner characteristics to expected outcomes. Such criteria would support teachers by making task–technology fit explicit at the point of instructional planning, helping them anticipate when added visual richness or interactivity is likely to support knowledge gain and situational interest, and when it is more likely to introduce extraneous cognitive load through redundancy, distraction, or unnecessary operational demands (Mayer & Moreno, 2003; Sweller, 1994; van Merriënboer & Sweller, 2005; Kalyuga, 2007). At the institutional level, shared criteria provide a common reference for professionalisation, curricular embedding, and template library prioritisation, so that investment in specific VR formats and technical setups is aligned with contexts in which their affordances plausibly contribute to supporting learning processes.

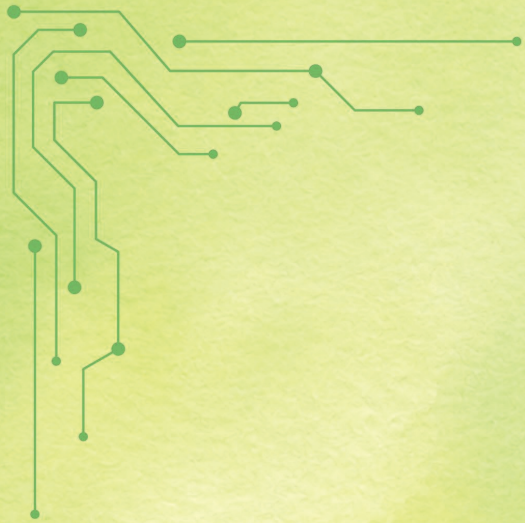
Within this thesis the HITE framework is presented at a conceptually generic level. This supports cross-context use but the dimensions require operationalisation before they can support analytically precise accounts of meaningful integration and inform decision-making in specific settings (Antonenko, 2015; Jabareen, 2009). Future research should therefore (a) specify each dimension and subdimension as an explicit set of observable indicators and decision points (e.g., minimum infrastructure and interoperability thresholds under Technology; concrete role distributions, support pathways, and review routines under Management), (b) develop and pilot measurement tools that allow these indicators to be assessed with acceptable reliability, and (c) examine documented integration trajectories longitudinally to understand how alignment is enacted, maintained, and repaired over time (May & Finch, 2009; G. F. Moore et al., 2015). Comparative research across primary, secondary, and tertiary education is particularly important because the same dimensions are likely to be instantiated differently under specific constraints. Context-sensitive operationalisations of the HITE Framework could be developed with accompanying instruments – for example combining document analysis and stakeholder interviews with survey-based assessment of integration work and routinisation using NPT-informed measures such as Normalisation Measure Development (NoMAD) – to track how Technology, Pedagogy, Context, Values, and Management remain aligned, or drift, across successive cycles (Damschroder et al., 2009; Finch et al., 2018; May et al., 2009; Rapley et al., 2018).

Future research should also strengthen the Values dimension by making explicit the value premises that often remain implicit in technology integration decisions, particularly as AI-enabled systems and data-driven infrastructures increasingly shape educational organisation and judgement practices (Castañeda & Selwyn, 2018b; Selwyn, Hillman, Bergviken-Rensfeldt, et al., 2023; Selwyn, Hillman, Bergviken Rensfeldt, et al., 2023; Williamson, 2015, 2016; Williamson et al., 2020).

In educational institutions, decisions about technologies are justified through seemingly consensual priorities such as efficiency, effectiveness, and positive learner experience or “enjoyability”, yet these priorities can entail substantive trade-offs once translated into resource allocation and criteria for “what counts” as educational benefit (Biesta, 2009; Kirkwood & Price, 2014). This is especially salient in primary and secondary education, where technology-supported differentiation can reinforce institutional categorisations of ability and distribute enrichment opportunities unevenly, with potential consequences for learners’ experiences and longer-term educational trajectories (Feniger et al., 2021; Lorijn et al., 2024). Empirical work on ability grouping illustrates that such arrangements are not value-neutral: they can shape learners’ psychosocial experiences and perceptions of fairness and may be accompanied by unequal instructional conditions across groups (Francis et al., 2019; McGillicuddy & Devine, 2020). Future research can therefore elicit and compare value commitments across stakeholder groups, including pupils and parents, as well as students, and to examine how these commitments are represented, contested, and enacted in governance, procurement, and classroom-level design.

Related to the Values dimension, a further research direction is to examine how increasing automation and improved technical usability in VR formats reshape teacher agency and professional judgement during instructional planning and delivery. This thesis highlights that operational complexity and the associated need for technical support and work allocation can constrain meaningful integration in practice. However, improved usability should not be treated as equivalent to pedagogical benefit. As usability constraints diminish, the central question becomes whether teachers retain informed control over whether, when, and how a technology is used, and whether the knowledge required to make pedagogically grounded decisions is supported rather than displaced (Biesta, 2009; Castañeda & Selwyn, 2018b; Kirkwood & Price, 2014). From a learning-theoretical perspective, inappropriate configuration of features that are easy to deploy – for example, visually rich environments, rapid viewpoint changes, or multiple concurrent information streams – can increase extraneous cognitive load and disrupt learning processes even when the technology is technically smooth to operate (R. E. Mayer & Moreno, 2003; Sweller, 2010). Future research could investigate teacher agency as both a governance issue (who has authority to decide on the tool and configuration) and a professional-capability issue (whether teachers have the conceptual and design expertise to use technical affordances selectively in relation to instructional goals). Exploring how instructional templates, presets, and decision supports are designed and institutionalised is important, as well as how to ensure that they stabilise quality without narrowing professional judgement and eroding agency of stakeholders. Longitudinal, comparative studies could therefore trace how teachers’ perceived agency, enacted decision-making, and instructional quality evolve as automation increases, and identify institutional conditions under which usability gains translate into sustainable practice without undermining the pedagogical deliberation on which meaningful integration depends.

Across the chapters, this thesis outlines the work, factors, and requirements that need to be met for meaningful, sustainable, and scalable integration of DVR technology in higher education, but it does not yet specify which institutional actors should carry this work and how it should be organised. Building on this gap, future research can examine how universities allocate and coordinate the integration work that typically sits between technology production and routine teaching, for example through teaching and learning centres, educational development units, or instructional design services, and how these structures translate technology capabilities into didactic use cases, teacher guidance, training, and ongoing support routines (Kirkwood & Price, 2014; Penuel et al., 2011). A related direction is to compare alternative organisational arrangements for scaling, such as shared support models, reusable template libraries, and sustained professional learning structures that reduce reliance on individual teacher improvisation while maintaining quality (Ertmer, 1999; Kopcha, 2012). Extending this line of inquiry beyond higher education is also relevant, because primary and secondary education often operate with limited specialist capacity and different forms of teacher professionalisation; research can therefore examine how comparable integration work is organised through shared or networked support across schools and how this shapes feasible, context-sensitive instructional designs supported by technology (Tondeur et al., 2012). Together, these directions bring attention to how educational institutions organise and sustain the integration work itself, including division of responsibilities, coordination routines, and ongoing support, so that meaningful integration persists beyond time-limited initiatives (Coburn & Penuel, 2016; Penuel et al., 2011).





Summary

Summary

This thesis addresses a recurring gap in technology-enhanced learning research: promising learning technologies can demonstrate local pedagogical value, yet still fail to become meaningfully integrated in routine teaching practice in ways that remain sustainable and scalable. The core problem is therefore not whether the technology works in isolation, but how teachers and institutions can define, enact, evaluate, and coordinate pedagogically purposeful use so that learning-relevant processes are supported over time, across contexts, and across increasing implementation complexity. This problem is examined through a design-based research (DBR) line focused on DVR-enhanced presentation technology (Edison) in synchronous university teaching, with attention to design requirements for meaningful technology integration at both classroom and organisational levels (Euler & Sloane, 2014; McKenney & Reeves, 2019; The Design-Based Research Collective, 2003).

Part 1: Problem analysis and exploration

The thesis begins by narrowing its focus to higher education and by eliciting stakeholder perspectives on what enables meaningful integration of DVR-enhanced presentation technology in ways that remain sustainable and scalable.

Chapter 1 reports a Group Concept Mapping study across two university contexts (a distance-learning university and a face-to-face university) to generate and organise stakeholder-informed requirements (Kane & Rosas, 2018; Rosas & Kane, 2012). Five clusters with requirement areas are distinguished – Evaluation, Institutional Requirements, Maintenance and Training, Student Requirements, and Affordances and Infrastructure. Stakeholder ratings indicate that these are generally judged both important and feasible, with Maintenance and Training and Institutional Requirements emerging as early priorities.

Chapter 2 complements the problem exploration by bringing the qualitative perspective through the single-case interview study in a distance-learning university. In this study it is examined how teachers, media design experts, and institutional managers articulate factors that shape how DVR tools can be used pedagogically purposefully in routine teaching practice. Stakeholder interviews identify five themes : Context (where integration takes place), Technology (what the tool affords), Pedagogy (how affordances are used), Values (why integration is warranted), and Management (how alignment is maintained). Two mechanisms operationalise this synthesis: a three-point audit of hardware, software, and staff expertise, and a value-aligned design workflow that links affordances to pedagogical purpose and screens risks through Values-Aligned Risk Evaluation.

Together, Chapters 1–2 provide a stakeholder-informed mapping of criteria and requirements that define what needs to be facilitated for meaningful, sustainable, and scalable integration of DVR at university level, thus establishing a clear basis for the subsequent investigation.

Part II: Design and Construction

Chapter 3 is a practical response to the requirements identified in Part 1 by designing and refining Technology-Specific Instructional (TSI) templates for DVR-enhanced presentations in online distance higher education. Across iterative development with stakeholders, three templates are produced and validated as feasible and pedagogically appropriate formats – slide presentation, 3D model presentation, and virtual environment presentation – which extend familiar presentation-based teaching while enabling purposeful use of DVR affordances. Clear design requirements for DVR-enhanced presentations are specified (May et al., 2009; May & Finch, 2009; Murray et al., 2010). It is important to distinguish knowledge goals from affective goals (including situational interest and intrinsic motivation) and to align design choices such as teacher presence (teacher visibility), cueing, and background design with the intended learning goal; at the same time, cognitive load management is treated as central, emphasising cueing, segmentation, and coherence while avoiding excessive visual effects and camera movement that can distract rather than support learning (R. E. Mayer, 2005; R. E. Mayer & Moreno, 2003; Sweller, 1994, 2010). Practice-facing feasibility requirements are also specified: reliable enactment depends on teacher training and rehearsal, and in many cases on technical support during live delivery so that operational workload remains manageable within routine teaching practice.

Part III: Evaluation and Reflection

In Part 3 DVR-enhanced presentations are tested in authentic settings. It is also examined what supports meaningful integration when the focus shifts from a designed format to use in routine practice.

Three small-scale pilots are presented in Chapter 4 in a distance-learning university. A selected DVR-enhanced presentation template is compared with traditional video-conferencing on knowledge gain, cognitive load, and intrinsic motivation during synchronous online lectures (Deci & Ryan, 1985; Leppink et al., 2013; Ryan & Deci, 2000a; Sweller, 1994). Across the pilots, differences between conditions are largely non-significant, with one isolated result indicating lower intrinsic cognitive load in the VR-enhanced condition; overall, the pattern supports feasibility and local viability, but does not (yet) provide evidence of superiority.

Evaluation is extended in Chapter 5 to three universities by comparing stakeholder accounts of meaningful, sustainable and scalable integration of the DVR-enhanced presentation technology across minimal, medium, and advanced hardware setups. A framework analysis informed by Normalisation Process Theory examines how stakeholders make sense of the technology's value and what is required for routine use. The findings show that the justification required increases with setup complexity: minimal hardware setups are valued mainly for pragmatic improvement to online lecture presentations; medium setups prompt stronger expectations for explicit educational function and scenario fit; and advanced setups add production-quality thresholds and a workable support–autonomy balance, with routine use often framed as product-oriented work requiring explicit resourcing, time allocation, and staging conditions (May et al., 2009; May & Finch, 2009; Murray et

al., 2010). The conclusions further emphasise that meaningful integration is supported by differentiating implementation scenarios by setup level rather than pursuing uniform roll-out expectations, and by treating context as decisive for what counts as feasible, worthwhile, and sustainable in routine practice (May et al., 2009; May & Finch, 2009; Murray et al., 2010).

Across Chapters 4–5, the combined findings provide an empirical basis for refining earlier requirements and design principles, and for specifying the institutional conditions under which DVR-enhanced presentations are perceived as worth doing and workable at scale.

Part IV: Theoretical Understanding

Chapter 6 presents the Holistic Integration of Technology in Education (HITE) Framework as a first conceptualisation of organisational-level conditions that shape meaningful, context-sensitive, sustainable, and scalable technology integration in education. The framework is developed by integrating empirical insights from a Group Concept Mapping study (Chapter 1) across two institutions, as well as an interview-based single-institution case study (Chapter 2), and by connecting this empirical base with research on technology-enhanced learning and organisational change, alongside expert review. HITE framework structures analysis through five conceptual dimensions – Technology, Pedagogy, Context, Values, and Management – and treats Management as the coordinating work through which the other dimensions are aligned over time, including planning, resourcing, governance, evaluation, and sustainment (Chambers et al., 2013; May et al., 2009). A central contribution is the integration of drivers of meaningful integration into a single conceptual plane, positioning the framework as an analytic means for inquiry and deliberation. It motivates further work to translate the five dimensions into practical supports and to test how the framework functions across a wider range of institutional contexts.

General Discussion

The General Discussion brings the thesis evidence together in a structured way. First, thesis-level answers to the two research questions are synthesised across all chapters, with three design requirements presented for meaningful, sustainable and scalable integration of DVR-enhanced presentations in higher education (making pedagogical purpose explicit through Technology-Specific Instructional Templates (TSI templates), aligning knowledge goals and affective goals including situational interest and intrinsic motivation, and managing cognitive load and operational workload so routinised use remains feasible) (R. E. Mayer & Moreno, 2003; McKenney & Reeves, 2019; Ryan & Deci, 2000a; Sweller, 1994). Five synthesis propositions are then formulated as the structured answer to the second research question, specifying integration as an institution-level coordination challenge: early stakeholder definition of pedagogically purposeful use, coordination across interdependent institutional conditions, a scalable support plus autonomy operational model differentiated by setup level, evaluation as a continuous cycle supporting effectiveness and long-term viability, and Values treated as binding

constraints shaping sustainability (Coburn, 2003; May & Finch, 2009; Murray et al., 2010; Orlikowski, 2000).

Apart from that, contributions and implications are consolidated across the full research line, centring on TSI templates as a practice-facing representation that links purpose, configuration, and enactment guidance, and on the Holistic Integration of Technology in Education (HITE) Framework as a conceptual structure for aligning Technology, Pedagogy, Context, Values, and Management when technology use is intended to become meaningful, sustainable and scalable (Jabareen, 2009; Penuel et al., 2011). Finally, limitations and future research directions are outlined at thesis level, emphasising the need for stronger longitudinal and comparative evidence, broader contextual testing, and further validation and operationalisation of templates and framework dimensions to support meaningful, sustainable and scalable integration beyond the studied settings (McKenney & Reeves, 2019; Penuel et al., 2011).

Samenvatting

Dit proefschrift gaat over een terugkerend probleem binnen technologieondersteund onderwijs: veelbelovende technologieën kunnen in een specifieke onderwijssetting waardevol zijn, maar worden niet vanzelf op een betekenisvolle, duurzame en schaalbare manier onderdeel van de dagelijkse onderwijspraktijk. De kernvraag is daarom niet alleen of een technologie op zichzelf werkt, maar hoe docenten en instellingen het gebruik ervan doelgericht kunnen vormgeven, uitvoeren, evalueren en organiseren. Dit probleem wordt onderzocht via ontwerpgericht onderzoek naar DVR-verrijkte presentatietechnologie, *Edison*, in synchroon universitair onderwijs. Daarbij staat centraal welke ontwerpvoorwaarden nodig zijn om deze technologie betekenisvol te integreren, zowel in de onderwijspraktijk als op organisatieniveau (Euler & Sloane, 2014; McKenney & Reeves, 2019; The Design-Based Research Collective, 2003).

Deel I: Probleemanalyse en verkenning

Het eerste deel van het proefschrift richt zich op de vraag wat betekenisvolle integratie van DVR-verrijkte presentatietechnologie vraagt binnen het hoger onderwijs. Hiervoor zijn perspectieven verzameld van verschillende belanghebbenden die betrokken zijn bij onderwijs, technologie en institutionele ondersteuning. Hoofdstuk 1 beschrijft een *Group Concept Mapping*-studie in twee universitaire contexten: een afstandsuniversiteit en een universiteit met voornamelijk contactonderwijs. Deze onderzoeksmethode maakt het mogelijk om ideeën van belanghebbenden systematisch te verzamelen, te ordenen en te beoordelen (Kane & Rosas, 2018; Rosas & Kane, 2012). De studie onderscheidt vijf voorwaarden: Evaluatie, Institutionele Randvoorwaarden, Onderhoud en Training, Studentgerelateerde Randvoorwaarden, en Affordances en Infrastructuur. De belanghebbenden beoordeelden deze voorwaarden over het algemeen als zowel belangrijk als haalbaar. Vooral Onderhoud en Training en Institutionele Randvoorwaarden kwamen naar voren als vroege prioriteiten.

In Hoofdstuk 2 wordt de probleemverkenning verdiept via een interviewstudie binnen één afstandsuniversiteit. In deze studie is onderzocht hoe docenten, mediaontwerpers en institutionele managers beschrijven wat nodig is om DVR-tools onderwijskundig doelgericht te gebruiken in de dagelijkse onderwijspraktijk. De interviews leidden tot vijf thema's: Context, Technologie, Pedagogiek, Waarden en Management. Deze thema's laten zien dat betekenisvolle integratie niet alleen afhangt van wat de technologie mogelijk maakt, maar ook van de context waarin zij wordt gebruikt, de pedagogische keuzes die ermee worden gemaakt, de waarden die het gebruik rechtvaardigen, en de manier waarop de instelling dit proces organiseert. In dit hoofdstuk worden deze inzichten uitgewerkt in twee praktische mechanismen. Het eerste is een driepuntsaudit van hardware, software en expertise van medewerkers. Het tweede is een waarden-gericht ontwerptraject, waarin technologische mogelijkheden worden verbonden aan onderwijskundige doelen en mogelijke risico's worden beoordeeld via *Values-Aligned Risk Evaluation*.

Samen laten Hoofdstuk 1 en 2 zien welke criteria en voorwaarden gefaciliteerd moeten worden om DVR-verrijkte presentatietechnologie op universitair niveau betekenisvol, duurzaam en schaalbaar te integreren. Daarmee vormt Deel I de basis voor het ontwerp, de evaluatie en de theoretische uitwerking in de rest van het proefschrift.

Deel II: Ontwerp en constructie

Hoofdstuk 3 bouwt voort op de voorwaarden uit Deel I. Het hoofdstuk beschrijft het ontwerp en de verfijning van *Technology-Specific Instructional templates*, of *TSI-templates*, voor DVR-verrijkte presentaties in online afstandsonderwijs in het hoger onderwijs. In samenwerking met betrokkenen bij onderwijsontwerp, technologie en institutionele ondersteuning zijn drie templates ontwikkeld en gevalideerd als haalbare en pedagogisch passende presentatieformats: een slidepresentatie, een 3D-modelpresentatie en een virtuele-omgevingpresentatie. Deze templates sluiten aan bij bekende presentatievormen, maar maken ook doelgericht gebruik van de specifieke mogelijkheden van DVR-technologie. Het hoofdstuk laat zien dat bij het ontwerpen van DVR-verrijkte presentaties onderscheid nodig is tussen kennisdoelen en affectieve doelen, zoals situationele interesse en intrinsieke motivatie. Ontwerpkeuzes, zoals zichtbaarheid van de docent, cueing, achtergrondontwerp en cameragebruik, moeten worden afgestemd op het beoogde leerdoel. Daarnaast staat het beheersen van cognitieve belasting centraal. DVR kan presentaties visueel rijker maken, maar te veel visuele effecten, beweging of afleiding kunnen het leren verstoren. Daarom zijn gerichte aandachtsturing, segmentatie, samenhang en een rustig ontwerp belangrijk (Mayer, 2005; Mayer & Moreno, 2003; Sweller, 1994, 2010). Tot slot laat het hoofdstuk zien dat haalbaarheid in de praktijk vraagt om meer dan een goed ontwerp. Docenten hebben training, voorbereiding en oefening nodig, en in veel gevallen ook technische ondersteuning tijdens live colleges. Zo blijft de extra praktische werkbelasting beheersbaar binnen de dagelijkse onderwijspraktijk (May et al., 2009; May & Finch, 2009; Murray et al., 2010).

Deel III: Evaluatie en reflectie

In Deel III worden DVR-verrijkte presentaties getest in authentieke onderwijssettings. Hoofdstuk 4 beschrijft drie kleinschalige pilots binnen een afstandsuniversiteit, waarin een DVR-verrijkte presentatietemplate wordt vergeleken met traditionele videoconferentie tijdens synchrone online colleges. De pilots richten zich op kenniswinst, cognitieve belasting en intrinsieke motivatie (Deci & Ryan, 1985; Leppink et al., 2013; Ryan & Deci, 2000; Sweller, 1994). De resultaten laten vooral zien dat de verschillen tussen de condities grotendeels niet significant zijn. Eén afzonderlijk resultaat wijst op een lagere intrinsieke *Cognitive Load* in de VR-verrijkte conditie. Daarmee ondersteunen de pilots de haalbaarheid en lokale bruikbaarheid van DVR-verrijkte presentaties, maar leveren zij nog geen bewijs dat deze vorm beter werkt dan traditionele videoconferentie.

In Hoofdstuk 5 is de evaluatie uitgebreid naar drie universiteiten. Daarbij zijn stakeholderbeschrijvingen vergeleken over drie hardwareopstellingen heen: minimaal, middelcomplex en geavanceerd. De analyse, gebaseerd op *Normalisation Process Theory*, richtte zich op hoe betrokkenen de waarde van DVR-verrijkte

presentatietechnologie begrijpen en welke voorwaarden zij nodig achten voor routinematig gebruik. De bevindingen laten zien dat de onderwijskundige onderbouwing belangrijker wordt naarmate de technische opstelling complexer is. Minimale opstellingen worden vooral gezien als praktische verbetering van online colleges, terwijl middelgrote en geavanceerde opstellingen duidelijkere onderwijsdoelen, hogere productiekwaliteit, meer ondersteuning en betere organisatorische voorwaarden vragen (May & Finch, 2009; May et al., 2009; Murray et al., 2010).

Samen laten Hoofdstuk 4 en Hoofdstuk 5 zien dat betekenisvolle integratie beter wordt ondersteund wanneer instellingen onderscheid maken tussen verschillende opstellingsniveaus en implementatiescenario's. Wat haalbaar, waardevol en duurzaam is, hangt sterk af van de context waarin DVR-verrijkte presentaties worden gebruikt.

Deel IV: Theoretisch inzicht

Hoofdstuk 6 presenteert het *Holistic Integration of Technology in Education Framework*, of *HITE Framework*. Dit framework biedt een eerste uitwerking van de organisatorische voorwaarden die betekenisvolle, contextgevoelige, duurzame en schaalbare integratie van technologie in het onderwijs ondersteunen.

Het *HITE Framework* is ontwikkeld op basis van de empirische inzichten uit de *Group Concept Mapping*-studie en de interviewstudie, en is verbonden met onderzoek naar technologieondersteund leren, organisatieverandering en implementatieprocessen (Chambers et al., 2013; May et al., 2009). Het framework bestaat uit vijf dimensies: Technologie, Pedagogiek, Context, Waarden en Management.

Management heeft binnen het framework een coördinerende rol. Het gaat daarbij om het afstemmen van de andere dimensies via planning, middelen, bestuur, evaluatie en borging. Zo biedt het *HITE Framework* een structuur om technologie-integratie systematisch te onderzoeken, te bespreken en verder te ontwikkelen. Het hoofdstuk laat ook zien dat vervolgonderzoek nodig is om de dimensies verder te vertalen naar praktische ondersteuning en te toetsen in andere onderwijscontexten.

Algemene discussie

Voor betekenisvolle, duurzame en schaalbare integratie van DVR-verrijkte presentaties in het hoger onderwijs worden in dit proefschrift drie ontwerpvoorwaarden geformuleerd. Ten eerste moet het onderwijskundige doel van de technologie expliciet worden gemaakt, bijvoorbeeld via *TSI-templates*. Ten tweede moeten kennisdoelen en affectieve doelen, zoals situationele interesse en intrinsieke motivatie, goed op elkaar worden afgestemd. Ten derde moeten zowel cognitieve belasting als praktische werkbelasting beheersbaar blijven, zodat het gebruik van de technologie uitvoerbaar blijft binnen de dagelijkse onderwijspraktijk (Mayer & Moreno, 2003; McKenney & Reeves, 2019; Ryan & Deci, 2000; Sweller, 1994).

Daarnaast laat het onderzoek in dit proeschrift zien dat betekenisvolle integratie niet alleen om een goed ontwerp vraagt, maar ook om institutionele coördinatie. De

vijf syntheseproposities benadrukken het belang van een gedeeld onderwijskundig doel, afstemming tussen institutionele voorwaarden, een werkbare balans tussen ondersteuning en autonomie, voortdurende evaluatie, en Waarden als richtinggevende randvoorwaarden voor duurzame integratie (Coburn, 2003; May & Finch, 2009; Murray et al., 2010; Orlikowski, 2000).

De belangrijkste bijdragen van dit proefschrift zijn de *TSI-templates* en het *HITE Framework*. De templates verbinden onderwijskundig doel, technische inrichting en uitvoering. Het *HITE Framework* biedt een bredere structuur om Technologie, Pedagogiek, Context, Waarden en Management op elkaar af te stemmen wanneer technologie betekenisvol, duurzaam en schaalbaar onderdeel moet worden van onderwijspraktijken (Jabareen, 2009; Penuel et al., 2011).

Tot slot worden op dissertatieniveau beperkingen en richtingen voor vervolgonderzoek benoemd. Vooral longitudinaal en vergelijkend onderzoek is nodig om vast te stellen of TSI-Templates en de HITE-frameworkdimensies betekenisvolle, duurzame en schaalbare integratie ook op langere termijn, in andere onderwijscontexten en buiten de onderzochte instellingen kunnen ondersteunen. Daarnaast is verdere toetsing nodig van de vraag hoe de templates en frameworkdimensies kunnen worden geoperationaliseerd voor gebruik buiten de onderzochte instellingen (McKenney & Reeves, 2019; Penuel et al., 2011).

Резюме

Ця дисертація розглядає повторювану проблему в дослідженнях навчання з використанням цифрових технологій: перспективні освітні технології можуть мати локальну педагогічну цінність, але не завжди стають частиною усталеної практики викладання у спосіб, що є сталим і масштабованим. Отже, ключове питання полягає не лише в тому, чи працює технологія в окремому навчальному контексті, а в тому, як викладачі й освітні інституції можуть визначати, реалізовувати, оцінювати та координувати її педагогічно доцільне використання. Таке використання має підтримувати навчально значущі процеси впродовж тривалого часу, у різних контекстах і за умов зростання організаційної та практичної складності.

Цю проблему досліджено в межах лінії дизайн-орієнтованого дослідження (design-based research, DBR), зосередженої на презентаційній технології з використанням настільної віртуальної реальності (desktop virtual reality, DVR; Edison) у синхронному університетському викладанні. Особливу увагу приділено вимогам до проєктування, які можуть підтримувати педагогічно осмислену інтеграцію технології як на рівні навчальної взаємодії, так і на організаційному рівні (Euler & Sloane, 2014; McKenney & Reeves, 2019; The Design-Based Research Collective, 2003).

Частина I. Аналіз і дослідження проблеми

Дисертація починається з уточнення фокусу на вищій освіті та з аналізу того, як різні зацікавлені сторони розуміють умови педагогічно осмисленої, сталої й масштабованої інтеграції презентаційної технології з використанням DVR.

У Розділі 1 представлено дослідження, проведене методом групового концептуального картування у двох університетських контекстах: в університеті дистанційного навчання та в університеті з очним форматом навчання. Метою дослідження було визначити й упорядкувати вимоги до інтеграції технології на основі поглядів зацікавлених сторін (Kane & Rosas, 2018; Rosas & Kane, 2012). У результаті було виокремлено п’ять груп вимог: *Оцінювання, Інституційні вимоги, Технічний супровід і навчання персоналу, Потреби студентів*, а також *Технологічні можливості та інфраструктура*. Оцінки зацікавлених сторін показали, що ці групи вимог загалом сприймаються як важливі й здійсненні. Водночас *Технічний супровід і навчання персоналу* та *Інституційні вимоги* постали як пріоритетні напрями на ранньому етапі інтеграції.

Розділ 2 поглиблює аналіз проблеми через якісне дослідження одного випадку на основі інтерв’ю в університеті дистанційного навчання. У цьому розділі розглянуто, як викладачі, фахівці з медіадизайну та інституційні менеджери описують чинники, що впливають на педагогічно доцільне використання DVR-інструментів в усталеній практиці викладання. Аналіз інтерв’ю дав змогу виокремити п’ять тем: *Контекст*, тобто умови, у яких відбувається інтеграція; *Технологія*, тобто можливості, які надає інструмент; *Педагогіка*, тобто способи використання цих можливостей для навчання;

Цінності, тобто підстави, які роблять інтеграцію виправданою; і *Менеджмент*, тобто координаційна робота, потрібна для підтримання узгодженості між цими елементами.

На основі цього синтезу запропоновано два практичні механізми. Перший механізм – це аудит трьох складників: апаратного забезпечення, програмного забезпечення та експертності персоналу. Другий механізм – це процедура проєктування, узгоджена з цінностями: вона пов'язує технологічні можливості з педагогічною метою та передбачає оцінювання ризиків через підхід *Values-Aligned Risk Evaluation*.

Разом Розділи 1–2 формують карту критеріїв і вимог, визначених на основі поглядів зацікавлених сторін. Ця карта показує, що саме потрібно підтримати, аби інтеграція DVR на рівні закладу вищої освіти могла бути педагогічно осмисленою, сталою й масштабованою. Вона також створює основу для подальших етапів дисертаційного дослідження.

Частина II. Проєктування і розроблення

Розділ 3 є практичною відповіддю на вимоги, визначені в Частині I. У ньому описано проєктування й уточнення технологічно специфічних навчальних шаблонів (Technology-Specific Instructional templates, TSI-шаблони) для презентацій з використанням настільної віртуальної реальності (DVR) в онлайн-дистанційній вищій освіті.

У процесі ітеративної розробки за участю зацікавлених сторін було створено й перевірено три шаблони: *слайдова презентація, презентація 3D-моделі та презентація віртуального середовища*. Ці шаблони були оцінені як здійсненні та педагогічно доцільні формати. Вони спираються на знайому для викладачів презентаційну форму навчання, але водночас дають змогу цілеспрямовано використовувати технологічні можливості DVR.

У розділі також визначено основні вимоги до проєктування DVR-презентацій (May et al., 2009; May & Finch, 2009; Murray et al., 2010). Насамперед важливо розрізняти цілі, пов'язані з набуттям знань, і афективні цілі, зокрема ситуаційний інтерес і внутрішню мотивацію. Дизайн-рішення мають узгоджуватися з відповідною навчальною метою. Це стосується, зокрема, візуальної присутності викладача, тобто його видимості на екрані, сигналізації уваги, вибору фону та способу представлення навчального матеріалу.

В одночас управління когнітивним навантаженням розглядається як центральний принцип проєктування. DVR-презентації мають підтримувати увагу студентів через *візуальне спрямування уваги*, сегментацію навчального матеріалу та узгодженість візуальних елементів. Надмірні візуальні ефекти, складний рух камери або декоративні елементи можуть, навпаки, відволікати студентів і знижувати навчальну цінність презентації (R. E. Mayer, 2005; R. E. Mayer & Moreno, 2003; Sweller, 1994, 2010).

Крім педагогічних вимог, у розділі визначено умови практичної здійсненності. Надійне використання DVR-презентацій потребує підготовки викладачів, репетицій і, у багатьох випадках, технічної підтримки під час синхронного заняття. Це необхідно для того, щоб організаційно-технічне навантаження

залишалося керованим і не перешкоджало використанню технології в усталеній практиці викладання.

Частина III. Оцінювання та аналіз

У Частині III презентації з використанням DVR перевіряються в реальних навчальних умовах. Основна увага зміщується від розробленого формату до питання про те, що підтримує педагогічно осмислену інтеграцію технології в усталеній практиці викладання.

У Розділі 4 представлено три маломасштабні пілотні дослідження, проведені в університеті дистанційного навчання. У цих дослідженнях обраний шаблон DVR-презентації порівнювався з традиційним відеоконференційним форматом під час синхронних онлайн-лекцій. Порівняння стосувалося трьох показників: *приросту знань*, *когнітивного навантаження* та *внутрішньої мотивації* (Deci & Ryan, 1985; Leppink et al., 2013; Ryan & Deci, 2000a; Sweller, 1994).

Загалом відмінності між умовами виявилися переважно статистично незначущими. Лише один окремий результат указував на нижче внутрішнє когнітивне навантаження в умові з використанням DVR-презентації. Отже, результати підтримують здійсненність і локальну придатність цього формату, але поки що не дають підстав стверджувати його перевагу над традиційним відеоконференційним форматом.

У Розділі 5 оцінювання розширено до трьох університетів. У цьому розділі порівнюються погляди зацікавлених сторін на педагогічно осмислену, сталу й масштабовану інтеграцію презентаційної технології з використанням DVR за різних конфігурацій обладнання: *мінімальної*, *середньої* та *розширеної*. Аналіз здійснено за допомогою рамкового аналізу, інформованого Теорією нормалізаційних процесів. Такий підхід дав змогу розглянути, як зацікавлені сторони осмислюють цінність технології та які умови вони вважають необхідними для її усталеного використання.

Результати показують, що зі зростанням складності конфігурації обладнання зростає і потреба в чіткішому обґрунтуванні використання технології. Мінімальна конфігурація цінується переважно за прагматичне покращення онлайн-лекцій. Середня конфігурація пов'язана з вищими очікуваннями щодо чіткої освітньої функції та відповідності конкретному педагогічному сценарію. Розширена конфігурація, своєю чергою, додає вимоги до якості виробництва, розподілу ролей і балансу між технічною підтримкою та автономією викладача. У такому випадку усталене використання технології часто розглядається як робота, зорієнтована на створення якісного освітнього продукту, що потребує окремих ресурсів, часу та організаційних умов (May et al., 2009; May & Finch, 2009; Murray et al., 2010).

Висновки Розділу 5 також підкреслюють, що педагогічно осмислена інтеграція потребує диференціації сценаріїв використання відповідно до рівня конфігурації обладнання. Єдина модель розгортання для всіх умов не є достатньою. Натомість контекст визначає, що саме може вважатися здійсненним, доцільним і сталим в усталеній практиці викладання (May et al., 2009; May & Finch, 2009; Murray et al., 2010).

Разом Розділи 4–5 дають емпіричну основу для уточнення попередніх вимог і принципів проєктування. Вони також конкретизують інституційні умови, за яких DVR-презентації можуть сприйматися як педагогічно доцільні, практично здійсненні та придатні для масштабування.

Частина IV. Теоретичне узагальнення

У Розділі 6 представлено *Фреймворк цілісної інтеграції технологій в освіту HITE* (Holistic Integration of Technology in Education Framework, HITE Framework). Фреймворк HITE узагальнює організаційні умови, що впливають на педагогічно осмислену, контекстно чутливу, сталу й масштабовану інтеграцію технологій в освіті.

Фреймворк HITE розроблено на основі кількох джерел. По-перше, він спирається на емпіричні результати дослідження методом групового концептуального картування у двох інституціях, представленого в Розділі 1. По-друге, він враховує результати інтерв'ю-дослідження одного інституційного випадку, представленого в Розділі 2. По-третє, ці емпіричні результати співвіднесено з дослідженнями навчання з використанням цифрових технологій та організаційних змін, а також із результатами експертного оцінювання.

Фреймворк HITE структурує аналіз через п'ять концептуальних вимірів: *Технологія*, *Педагогіка*, *Контекст*, *Цінності* та *Менеджмент*. Вимір *Менеджмент* описує координаційну роботу, завдяки якій інші виміри узгоджуються в часі. До цієї роботи належать планування, ресурсне забезпечення, управління, оцінювання та підтримання сталості інтеграції (Chambers et al., 2013; May et al., 2009).

Основний внесок фреймворку HITE полягає в тому, що він поєднує ключові чинники педагогічно осмисленої інтеграції в єдиній аналітичній структурі. Завдяки цьому HITE може використовуватися як інструмент для дослідження, обговорення й узгодження технологічної інтеграції на організаційному рівні.

Подальша робота має бути спрямована на перетворення п'яти вимірів HITE на практичні інструменти підтримки, а також на перевірку того, як цей фреймворк функціонує в ширшому колі освітніх інституційних контекстів.

Узагальнення результатів

Завершальний розділ дисертації узагальнює результати всієї дослідницької лінії. Насамперед у ньому сформульовано відповіді на два дослідницькі питання на основі результатів усіх розділів дисертації.

Відповідь на перше дослідницьке питання представлено через три вимоги до проєктування педагогічно осмисленої, сталої й масштабованої інтеграції презентацій з використанням DVR у вищій освіті. Перша вимога полягає в тому, щоб на ранніх етапах чітко визначати педагогічну мету використання технології за допомогою технологічно специфічних навчальних шаблонів (Technology-Specific Instructional templates, TSI-шаблони). Друга вимога стосується узгодження цілей, пов'язаних із набуттям знань, з афективними цілями, зокрема *ситуаційним інтересом* і *внутрішньою мотивацією*. Третя вимога передбачає управління *когнітивним навантаженням* і організаційно-технічним

навантаженням, щоб регулярне використання технології залишалося практично здійсненним в усталеній практиці викладання (R. E. Mayer & Moreno, 2003; McKenney & Reeves, 2019; Ryan & Deci, 2000a; Sweller, 1994).

Відповідь на друге дослідницьке питання сформульовано у вигляді п'яти узагальнювальних положень. У цих положеннях інтеграція розглядається як координаційний виклик на рівні освітньої інституції. По-перше, педагогічно доцільне використання технології має визначатися разом із зацікавленими сторонами вже на початкових етапах. По-друге, інтеграція потребує узгодження взаємозалежних інституційних умов. По-третє, операційна модель має поєднувати підтримку й автономію та враховувати рівень конфігурації обладнання. По-четверте, оцінювання має бути безперервним циклом, що підтримує ефективність і довгострокову життєздатність інтеграції. По-п'яте, *Цінності* мають розглядатися як обов'язкові орієнтири й обмеження, що визначають умови сталої інтеграції (Coburn, 2003; May & Finch, 2009; Murray et al., 2010; Orlikowski, 2000).

У розділі також узагальнено наукові й практичні внески дисертації. Одним із ключових внесків є TSI-шаблони, які пов'язують педагогічну мету, технологічну конфігурацію та рекомендації щодо реалізації в практично придатну форму. Іншим внеском є фреймворк HITE, який пропонує концептуальну основу для узгодження *Технології*, *Педагогіки*, *Контексту*, *Цінностей* і *Менеджменту* тоді, коли використання технології має стати педагогічно осмисленим, сталим і масштабованим (Jabareen, 2009; Penuel et al., 2011).

Насамкінець у завершальному розділі окреслено обмеження дисертації та напрями подальших досліджень. Подальша робота має спиратися на ширшу лонгітюдну й порівняльну емпіричну базу, перевіряти результати в різних освітніх контекстах, а також продовжувати валідацію й операціоналізацію TSI-шаблонів і вимірів фреймворку HITE. Це необхідно для того, щоб підтримувати педагогічно осмислену, сталу й масштабовану інтеграцію технологій поза межами досліджених контекстів (McKenney & Reeves, 2019; Penuel et al., 2011).

Zusammenfassung

Diese Dissertation befasst sich mit einer wiederkehrenden Lücke in der Forschung zum technologiegestützten Lernen: Vielversprechende Lerntechnologien können zwar lokal einen didaktischen Mehrwert entfalten, ihre nachhaltige und skalierbare Integration in die routinemäßige Lehrpraxis scheitert jedoch häufig. Das Kernproblem besteht daher nicht darin, ob die Technologie für sich genommen funktioniert, sondern darin, wie Lehrende und Institutionen einen didaktisch zielgerichteten Einsatz definieren, umsetzen, evaluieren und koordinieren können, sodass lernrelevante Prozesse über die Zeit, über Kontexte hinweg und bei zunehmender Implementierungskomplexität hinweg unterstützt werden. Untersucht wird dieses Problem in einer auf Design-Based-Research (DBR) basierenden Studienreihe, die sich auf Desktop Virtual Reality (DVR)-gestützte Präsentationstechnologie (Edison) in der synchronen Hochschullehre konzentriert, unter besonderer Berücksichtigung von Gestaltungsanforderungen für eine sinnvolle Technologieintegration sowohl für den Unterricht als auch auf der Organisationsebene (Euler & Sloane, 2014; McKenney & Reeves, 2019; The Design-Based Research Collective, 2003).

Teil I: Problemanalyse und Exploration

Die Dissertation beginnt mit einer Fokussierung auf die Hochschulbildung und mit der Erhebung von Stakeholderperspektiven darauf, was eine sinnvolle Integration DVR-gestützter Präsentationstechnologie ermöglicht, die zugleich nachhaltig und skalierbar bleibt.

Kapitel 1 berichtet über eine Group-Concept-Mapping-Studie in zwei Hochschulkontexten – einer Fernuniversität und einer Präsenzuniversität –, um von Stakeholdern informierte Anforderungen zu generieren und zu strukturieren (Kane & Rosas, 2018; Rosas & Kane, 2012). Es werden fünf Anforderungscluster unterschieden – Evaluation, institutionelle Anforderungen, Wartung und Schulung, Anforderungen der Studierenden sowie Leistungsangebot und Infrastruktur. Die Bewertungen der Stakeholder zeigen, dass diese Bereiche insgesamt sowohl als wichtig als auch als umsetzbar eingeschätzt werden, wobei Wartung und Schulung sowie institutionelle Anforderungen als frühe Prioritäten hervortreten.

Kapitel 2 ergänzt diese Problemanalyse um eine qualitative Perspektive in Form einer Interviewstudie als Einzelfallstudie an einer Fernuniversität. Untersucht wird, wie Lehrende, Mediendesign-Expertinnen und -Experten sowie institutionelle Leitungspersonen diejenigen Faktoren artikulieren, die prägen, wie DVR-Werkzeuge in der routinierten Lehrpraxis didaktisch zielgerichtet eingesetzt werden können. Die Stakeholderinterviews identifizieren fünf Themen: Kontext (wo Integration stattfindet), Technologie (welche Möglichkeiten das Werkzeug bietet), Didaktik (wie Affordanzen genutzt werden), Werte (warum Integration gerechtfertigt ist) und Management (wie Abstimmung aufrechterhalten wird). Zwei Mechanismen operationalisieren diese Synthese: ein Drei-Punkte-Audit von Hardware, Software und Personalexpertise sowie ein werteorientierter Design-Workflow, der Affordanzen

mit didaktischer Zielsetzung verknüpft und Risiken mithilfe von Values-Aligned Risk Evaluation prüft.

Zusammen genommen liefern Kapitel 1–2 eine durch Stakeholder informierte Kartierung von Kriterien und Anforderungen, die definieren, was für eine sinnvolle, nachhaltige und skalierbare Integration von DVR auf Hochschulebene ermöglicht werden muss, und schaffen damit eine klare Grundlage für die nachfolgenden Untersuchungen.

Teil II: Design und Konstruktion

Kapitel 3 stellt eine praktische Antwort auf die in Teil I identifizierten Anforderungen dar, indem *Technology-Specific Instructional* (TSI) Templates für DVR-gestützte Präsentationen in der Online-Fernhochschullehre entwickelt und verfeinert werden. In einem iterativen Entwicklungsprozess mit Stakeholdern werden drei Templates erarbeitet und als praktikable sowie didaktisch angemessene Formate validiert – Folienpräsentation, 3D-Modell-Präsentation und Präsentation virtueller Umgebungen. Diese knüpfen an vertraute präsentationsbasierte Lehrformate an und ermöglichen zugleich einen zielgerichteten Einsatz von DVR. Es werden klare Gestaltungsanforderungen für DVR-gestützte Präsentationen spezifiziert (May et al., 2009; May & Finch, 2009; Murray et al., 2010). Dabei ist es wichtig, Wissensziele von affektiven Zielen – einschließlich situationalem Interesse und intrinsischer Motivation – zu unterscheiden und Gestaltungsentscheidungen wie *Teacher Presence* (Sichtbarkeit der Lehrperson), Cueing und Hintergrundgestaltung auf das intendierte Lernziel abzustimmen. Zugleich wird das Management der *Cognitive Load* als zentral behandelt, mit einem Schwerpunkt auf Cueing, Segmentierung und Kohärenz, während übermäßige visuelle Effekte und Kamerabewegungen vermieden werden sollen, die eher ablenken als das Lernen zu unterstützen (Mayer, 2005; R. E. Mayer & Moreno, 2003; Sweller, 1994, 2010). Darüber hinaus werden praxisbezogene Machbarkeitsanforderungen spezifiziert: Eine verlässliche Umsetzung hängt von der Schulung und dem Einüben durch Lehrende ab und in vielen Fällen auch von technischer Unterstützung während der Live-Durchführung, damit die operative Arbeitsbelastung im Rahmen routinierter Lehrpraxis beherrschbar bleibt.

Teil III: Evaluation und Reflexion

In Teil III werden DVR-gestützte Präsentationen in authentischen Settings erprobt. Zudem wird untersucht, was eine sinnvolle Integration unterstützt, wenn sich der Fokus von einem gestalteten Format auf den Einsatz in der routinierten Praxis verlagert.

In Kapitel 4 werden drei kleinskalige Pilotstudien an einer Fernuniversität vorgestellt. Ein ausgewähltes Template für DVR-gestützte Präsentationen wird mit traditioneller Videokonferenzlehre hinsichtlich Wissenszuwachs, kognitiver Belastung und intrinsischer Motivation während synchroner Online-Vorlesungen verglichen (Deci & Ryan, 1985; Leppink et al., 2013; Ryan & Deci, 2000a; Sweller, 1994). Über die Pilotstudien hinweg sind die Unterschiede zwischen den Bedingungen weitgehend nicht signifikant, wobei ein isoliertes Ergebnis auf eine geringere intrinsische Cognitive Load in der VR-gestützten Bedingung hinweist.

Insgesamt spricht dieses Muster für Machbarkeit und lokale Tragfähigkeit, liefert jedoch noch keinen Nachweis einer Verbesserung.

In Kapitel 5 wird die Evaluation auf drei Hochschulen ausgeweitet, indem mit Stakeholdern erstellte Darstellungen einer sinnvollen, nachhaltigen und skalierbaren Integration der DVR-gestützten Präsentationstechnologie über minimale, mittlere und fortgeschrittene Hardware-Setups hinweg verglichen werden. Eine durch die *Normalisation Process Theory* informierte Framework-Analyse untersucht, wie Stakeholder den Wert der Technologie deuten und was für eine routinisierte Nutzung erforderlich ist. Die Befunde zeigen, dass die notwendige Rechtfertigung mit zunehmender Setup-Komplexität steigt: Minimale Hardware-Setups werden vor allem aufgrund pragmatischer Verbesserungen von Online-Vorlesungspräsentationen geschätzt; mittlere Setups erzeugen stärkere Erwartungen an eine explizite Bildungsfunktion und Passung zum jeweiligen Szenario; und fortgeschrittene Setups bringen Schwellenwerte hinsichtlich Produktionsqualität sowie ein tragfähiges Gleichgewicht von Unterstützung und Autonomie mit sich. Routinisierte Nutzung wird dabei häufig als produktorientierte Arbeit gerahmt, die explizite Ressourcen, Zeitzuweisung und inszenatorische Rahmenbedingungen erfordert (May et al., 2009; May & Finch, 2009b; Murray et al., 2010). Die Schlussfolgerungen betonen darüber hinaus, dass sinnvolle Integration dadurch unterstützt wird, Implementierungsszenarien nach Setup-Niveau zu differenzieren, anstatt einheitliche Roll-out-Erwartungen zu verfolgen, und Kontext als maßgeblich dafür zu behandeln, was in der routinierten Praxis als machbar, lohnend und nachhaltig gilt (May et al., 2009; May & Finch, 2009b; Murray et al., 2010).

Die kombinierten Befunde aus Kapitel 4 und 5 liefern eine empirische Grundlage dafür, frühere Anforderungen und Gestaltungsprinzipien weiter zu schärfen und die institutionellen Bedingungen zu spezifizieren, unter denen DVR-gestützte Präsentationen als lohnend und im größeren Maßstab praktikabel wahrgenommen werden.

Teil IV: Theoretisches Verständnis

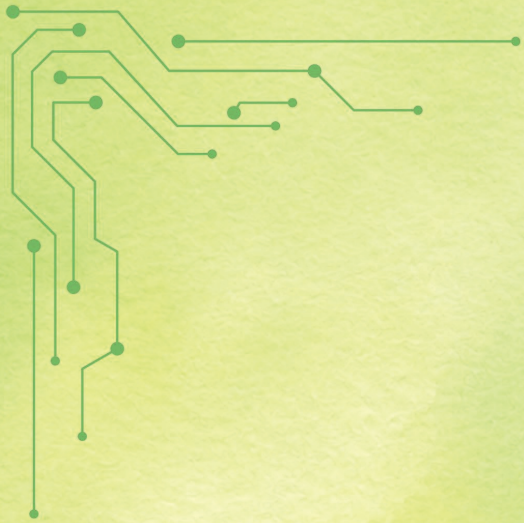
Kapitel 6 präsentiert das *Holistic Integration of Technology in Education (HITE)* Framework als eine erste Konzeptualisierung von Bedingungen auf Organisationsebene, die eine sinnvolle, kontextsensitive, nachhaltige und skalierbare Technologieintegration im Bildungsbereich prägen. Das Framework wird entwickelt, indem empirische Erkenntnisse aus einer Group-Concept-Mapping-Studie (Kapitel 1) bei zwei Institutionen sowie aus einer interviewbasierten Einzelfallstudie innerhalb einer Institution (Kapitel 2) integriert und diese empirische Basis mit Forschung zu technology-enhanced learning und organisationalem Wandel sowie mit Expertenreview verbunden werden. Das HITE-Framework strukturiert die Analyse anhand von fünf konzeptionellen Dimensionen – Technologie, Didaktik, Kontext, Werte und Management – und versteht Management als jene koordinierende Arbeit, durch die die anderen Dimensionen über die Zeit hinweg aufeinander abgestimmt werden, einschließlich Planung, Personal- und Mitteleinsatz, Governance, Evaluation und Verstetigung (Chambers et al., 2013; May

et al., 2009). Ein zentraler Beitrag besteht in der Integration der Triebkräfte sinnvoller Integration in eine gemeinsame konzeptionelle Ebene, wodurch das Framework als analytisches Instrument für Untersuchung und Deliberation positioniert wird. Es begründet weiteren Forschungsbedarf, um die fünf Dimensionen in praktische Unterstützungsformen zu übersetzen und zu prüfen, wie das Framework in einer breiteren Vielfalt institutioneller Kontexte funktioniert.

Allgemeine Diskussion

Die allgemeine Diskussion führt die Ergebnisse der Dissertation in strukturierter Weise zusammen. Zunächst werden Antworten auf die beiden zentralen Forschungsfragen der Dissertation über alle Kapitel hinweg synthetisiert, wobei drei Gestaltungsanforderungen für eine sinnvolle, nachhaltige und skalierbare Integration DVR-gestützter Präsentationen in der Hochschulbildung vorgestellt werden: die didaktischen Zielsetzung durch TSI-Templates explizit machen, Lernziele und affektive Ziele einschließlich situationalem Interesse und intrinsischer Motivation abstimmen, sowie kognitive Belastung und operative Arbeitsbelastung managen, damit regelmäßige und dauerhafte Nutzung machbar bleibt (Mayer & Moreno, 2003; McKenney & Reeves, 2019; Ryan & Deci, 2000; Sweller, 1994). Anschließend werden fünf Synthesepropositionen als strukturierte Antwort auf die zweite Forschungsfrage formuliert, die Integration als Koordinationsherausforderung auf Institutionsebene bestimmen: eine frühe, Stakeholder-gestützte Bestimmung didaktisch zielgerichteter Nutzung, Koordination über wechselseitige institutionelle Abhängigkeiten hinweg, ein skalierbares operatives Modell aus Unterstützung und Autonomie, differenziert nach Setup-Niveau, Evaluation als kontinuierlicher Zyklus zur Unterstützung von Wirksamkeit und langfristiger Tragfähigkeit sowie Werte, die als bindende Rahmenbedingungen behandelt werden, welche Nachhaltigkeit formen (Coburn, 2003; May & Finch, 2009b; Murray et al., 2010; Orlikowski, 2000).

Darüber hinaus werden Beiträge und Implikationen über die gesamte Dissertation hinweg gebündelt, mit einem Fokus auf TSI-Templates als praxisnaher Repräsentation, die Zielsetzung, Konfiguration und Hinweise zur Umsetzung miteinander verbindet, sowie auf dem HITE Framework als konzeptioneller Struktur zur Abstimmung von Technologie, Didaktik, Kontext, Werten und Management, wenn Technologienutzung sinnvoll, nachhaltig und skalierbar werden soll (Jabareen, 2009; Penuel et al., 2011). Abschließend werden Einschränkungen und zukünftige Forschungsrichtungen auf Dissertationsebene umrissen, wobei die Notwendigkeit stärkerer longitudinaler und vergleichender Evidenz, breiterer Prüfung in unterschiedlichen Kontexten sowie weiterer Validierung und Operationalisierung von Templates und Framework-Dimensionen betont wird, um eine sinnvolle, nachhaltige und skalierbare Integration über die untersuchten Settings hinaus zu unterstützen (McKenney & Reeves, 2019; Penuel et al., 2011).





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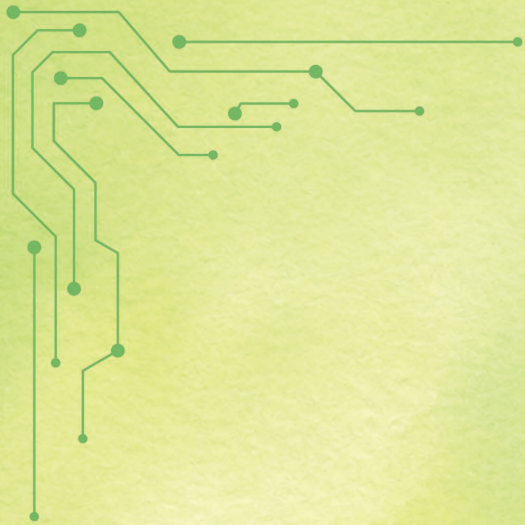
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Appendices

Appendices

Appendix A (Chapter 1)

1. Demographic questions

1.1. Role in the institution for the brainstorming phase

Figure 1

Demographic data for OU for the brainstorming activity: role in the institution

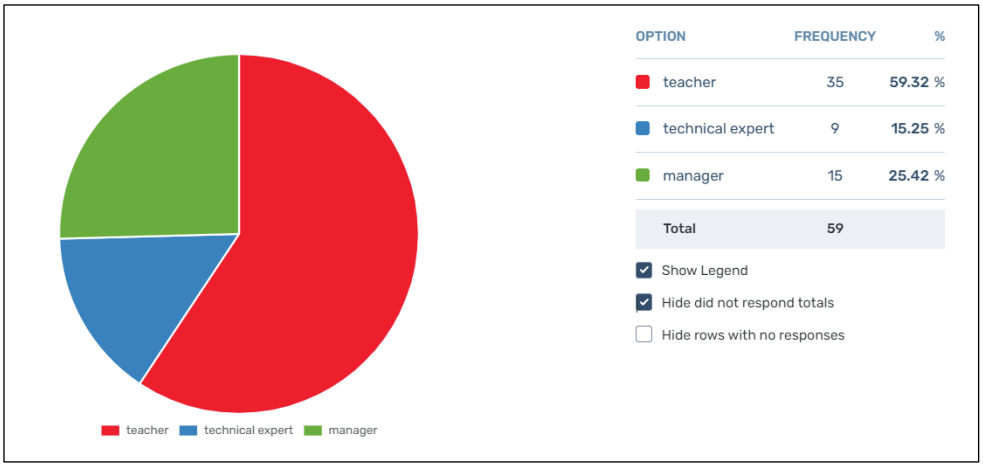
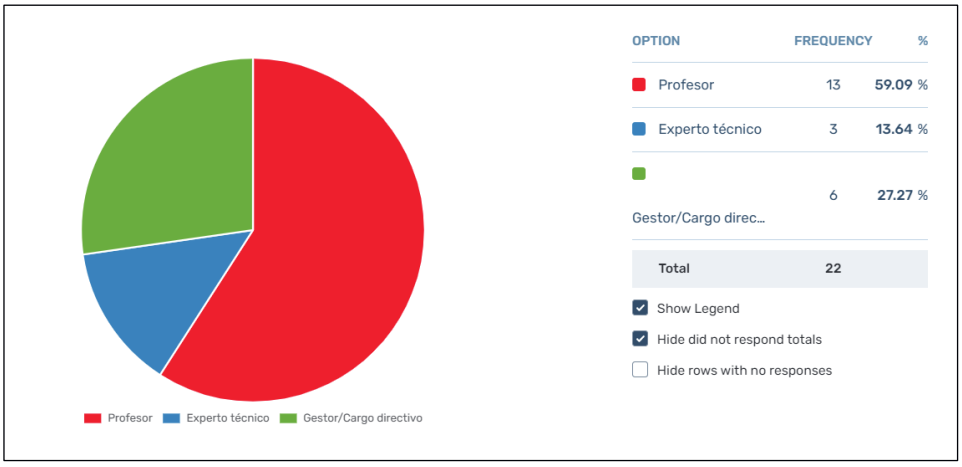


Figure 2

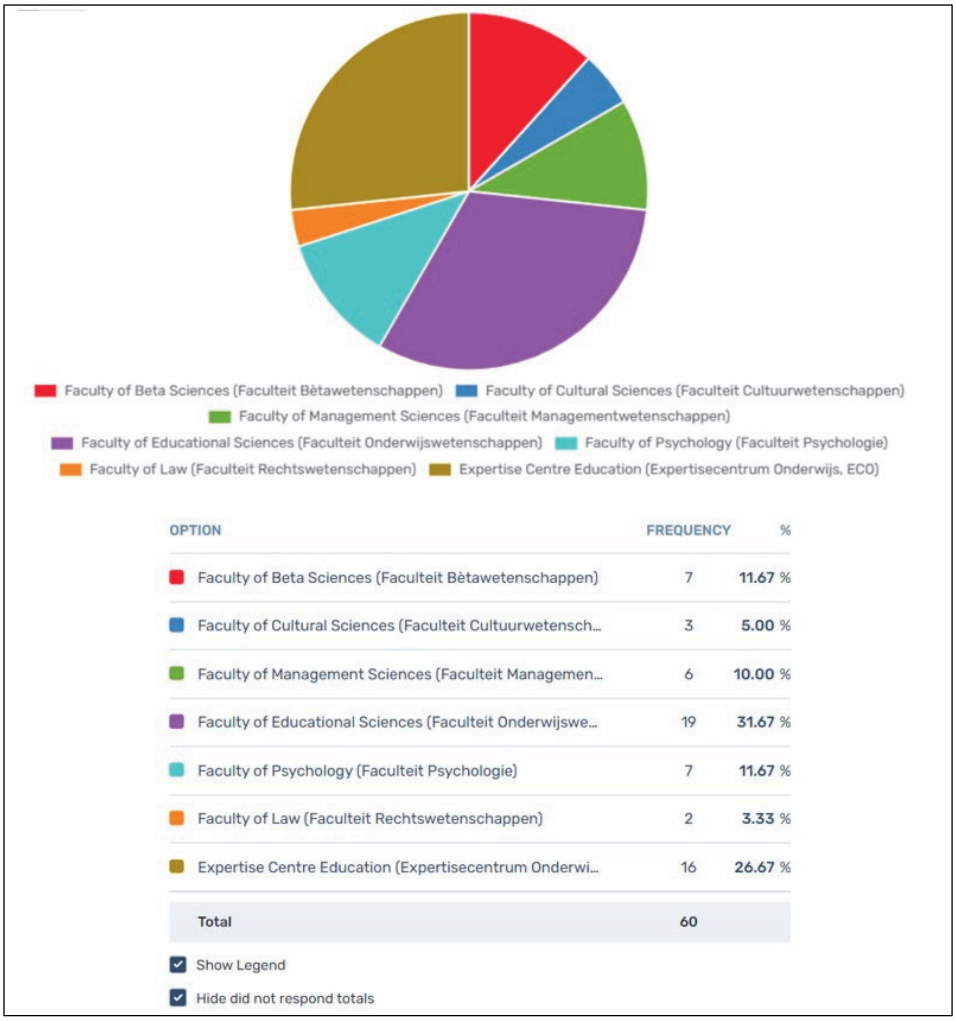
Demographic data for USC for the brainstorming activity: role in the institution (red colour marks teachers, blue – technical experts, green – managers)



7¡8¡ ***Faculty affiliation for the brainstorming phase***

Figure 3

Demographic data for OU for the brainstorming activity: faculty affiliation



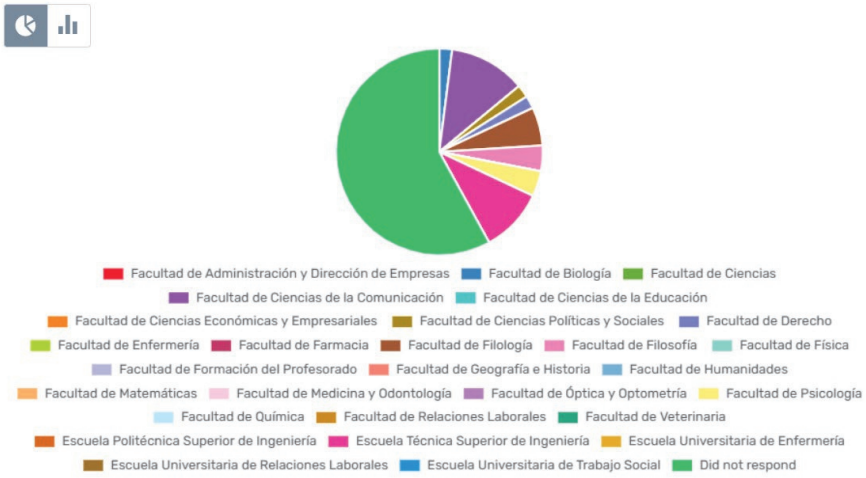
OPTION	FREQUENCY	%
Faculty of Beta Sciences (Faculteit Bètawetenschappen)	7	11.67 %
Faculty of Cultural Sciences (Faculteit Cultuurwetensch...	3	5.00 %
Faculty of Management Sciences (Faculteit Managemen...	6	10.00 %
Faculty of Educational Sciences (Faculteit Onderwijswe...	19	31.67 %
Faculty of Psychology (Faculteit Psychologie)	7	11.67 %
Faculty of Law (Faculteit Rechtswetenschappen)	2	3.33 %
Expertise Centre Education (Expertisecentrum Onderwi...	16	26.67 %
Total	**60**	

Show Legend

Hide did not respond totals

Figure 4

Demographic data for USC for the brainstorming activity: faculty affiliation



OPTION	FREQUENCY	%
Facultad de Administración y Dirección de …	0	0.00 %
Facultad de Biología	1	2.00 %
Facultad de Ciencias	0	0.00 %
Facultad de Ciencias de la Comunicación	6	12.00 %
Facultad de Ciencias de la Educación	0	0.00 %
Facultad de Ciencias Económicas y Empres…	0	0.00 %
Facultad de Ciencias Políticas y Sociales	1	2.00 %
Facultad de Derecho	1	2.00 %
Facultad de Enfermería	0	0.00 %
Facultad de Farmacia	0	0.00 %
Facultad de Filología	3	6.00 %
Facultad de Filosofía	2	4.00 %
Facultad de Física	0	0.00 %
Facultad de Formación del Profesorado	0	0.00 %
Facultad de Geografía e Historia	0	0.00 %
Facultad de Humanidades	0	0.00 %

Facultad de Matemáticas	0	**0.00** %
Facultad de Medicina y Odontología	0	**0.00** %
Facultad de Óptica y Optometría	0	**0.00** %
Facultad de Psicología	2	**9.52** %
Facultad de Química	0	**0.00** %
Facultad de Relaciones Laborales	0	**0.00** %
Facultad de Veterinaria	0	**0.00** %
Escuela Politécnica Superior de Ingeniería	0	**0.00** %
Escuela Técnica Superior de Ingeniería	5	**23.81** %
Escuela Universitaria de Enfermería	0	**0.00** %
Escuela Universitaria de Relaciones Labora...	0	**0.00** %
Escuela Universitaria de Trabajo Social	0	**0.00** %
Total	**21**	

☑ Show Legend

☑ Hide did not respond totals

2. Results of the brainstorming phase – 95 single unique statements

Table 2.

The list of all single unique statements that were generated in the brainstorming phase.

#	Statement
1	the added value of CloudClass outweighs its costs
2	there is a working group to evaluate and discuss the added value of CloudClass
3	students can manipulate the environment and the 3D models
4	that observable efficiency gains can be achieved
5	a large green screen room for online lectures is provided
6	a variety of best practice examples and use cases are provided for educators
7	instructional materials are created to help work with CloudClass, e.g. video tutorials, manuals, workshops
8	training on how to use CloudClass including manuals, hands on workshops, lectures
9	learning materials are adapted to the CloudClass environment
10	there is sustained maintenance of the tool, also after the end of the project
11	interaction between students and the teacher is supported
12	there is an option to view the lecture in 3D-enabled devices, e.g. VR headsets or simpler "cardboard" headsets using mobile phones
13	research is conducted on the effectiveness of CloudClass in different contexts
14	the user interface is made as user-friendly as possible
15	the added value of CloudClass over an "ordinary" virtual class is clearly communicated
16	teachers know about the added value of CloudClass in specific contexts
17	information about CloudClass is disseminated widely throughout the university community including teachers
18	CloudClass is useful for pre-produced films
19	CloudClass can be useful as a kind of whiteboard
20	CloudClass can be used flexibly in terms of time and place
21	this tool does not impose restrictions on users who do not have the right equipment
22	students are provided with opportunities and tools to work collaboratively on CloudClass activities
23	as many relevant stakeholders as possible are involved in the implementation process, i.e., university leaders, students, faculty, student advisors, ICT professionals, educational technologists, professionals in the field, and alumni
24	as many relevant stakeholders as possible are involved in the evaluation process, i.e., students, faculty, student advisors, ICT professionals, educational technologists, professionals in the field, and alumni

25	teachers are well-trained on how and when to use CloudClass in specific contexts to add value to teaching
26	the changes in teaching related to the use of CloudClass are facilitated
27	teachers have training in script-writing
28	instructions for students are provided for smooth technical use of the software
29	facilities, equipment and tools are provided to conduct and record a session of high quality like green screens and cameras, also in the study centres
30	teachers are trained to create high-quality content with CloudClass - e.g. record instructional videos themselves
31	there is research into whether the added value of CloudClass is different for different target groups.
32	students do not get distracted by the unnecessarily cluttered environment when using CloudClass
33	teachers have access to templates for 3D objects they can use easily
34	evaluation is carried out to measure the effects of CloudClass in short and long term
35	pedagogical scenarios are developed for different contexts/purposes
36	it is ensured that CloudClass is seamlessly integrated with other learning technologies that the university is using, e.g. virtual learning environment, video conferencing system, provisioning student and staff logins, single sign-on
37	it is clear what goals need to be achieved with CloudClass
38	there is a GDPR processing agreement
39	it is known what is happening to user data that will be generated and shared
40	it works on the devices and applications that users have
41	the added value is compared with other learning technologies that can be used
42	the 'novelty effect' is considered when interpreting results of CloudClass evaluation; "novelty effect" is a temporary improvement in performance due to initial interest in a new technology
43	the students are savvy for this, so digitally proficient
44	a teacher knows what choices they can make in CloudClass and in what way
45	it is known which instructional design is best for learning with CloudClass
46	the image/3D model rights are considered
47	it is made really functional
48	it is considered if one can request tailor-made 3d assets from the developers
49	it is considered if it is possible to import 3d objects created in 3rd party software
50	it is considered if it is possible to create 3d assets within CloudClass
51	it is considered if it is possible to create CloudClass templates
52	the usage options are thought through together with students, participatively
53	the usage options are designed together with students, participatively
54	it can be used as a discussion platform for students
55	each student should have their own camera view

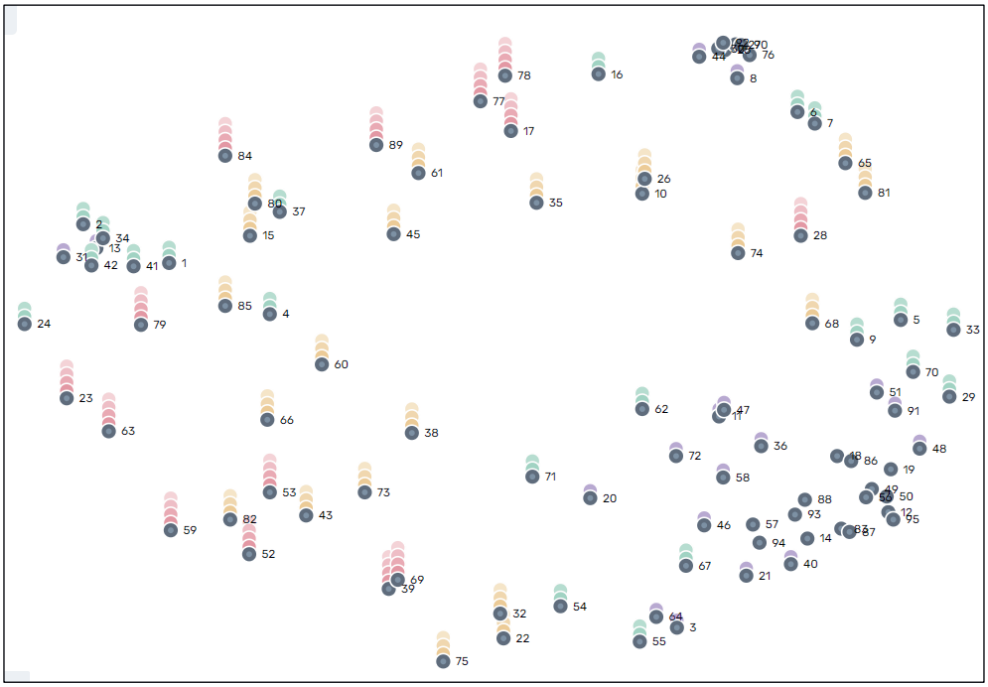
56	several presenters can be put in the environment
57	it supports sessions with large groups of students
58	there is a good internet connection
59	it is known what the students find appealing
60	effectiveness, efficiency and enjoyability are balanced
61	there is a clear instructional objectives and a plan for the use of CloudClass
62	users are equipped with the necessary facilities to participate in the session
63	there is a study to find out whether people with a disability can also follow in learning activities with CloudClass
64	there is the possibility, as a student, to also choose for plain or 'quiet' backgrounds
65	there is a helpdesk/CloudClass expert available who can assist in setting up and using the environment
66	using CloudClass positively affects social presence
67	the 3D environment (background) has a function to protect the privacy of the teacher/student, e.g. other participants cannot see the house
68	a teacher can see that a participant is really participating
69	it is not anonymous to avoid the risk of sabotage
70	a teacher has enough control to be able to throw someone out.
71	it does not take a lot of time to start using it
72	it is foolproof
73	in terms of content, the system should increase student engagement
74	it is easy to use for teachers
75	it is easy to use for students
76	teachers are trained in using the equipment like green screens, cameras, microphones and lighting
77	the institutional support for distance teaching practices is clearly defined, also at the end of the project
78	the staff gets allocated additional hours to use CloudClass
79	there is financial investment in CloudClass.
80	there is academic recognition as a teaching merit.
81	the technical support staff optimise the use of CloudClass
82	student acceptance of the technology is considered
83	CloudClass presentations can be run/operated on a tablet to make it more natural
84	there is a strategic definition of using CloudClass in line with the vision of the educational institute/establishment
85	CloudClass is economically affordable
86	it is possible to automate the preparation process prior to the class
87	the use of CloudClass is supported for mobile devices with small screens

88	it has a good sound pick-up
89	there is recognition that teaching with CloudClass should be delivered differently from face-to-face teaching
90	there is in-person teacher training on the use of CloudClass.
91	there is an extensive library available of 3D models and virtual environments that can be adapted to different disciplines
92	there is teacher training in didactically sound use of CloudClass
93	CloudClass functions as a web-based content management system
94	there are visually attractive digital elements.
95	high quality videos in the 3D background can be used

3. Point map with bridging and anchoring values

Figure 5

A point map displaying all the statements in relation to others with bridging values.



4. Go-zone charts

0¡7¡ *Go-zone for the cluster Evaluation*

Figure 6

Go-zone for the cluster Evaluation.

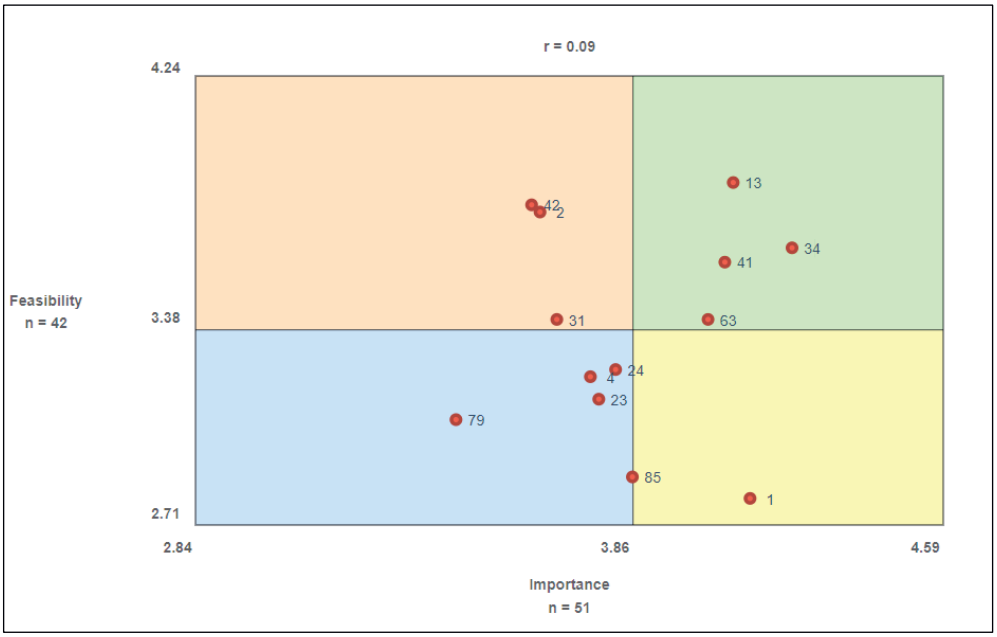


Table 2

Summary for the go-zone of the cluster Evaluation featuring the statements with individual and average ratings for importance and feasibility.

(Focus prompt:) *To use/implement CloudClass in education it is required/ needed that...*		Importance Scale [2.8431]-[4.5882] Median = 2.2941 n = 51	Feasibility Scale [2.7143]-[4.2439] Median = 2.12195 n = 42
Evaluation			
R=0.092918804500147			
#	Statements	Average Rating	Average Rating
4	that observable efficiency gains can be achieved	3.7647	3.2195
23	as many relevant stakeholders as possible are involved in the implementation process, i.e., university leaders, students, faculty, student advisors, ICT professionals, educational technologists, professionals in the field, and alumni	3.7843	3.1429
24	as many relevant stakeholders as possible are involved in the evaluation process, i.e., students, faculty, student advisors, ICT	3.8235	3.2439

	professionals, educational technologists, professionals in the field, and alumni		
79	there is financial investment in CloudClass.	3.4510	3.0732
85	CloudClass is economically affordable	3.8627	2.8780
1	the added value of CloudClass outweighs its costs	4.1373	2.8049
2	there is a working group to evaluate and discuss the added value of CloudClass	3.6471	3.7805
31	there is research into whether the added value of CloudClass is different for different target groups.	3.6863	3.4146
42	the 'novelty effect' is considered when interpreting results of CloudClass evaluation; "novelty effect" is a temporary improvement in performance due to initial interest in a new technology	3.6275	3.8049
13	research is conducted on the effectiveness of CloudClass in different contexts	4.0980	3.8810
34	evaluation is carried out to measure the effects of CloudClass in short and long term	4.2353	3.6585
41	the added value is compared with other learning technologies that can be used	4.0784	3.6098
63	there is a study to find out whether people with a disability can also follow in learning activities with CloudClass	4.0392	3.4146

0¡8¡ *Go-zone for the cluster "Institutional Requirements*

Figure 7

Go-zone for the cluster Institutional Requirements.

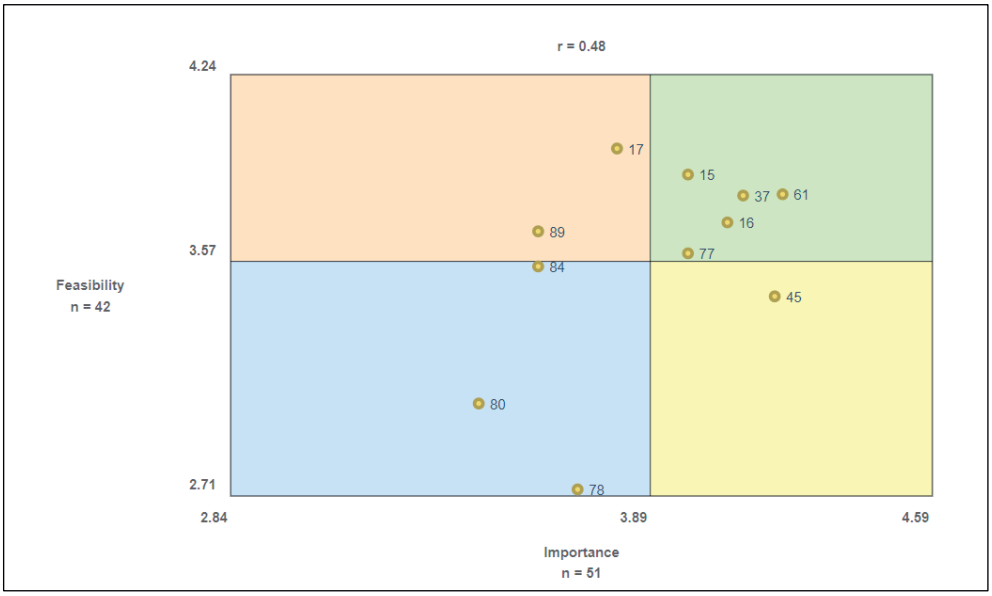


Table 3

Summary for the go-zone of the cluster Institutional Requirements featuring the statements with individual and average ratings for importance and feasibility.

(Focus prompt:) *To use/implement CloudClass in education it is required/ needed that*...		Importance Scale [2.8431]-[4.5882] Median = 2.2941 n = 51	Feasibility Scale [2.7143]-[4.2439] Median = 2.12195 n = 42
Institutional requirements			
R=0.47724645235701			
#	Statements	Average Rating	Average Rating
78	the staff gets allocated additional hours to use CloudClass	3.7059	2.7381
80	there is academic recognition as a teaching merit.	3.4600	3.0500
84	there is a strategic definition of using CloudClass in line with the vision of the educational institute/establishment	3.6078	3.5476
45	it is known which instructional design is best for learning with CloudClass	4.1961	3.4390
17	information about CloudClass is disseminated widely throughout the university community including teachers	3.8039	3.9756
89	there is recognition that teaching with CloudClass should be delivered differently from face-to-face teaching	3.6078	3.6750
15	the added value of CloudClass over an "ordinary" virtual class is clearly communicated	3.9804	3.8810
16	teachers know about the added value of CloudClass in specific contexts	4.0784	3.7073
37	it is clear what goals need to be achieved with CloudClass	4.1176	3.8049
61	there is a clear instructional objectives and a plan for the use of CloudClass	4.2157	3.8095
77	the institutional support for distance teaching practices is clearly defined, also at the end of the project	3.9804	3.5952

0¡9¡ *Go-zone for the cluster Maintenance and Training*

Figure 8

Go-zone for the cluster Maintenance and Training.

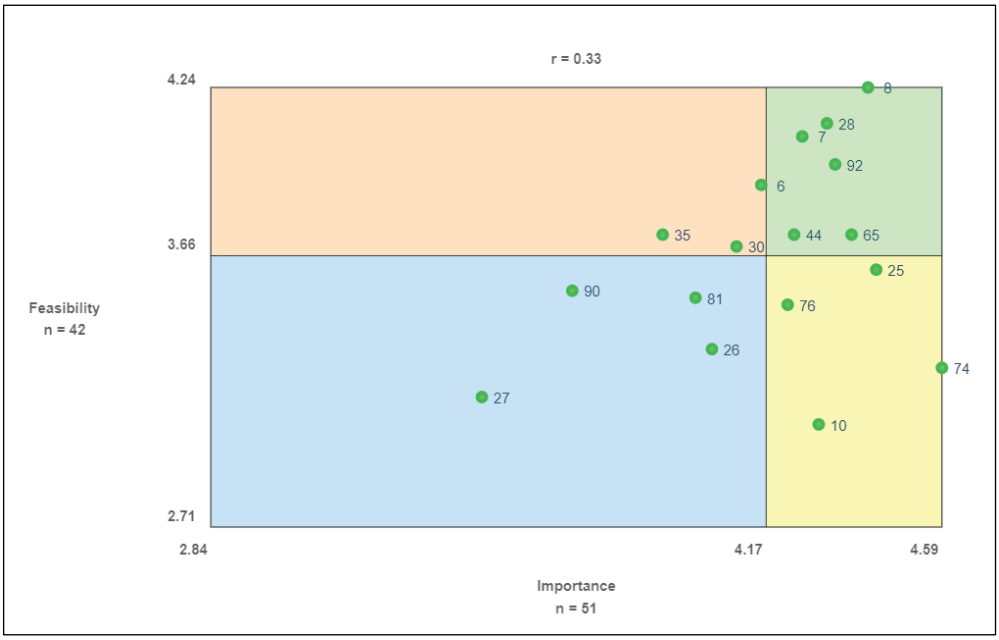


Table 4

Summary for the go-zone of the cluster Maintenance and Training featuring the statements with individual and average ratings for importance and feasibility.

(Focus prompt:) *To use/implement CloudClass in education it is required/ needed that...*		Importance Scale [2.8431]-[4.5882] Median = 2.2941 n = 51	Feasibility Scale [2.7143]-[4.2439] Median = 2.12195 n = 42
Maintenance and training			
R=0.33154736322077			
#	Statements	Average Rating	Average Rating
26	the changes in teaching related to the use of CloudClass are facilitated	4.0392	3.3333
27	teachers have training in script-writing	3.4902	3.1667
81	the technical support staff optimise the use of CloudClass	4.0000	3.5122
90	there is in-person teacher training on the use of CloudClass.	3.7059	3.5366
10	there is sustained maintenance of the tool, also after the end of the project	4.2941	3.0714
25	teachers are well-trained on how and when to use CloudClass in specific contexts to add value to teaching	4.4314	3.6098

74	it is easy to use for teachers	4.5882	3.2683
76	teachers are trained in using the equipment like green screens, cameras, microphones and lighting	4.2200	3.4878
6	a variety of best practice examples and use cases are provided for educators	4.1569	3.9048
30	teachers are trained to create high-quality content with CloudClass - e.g. record instructional videos themselves	4.0980	3.6905
35	pedagogical scenarios are developed for different contexts/purposes	3.9216	3.7317
7	instructional materials are created to help work with CloudClass, e.g. video tutorials, manuals, workshops	4.2549	4.0732
8	training on how to use CloudClass including manuals, hands on workshops, lectures	4.4118	4.2439
28	instructions for students are provided for smooth technical use of the software	4.3137	4.1190
44	a teacher knows what choices they can make in CloudClass and in what way	4.2353	3.7317
65	there is a helpdesk/ CloudClass expert available who can assist in setting up and using the environment	4.3725	3.7317
92	there is teacher training in didactically sound use of CloudClass	4.3333	3.9762

0¡0¡ *Go-zone for the cluster Student Requirements*

Figure 9

Go-zone for the cluster Student Requirements.

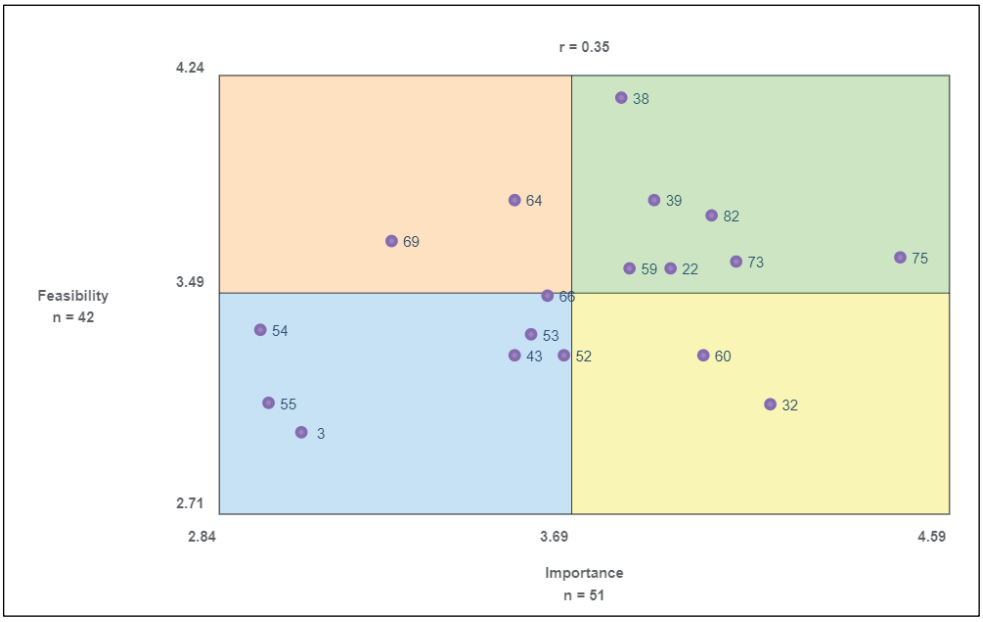


Table 5

Summary for the go-zone of the cluster Student Requirements featuring the statements with individual and average ratings for importance and feasibility.

(Focus prompt:) *To use/implement CloudClass in education it is required/ needed that...*		Importance Scale [2.8431]-[4.5882] Median = 2.2941 n = 51	Feasibility Scale [2.7143]-[4.2439] Median = 2.12195 n = 42
Student requirements			
R=0.35417894464377			
#	Statements	Average Rating	Average Rating
3	students can manipulate the environment and the 3D models	3.0392	3.0000
43	the students are savvy for this, so digitally proficient	3.5490	3.2683
52	the usage options are thought through together with students, participatively	3.6667	3.2683
53	the usage options are designed together with students, participatively	3.5882	3.3415
54	it can be used as a discussion platform for students	2.9412	3.3571
55	each student should have their own camera view	2.9608	3.1026
66	using CloudClass positively affects social presence	3.6275	3.4762

32	students do not get distracted by the unnecessarily cluttered environment when using CloudClass	4.1600	3.0976
60	effectiveness, efficiency and enjoyability are balanced	4.0000	3.2683
64	there is the possibility, as a student, to also choose for plain or 'quiet' backgrounds	3.5490	3.8095
69	it is not anonymous to avoid the risk of sabotage	3.2549	3.6667
22	students are provided with opportunities and tools to work collaboratively on CloudClass activities	3.9216	3.5714
38	there is a GDPR processing agreement	3.8039	4.1667
39	it is known what is happening to user data that will be generated and shared	3.8824	3.8095
59	it is known what the students find appealing	3.8235	3.5714
73	in terms of content, the system should increase student engagement	4.0784	3.5952
75	it is easy to use for students	4.4706	3.6098
82	student acceptance of the technology is considered	4.0196	3.7561

0¡❶ *Go-zone for the cluster Affordances and Infrastructure*

Figure 10

Go-zone for the cluster Affordances and Infrastructure.



Table 6

Summary for the go-zone of the cluster Affordances and Infrastructure featuring the statements with individual and average ratings for importance and feasibility.

(Focus prompt:) *To use/implement CloudClass in education it is required/ needed that...*		Importance Scale [2.8431]-[4.5882] Median = 2.2941 n = 51	Feasibility Scale [2.7143]-[4.2439] Median = 2.12195 n = 42
Affordances and infrastructure			
R=0.13185574098231			
#	Statements	Average Rating	Average Rating
12	there is an option to view the lecture in 3D-enabled devices, e.g. VR headsets or simpler "cardboard" headsets using mobile phones	2.8431	2.9048
48	it is considered if one can request tailor-made 3d assets from the developers	3.1373	3.1190
49	it is considered if it is possible to import 3d objects created in 3rd party software	3.3725	3.4524
50	it is considered if it is possible to create 3d assets within CloudClass	2.9804	3.4500
86	it is possible to automate the preparation process prior to the class	3.4706	3.1667

87	the use of CloudClass is supported for mobile devices with small screens	3.3137	3.0000
93	CloudClass functions as a web-based content management system	2.8431	2.9762
9	learning materials are adapted to the CloudClass environment	3.8039	3.3810
21	this tool does not impose restrictions on users who do not have the right equipment	4.0784	2.7143
29	facilities, equipment and tools are provided to conduct and record a session of high quality like green screens and cameras, also in the study centres	4.0784	3.1220
36	it is ensured that CloudClass is seamlessly integrated with other learning technologies that the university is using, e.g. virtual learning environment, video conferencing system, provisioning student and staff logins, single sign-on	4.1765	2.9756
71	it does not take a lot of time to start using it	4.1373	2.9024
72	it is foolproof	4.1569	3.1707
91	there is an extensive library available of 3D models and virtual environments that can be adapted to different disciplines	3.7059	3.4390
5	a large green screen room for online lectures is provided	3.6471	3.7805
18	CloudClass is useful for pre-produced films	3.0196	3.5854
19	CloudClass can be useful as a kind of whiteboard	2.9804	3.5000
46	the image/3D model rights are considered	3.2941	3.9268
56	several presenters can be put in the environment	3.5490	3.8049
67	the 3D environment (background) has a function to protect the privacy of the teacher/student, e.g. other participants cannot see the house	3.4706	3.9268
68	a teacher can see that a participant is really participating	3.4706	3.5238
70	a teacher has enough control to be able to throw someone out.	3.3137	3.8293
83	CloudClass presentations can be run/operated on a tablet to make it more natural	3.2353	3.6429
94	there are visually attractive digital elements.	3.4314	3.8780
95	high quality videos in the 3D background can be used	3.3922	3.6667
11	interaction between students and the teacher is supported	4.4706	3.8810
14	the user interface is made as user-friendly as possible	4.5686	3.8049
20	CloudClass can be used flexibly in terms of time and place	4.0784	3.5854
33	teachers have access to templates for 3D objects they can use easily	3.9020	3.6585
40	it works on the devices and applications that users have	4.4902	3.5122
47	it is made really functional	4.3725	3.5610
51	it is considered if it is possible to create CloudClass templates	3.7000	3.8333
57	it supports sessions with large groups of students	3.9412	3.5238
58	there is a good internet connection	4.3137	4.0714
62	users are equipped with the necessary facilities to participate in the session	4.3529	3.5122
88	it has a good sound pick-up	4.0392	3.9512

5. T-Tests for each cluster

❶¡7¡ *T-Test for the cluster Evaluation*

Figure 11

T-Test for importance and feasibility ratings of the cluster Evaluation

T-Value	**4.2838**	Degrees of Freedom	24
		Level of Significance	p < 0.001
P-Value (one tail)	**0.0001**	**P-Value (two tails)**	**0.0003**

	GROUP 1	GROUP 2
Cluster	1. Evaluation	1. Evaluation
Rating Question	Rtg. **Importance**	Rtg. **Feasibility**
Participants Included	**51** of 51	**42** of 42
Filters	0 Filters	0 Filters
Cluster Rating Average	**3.8643**	**3.3789**
Cluster Rating Variance	**0.0513**	**0.1155**
Number of Statements	**13**	**13**

❶¡8¡ *T-Test for the cluster Institutional Requirements*

Figure 12

T-Test for importance and feasibility ratings of the cluster Institutional Requirements

T-Value	**2.4523**	Degrees of Freedom	20
		Level of Significance	p < 0.05
P-Value (one tail)	**0.0118**	**P-Value (two tails)**	**0.0235**

	GROUP 1	GROUP 2
Cluster	2. Institutional requirements	2. Institutional requirements
Rating Question	Rtg. **Importance**	Rtg. **Feasibility**
Participants Included	**51** of 51	**42** of 42
Filters	0 Filters	0 Filters
Cluster Rating Average	**3.8867**	**3.5657**
Cluster Rating Variance	**0.0626**	**0.1258**
Number of Statements	**11**	**11**

❶9¡ *T-Test for the cluster Maintenance and Training*

Figure 13

T-Test for importance and feasibility ratings of the cluster Maintenance and Training.



T-Value	4.9874	Degrees of Freedom	32
		Level of Significance	p < 0.001
P-Value (one tail)	0.0000	P-Value (two tails)	0.0000

	GROUP 1	GROUP 2
Cluster	3. Maintenance and training	3. Maintenance and training
Rating Question	Rtg. Importance	Rtg. Feasibility
Participants Included	51 of 51	42 of 42
Filters	0 Filters	0 Filters
Cluster Rating Average	4.1686	3.6582
Cluster Rating Variance	0.0712	0.1069
Number of Statements	17	17

❶0¡ *T-Test for the cluster Affordances and Infrastructure*

Figure 14

T-Test for importance and feasibility ratings of the cluster Affordances and Infrastructure.



T-Value	2.0249	Degrees of Freedom	70
		Level of Significance	p < 0.05
P-Value (one tail)	0.0233	P-Value (two tails)	0.0467

	GROUP 1	GROUP 2
Cluster	5. Affordances and infrastructure	5. Affordances and infrastructure
Rating Question	Rtg. Importance	Rtg. Feasibility
Participants Included	51 of 51	42 of 42
Filters	0 Filters	0 Filters
Cluster Rating Average	3.6981	3.4926
Cluster Rating Variance	0.2480	0.1227
Number of Statements	36	36

❶❶ *T-Test for the cluster Student Requirements*

Figure 13

T-Test for importance and feasibility ratings of the cluster Student Requirements.



T-Value	**1.6785**	Degrees of Freedom	**34**
		Level of Significance	**> 0.05 (Not Significant)**
P-Value (one tail)	**0.0512**	**P-Value (two tails)**	**0.1024**

	GROUP 1	GROUP 2
Cluster	4. **Student requirements**	4. **Student requirements**
Rating Question	Rtg. **Importance**	Rtg. **Feasibility**
Participants Included	**51** of 51	**42** of 42
Filters	0 Filters	0 Filters
Cluster Rating Average	**3.6854**	**3.4853**
Cluster Rating Variance	**0.1704**	**0.0852**
Number of Statements	**18**	**18**

Appendix B (Chapter 2)

4.1. Interview Protocol

Topic and Purpose of the Interview

This interview will be conducted as part of an in-depth interview study exploring how a desktop-based 3D/VR/AR visualisation tool (Edison) might be meaningfully integrated into distance higher education. Edison will be used as a concrete example to investigate how such tools can support effective and efficient learning processes, and what pedagogical, organisational, and technical conditions are needed for their sustainable use. The interview will also inform further development of Edison.

Interview Stages

The interview will follow a semi-structured format consisting of six stages (Castillo-Montoya, 2016; Ritchie, 2014b):

1. Welcome and introductions – Building rapport and outlining purpose
2. Introducing the study – Confirming informed consent and scope
3. Initial context setting – Sharing a short demonstration of Edison
4. Exploring the guiding questions – Allowing space for elaboration and dialogue
5. Closing reflections – Summarising key ideas and offering space for final thoughts
6. Post-interview follow-up – Explaining data handling and potential follow-up invitations

Table 1

Guiding Questions for the Interview

Section	Example Questions
Participant Background	What is your role at OU? Which subjects do you teach? Do you teach online, face-to-face, or both?
Understanding of Edison	What is your understanding of what Edison does? What features stood out to you in the demonstration? What was your initial reaction?
Relevance and Use	How might a tool like Edison be relevant to your teaching? In what ways could you imagine using this tool in your courses? Would it support your subject-specific needs?
Pedagogical Potential	What kind of impact could this tool have on students' learning? How might it help convey abstract or complex concepts? Are there any risks or downsides?
Barriers and Enablers	What might make it difficult for you or your students to use this tool? What would OU need to support meaningful integration of a tool like this?
Suggestions for Improvement	What would make the tool more useful or adaptable to your context? Are there any features you would like to see added or changed?
Closing Reflections	Do you have any final thoughts or suggestions? Would you be interested in participating in future activities related to this tool?

Appendix C (Chapter 3)

Table 1

Design Requirements and Design Propositions

Design Requirement	Design Proposition (If–then–because)	Sources of Data & Theory
Infrastructure & devices – Scenarios must run on standard institutional infrastructure (desktops, laptops) without requiring HMDs; must be cross-platform.	If scenarios function on standard institutional hardware without specialised equipment, then integration will be feasible and scalable, because accessibility increases when no additional costs or devices are required.	GCM – Affordances & Infrastructure; Interviews – Context
Integration with platforms – Scenarios must integrate with existing platforms (LMS, Teams, Zoom).	If scenarios connect seamlessly to existing teaching platforms, then instructional embedding will be smoother, because teachers and students prefer continuity with established workflows.	GCM – Affordances & Infrastructure; Interviews – Technology
Technical simplicity – Scenarios must be intuitive and easy to operate.	If the interface is simple and requires minimal technical expertise, then both teachers and students will engage more effectively, because reduced complexity supports competence and lowers barriers to integration.	GCM – Student Requirements; Interviews – Technology; SDT (Ryan & Deci, 2000)
Multimedia & artefact flexibility – Scenarios should allow use of 3D models, video, slides.	If teachers can integrate diverse artefacts, then abstract and complex content will be represented more effectively, because **dual coding** of words and visuals enhances knowledge gain.	GCM – Affordances & Infrastructure; Mayer, 2021; Castro-Alonso et al., 2021
Flexible display – Scenarios should blend pre-recorded video, slides, and VR visuals.	If scenarios allow flexible blending of media formats, then teachers can adapt instruction to diverse needs, because flexible design supports contextual embedding.	GCM – Affordances & Infrastructure
Technical + pedagogical training – Training should cover both tool operation and design principles.	If training links technical operation with evidence-informed design principles (e.g., signalling, segmentation, load management), then teachers will use scenarios more effectively, because they understand both how and why VR supports learning.	GCM – Maintenance & Training; Mayer & Moreno, 2003; Sweller, 2010
Pedagogical context awareness – Teachers must know when/why VR is useful.	If training clarifies which learning goals and teaching scenarios are most suitable for VR, then teachers will integrate it more meaningfully, because decisions will be guided by pedagogical principles rather than novelty.	GCM – Maintenance & Training; Interviews – Pedagogy

Accessibility & inclusivity as a core value – Scenarios must reflect accessibility and inclusivity principles.	If accessibility features (captions, screen reader compatibility) are embedded, then scenarios will be usable for all students, because inclusivity is an institutional value and a legal requirement.	Interviews – Values
Knowledge acquisition – Scenarios must support declarative and procedural knowledge acquisition.	If VR-enhanced presentations are used to visualise abstract concepts (declarative knowledge) or model processes (procedural knowledge), then students' knowledge gains will improve, because dual coding and worked examples support both forms of learning. VR should be designed so that learning goals (knowledge gains) are explicitly facilitated.	Interviews – Pedagogy; Mayer, 2021; Sweller, 2010
Motivation – Scenarios should strengthen motivation by supporting autonomy, competence, and relatedness.	If scenarios provide choice and reflection (autonomy), clear guidance and achievable tasks (competence), and visible teacher presence and peer connection (relatedness), then intrinsic motivation will be strengthened, because Self-Determination Theory identifies these as core psychological needs.	Interviews – Pedagogy; SDT (Ryan & Deci, 2000); Plass, Mayer, & Homer, 2019
Teacher presence – Teacher presence must be maintained (visual inclusion, gestures, explanations).	If teachers remain visible and active in VR-enhanced presentations, then relatedness and social presence will be supported, because embodiment and social agency principles show that gestures and visibility enhance engagement and trust.	Interviews – Pedagogy; Mayer, 2021; SDT
Cognitive load management – Scenarios must manage cognitive load through signalling, coherence, and segmentation.	If signalling, coherence, and segmentation principles are applied, then extraneous load will be reduced and essential processing enhanced, because working memory is limited and learners must be guided to focus on core content.	Interviews – Pedagogy; Sweller, 2010; Mayer & Moreno, 2003
Reflection and follow-up – Scenarios should foster reflection and follow-up activities.	If VR-enhanced presentations are embedded as an initial phase leading into tasks or discussions, then deeper learning will be achieved, because generative processing and autonomy support foster consolidation.	Interviews – Pedagogy; Chi & Wylie, 2014; SDT
Alignment with strategies – Scenarios must allow integration with diverse pedagogical strategies.	If scenarios are flexible across different approaches (lecture, problem-based, collaborative), then instructional embedding will be stronger, because DBR emphasises contextual fit and teachers need autonomy in aligning with their pedagogy.	Interviews – Pedagogy; McKenney & Reeves, 2012; SDT
Active engagement – Scenarios should promote active student engagement during or after presentations.	If interactive prompts or post-scenario activities are included, then learners will process information more deeply, because active learning principles and competence support enhance generative learning.	Interviews – Pedagogy; Plass et al., 2019; Mayer, 2021; SDT

Appendix D (Chapter 4)

D1 Measurement tools

1. Knowledge questions

1.1 Pilot A (Pre-teaching Lecture in Educational Sciences)

Pre-test Questionnaire

Instructions: The following questions were distributed to participants before the intervention. Correct answers are indicated in bold.

1. Hoe zou je de rol van een instructional designer omschrijven?

    a) Als kennisproducent

    b) Als kennisgebruiker

    c) Beide

    d) Geen van bovenstaande

2. Welke instructional design models ken je? Schrijf hun namen op.

    a) Ik ken er geen

    b) *[Open antwoordruimte]*

3. Alle instructional design modellen hebben enkele fasen gemeen:

    a) a. Analysefase

    b) b. Evaluatiefase

    c) c. Iteratiefase

    d) **d. Analyse- en evaluatiefase**

4. Welke van de onderstaande beweringen is meer FALSE dan waar? "Onderwijsontwerpers..."

    a) . Zoeken antwoorden en oplossingen in de theorie

    b) b. Zijn gewend om snel beslissingen te nemen en te handelen onder de druk van de praktijk

    c) c. Handelen op een prescriptieve en vooraf gedefinieerde manier gebaseerd op gevestigde instructional design modellen

    d) d. Ontwerpen instructies op een gevoelige manier die soms een intuïtieve en creatieve aanpak vereist om aan de behoeften van een doelgroep te voldoen

5. DD in ADDIE staan voor …

    [Open antwoordruimte]

Post-test Questionnaire

Instructions: The following questions were distributed to participants after the intervention. Correct answers are indicated in bold.

1. Welke van de onderstaande zinnen maken de zin NIET af: “Instructional Designer...”

    a) Is zowel kennisgebruiker als kennisproducent

    b) Moet zich richten op de behoeften van een specifieke doelgroep

    c) **Werkt in experimentele omstandigheden in een lab setting**

    d) Is geïnteresseerd in generaliseerbaarheid en toepasbaarheid van de uitkomsten/kennis die gegenereerd wordt tijdens het uitproberen van het ontwerp

2. Welke instructional design modellen ken je? Schrijf hun namen op.

    a) Ik ken er geen

    b) [Open antwoordruimte]

3. Alle instructional design modellen:

    a) a. Zijn procesgeoriënteerd

    b) b. Zijn productgeoriënteerd

    c) c. Zijn zowel proces- als productgericht

    d) d. Alle bovenstaande

    e) e. Kunnen niet geclassificeerd worden vanwege hun diversiteit

4. Welke van de onderstaande beweringen is meer WAAR dan false? “Modellen voor onderwijsontwerpen …”

    a) Focussen voornamelijk op de uitkomsten en artefacten

    b) Zijn prescriptief, ze beschrijven de weg naar goed onderwijs

    c) Zijn universeel, ze hoeven niet te worden aangepast aan het niveau, de leeftijd en de doelgroep

    d) **Zijn gericht op het helpen van docenten bij het ontwikkelen van geschikte instructieoplossingen die aansluiten bij de behoeften van de doelgroep en voldoen aan de leerdoelen**

5. A in ADDIE model staat voor

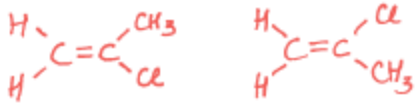
    [Open antwoordruimte]

1.2 Pilot C (Chemistry Lecture)

Pre-test Questionnaire

Instructions: The following questions were distributed to participants before the intervention. Correct answers are indicated in bold.

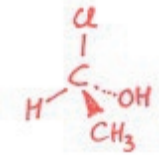
1. Gegeven:
   Twee stoffen met onderstaande structuurformules:



   Deze stoffen zijn:

   a. Isomeren
   b. Geometrische isomeren
   c. Optische isomeren
   d. Geen isomeren

2. Wat is de systematische naam van de volgende stof?



   e. 1-chloor-ethanol
   f. S-1-chloor-ethanol
   g. R-1-chloor-ethanol
   h. 2-chloor-ethanol

3. Waar zijn de prioriteitsregels van Cahn, Ingold en Prelog voor nodig?
   i. Voor een eenduidige naamgeving van configuratie isomeren
   j. Om vast te stellen of er van een stof isomeren bestaan
   k. Om de toxiciteit van een stof aan te geven
   l. Om de polariteit van een stof aan te geven

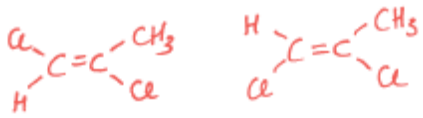
4. Welk van de volgende groepen heeft de hoogste prioriteit volgens de regels van Cahn, Ingold en Prelog?
   m. –Cl
   n. –OH
   o. –O–CH_3
   p. –H

5. Waar gebruik je een polarimeter voor?
   q. Om de polariteit van een stof te meten
   r. Om de configuratie van een optische isomeer te bepalen
   s. Om de configuratie van een geometrische isomeer te bepalen
   t. Om de temperatuur van een stof te bepalen

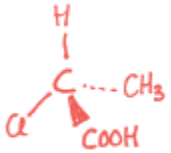
6. Wat zijn ‘enantiomeren’ ?
   u. Spiegelbeeld isomeren
   v. Geometrische isomeren
   w. Rechtsdraaiende isomeren
   x. Linksdraaiende isomeren

Post-test Questionnaire

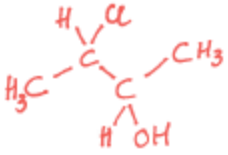
1. Gegeven:
   Twee stoffen met onderstaande structuurformules:



   Deze stoffen zijn:
   a. Isomeren
   b. Geometrische isomeren
   c. Optische isomeren
   d. Geen isomeren
2. Wat is de systematische naam van de volgende stof?



   e. 2-chloorpropaanzuur
   f. 2-chloorbutaanzuur
   g. S-2-chloorpropaanzuur
   h. R-2-chloorpropaanzuur
3. Hoeveel optische isomeren heeft de onderstaande stof maximaal?



   i. 2
   j. 4
   k. 8
4. Geen optische isomeren
   Welk van de volgende groepen heeft de hoogste prioriteit volgens de regels van Cahn, Ingold en Prelog?
   l. $–CH_3$
   m. $–O–CH_3$
   n. $–O–CCl_3$
   o. $–CH_2Cl$

5. Isomeren zijn stoffen met
   p. Dezelfde structuurformule, maar een verschillende moleculaire massa
   q. Dezelfde molecuulformule, maar een verschillende structuur
   r. Een verschillende molecuulformule, maar dezelfde fysische eigenschappen
   s. Dezelfde molecuulformule en dezelfde structuur

6. Welke uitspraak over een racemisch mengsel is ***onjuist***?

t. Een racemisch mengsel bestaat uit verschillende optische isomeren

u. Een racemisch mengsel vertoont geen optische activiteit

v. Een racemisch mengsel bestaat uit evenveel Z- als E-isomeren

w. Een racemisch mengsel bevat evenveel van twee enantiomeren

2. Cognitive Load Questionnaire

All of the following questions refer to the activity (lecture, class, discussion session, skills training or study session) that just finished. Please respond to each of the questions on the following scale (0 meaning not at all the case and 10 meaning completely the case) (Leppink et al., 2013).

10-point Likert scale

[1] The topic/topics covered in the activity was/were very complex. (IL)

[2] The activity covered notions that I perceived as very complex. (IL)

[3] The activity covered concepts and definitions that I perceived as very complex. (IL)

[4] The instructions and/or explanations during the activity were very unclear. (EL)

[5] The instructions and/or explanations were, in terms of learning, very ineffective. (EL)

[6] The instructions and/or explanations were full of unclear language. (EL)

[7] The activity really enhanced my understanding of the topic(s) covered. (GL)

[8] The activity really enhanced my knowledge and understanding of statistics. (GL)

[9] The activity really enhanced my understanding of the notions covered. (GL)

[10] The activity really enhanced my understanding of concepts and definitions. (GL)

IL = intrinsic load
EL = extraneous load
GL = germane load

3. Motivation Questionnaire (Intrinsic Motivation Inventory)

7-point Likert scale

Interest/Enjoyment

1 I enjoyed doing this activity very much

2 This activity was fun to do.

3 I thought this was a boring activity. (R)

4 This activity did not hold my attention at all. (R)

5 I would describe this activity as very interesting.

6 I thought this activity was quite enjoyable.

7 While I was doing this activity, I was thinking about how much I enjoyed it.

Value/Usefulness

1 I believe this activity could be of some value to me.

2 I think that doing this activity is useful for _____

3 I think this is important to do because it can _____

4 I would be willing to do this again because it has some value to me.

5 I think doing this activity could help me to _____

6 I believe doing this activity could be beneficial to me.

7 I think this is an important activity.

Relatedness

1 I felt really distant to the teacher. (R)

2 I really doubt that the teacher and I would ever be friends. (R)

3 I felt like I could really trust the teacher/presenter in the video.

4 I'd like a chance to interact with the teacher more often.

5 I'd really prefer not to interact with the teacher in the future. (R)

6 I don't feel like I could really trust the teacher. (R)

7 It is likely that the teacher and I could become friends if we interacted a lot.

8 I feel close to the teacher.

D2 Screenshots of the live online lectures in control and experimental conditions.

1. Pilot A

Figure 1

Screenshot of the session in control condition (Zoom)

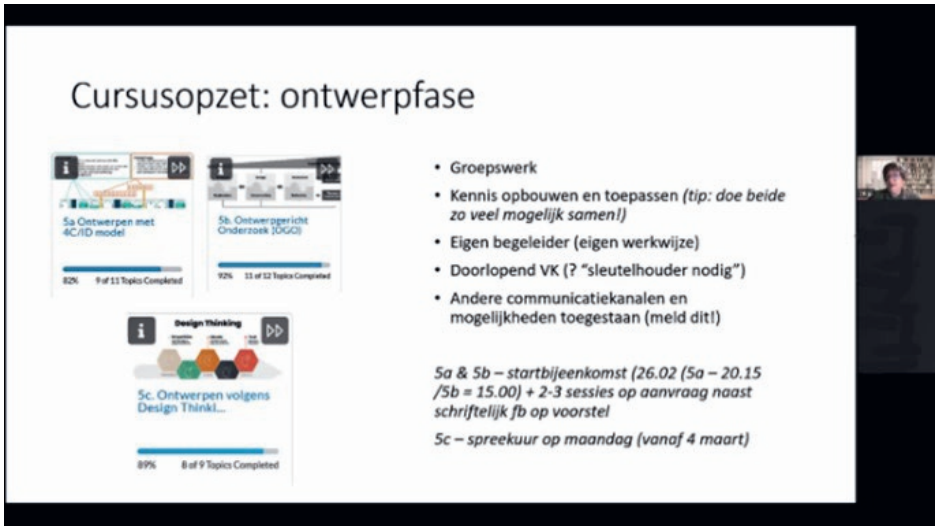


Figure 2

Screenshot of the session in experimental condition (CloudClass via Zoom)



2. Pilot B

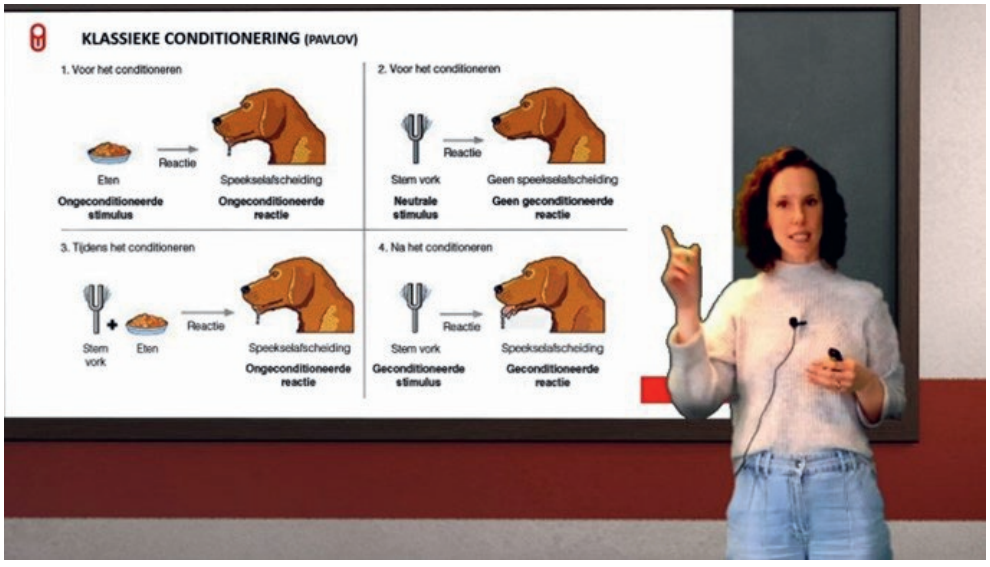
Figure 3

Screenshot of the session in control condition (Kaltura).



Figure 4

Screenshot of the session in experimental condition (CloudClass via Zoom)



3. Pilot C

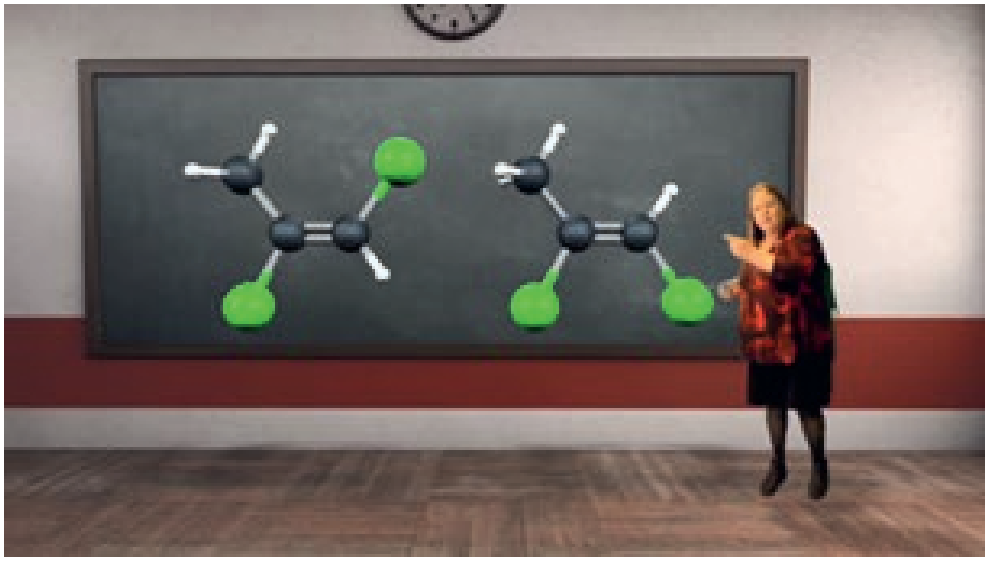
Figure 5

Screenshot of the session in control condition (Kaltura).



Figure 6

Screenshot of the session in experimental condition (CloudClass via Zoom)



Appendix E (Chapter 5)

1. Focus Group Protocol

1.1. Background

Project group meetings/ focus groups with identical setup in

- OU(NL)
- Alicante (Spain)
- Santiago USC (Spain)

Participants:

- teachers
- technical/media design/production professionals: media support/production units
- educational managers: deans, department heads, managers
- curriculum designers
- educational [design] experts

Setting:

- 2-hour focus groups; (up to 8 participants per session; if more – split into smaller working/discussion groups (recorded) with shared feedback rounds?)

Aims:

- Evaluate/validate the implementation of the designed scenarios
- Identify strongholds and opportunities for the use of technology in HE
- Shape the vision for further [wider/scalable] institutional implementation

1.2. Protocol

Total time: 2hrs

Part 1. Introduction 10-15 min

- Project background; stakeholders and their roles
- Research goals and research questions (linking with previous research); aims for the session – briefly
- Agenda/ session format

Part 2. Case presentations and disccussions – 90 min in total:

- Alicante – 25min
- OU – 25 min
- Santiago 25 min

Workflow for each university (x3):

1. **Presentation** with the video/s (5 min):

- introduce the university setting

- production facilities
- design workflow and people involved
- teaching setting/use of technology
- survey introduced (participants can answer right after the presentation)

2. **Group discussion with participants** (15 min)

- What did you like about this way of using technology?
- How can this way of teaching/presenting be best used in this university setting?
- How do you think teachers and students can best benefit from this use of technology in the educational setting?
- How would you see teachers using this technology in their practice? What are potential challenges and how can they be overcome?

Themes that can be elicited form participants/expanded once mentioned by participants (given here as examples; feel free to think along the lines and address the issues raised by participants to explore them further):

Potential uses in other/similar contexts

- You have seen some use cases in specific subjects. Do you think these learning scenarios can effectively be used by teachers of other subjects/other universities? Why (not)? How? What would be needed to make it work? (e.g. teacher training, availability of facilities, technical requirements from students, institutional support etc)

Feasibility/time investment

- How much work/time investment do you think it takes to make a learning experience with CloudClass/Edison? How does it fit in the regular teaching workflow? How can the use of such tool be facilitated? (e.g. teachers working together on something they will all use in the future)
- Teachers usually have busy schedules, but some might go an extra mile making a lesson or a video that they could reuse in the future or share with colleagues. How do you think CloudClass/Edison can make teachers' work more efficient (in the context of a specific university or department)?
- Do you think this tool makes teachers' lives easier? In which contexts would it be most feasible/justifiable to use this tool?

Facilities

- What kind of infrastructure do you think would be needed to make use of this technology at a university? To what extent/how should it be used? (e.g. one advanced unit per institution vs. every faculty having a smaller and simpler lab)

- What are the optimal uses of different hardware options for teaching (looking at the three scenarios in 3 universities)? Which option do you think the teachers and students (other stakeholders) will appreciate more and why?

Usability and training

- How feasible is it to suggest this technology to every teacher within the institution? What could be alternatives (only tech-savvy teachers? Start with a few, test, improve and offer to other teachers? Is it a niche technology that should only be used in a small range of specific use cases?)
- How easy or difficult do you think this technology is for teachers to use?
- How can it be made more accessible for teachers and students?
- What kind of training teachers and students might need to effectively use the technology in different scenarios?
- What kind of support teachers and production units might need to effectively use the technology? (e.g. a professional camera person, audio editor, etc)

Technical struggles – ways to overcome

- You could see that in some use cases the setup was pretty basic and probably not ideal (e.g. sharpness of the video, unnatural angles). How can these challenges be overcome for the optimal use of the tool (in low-resource settings)?

Added value, comparison with other tools

- How do you see the main added value of this technology?
- How is it different from other tools on the market (immersive VR sets, professional video production studios, more simple video conferencing/streaming services)?
- How do you think this technology should be developed further to yield maximum impact? What would be the optimal cases/scenarios for the use of the tool that would have most added value for teaching and learning/for commercial success of the tool/institution?

Security and privacy

- What factors should be considered to ensure safe use of this tool without violating privacy and security (teachers and/or students may be videorecorded)?
- What accessibility and inclusion features should be facilitated/integrated to make the tool suitable for e.g. people with special needs, disabilities, limited mobility etc.?

Part 3. General discussion 30 min

Explore the potential of further use and wider mainstream implementation

- [micro] Didactic scenarios/classroom situation
- [meso] Institutional level

You have seen a range of different implementation settings for the technology in education, from the most simple, to the most advanced.

How do you see the technology being effectively deployed in teaching in the future?
What are potential challenges and how could they be overcome?
What is the core value of technology? How should it be developed?
What are other contexts (beyond HE) that you see the technology being effectively deployed?

What do you think is the main impact of this tool

- on the level of a single classroom? (most likely, it has already been discussed in the previous stages) if not: Why would a teacher decide to use CloudClass over a regular video recording/video conferencing tool/showing a 3D model/environment/VR headset?

How far can the impact of using the tool in education go beyond the novelty effect? What do you think students gain when they are exposed to CloudClass/Edison? (e.g. improved motivation, feeling close to the teacher, better understanding of complex graphic concepts etc)

- on the institutional/national level? Why would a university/school want to adapt a technology like CloudClass/Edison? (e.g. more modern image, higher status, attract international/different audience, participate in projects/initiatives, extra sources of income etc). What would a university benefit from if it adopted a tool like CloudClass/Edison?
What kind of technical setup be optimal for the needs? How should it be implemented?

2. Codebooks for data analysis

Table 1

Micro-level (classroom-level) coding codebook

Code family	Code	Operational definition (apply when…)	Typical indicators in data	Theoretical anchor
Affordances	pedagogical added value (incl. differentiation and conceptualisation)	Stakeholders articulate the technology's *pedagogical action possibilities* and why these matter for teaching/learning – including (a) attributed educational value, (b) explicit differentiation from current practice, and/or (c) a conceptualisation of intended use in the learning situation.	"Enables X / improves Y", "different from video/Zoom/ppt because…", "best used for…", "fits when the goal is…", "changes how we teach/learn…".	Affordances (ecological + educational ICT affordances) (Bornstein & Gibson, 1980; Conole & Dyke, 2004b)
Instructional Design	multimedia learning principles and teacher presence	Stakeholders evaluate how the instructional message is designed and delivered, including (a) multimedia learning principles (e.g., coherence, signaling, segmentation/pacing) and (b) teacher presence as a design choice, described as either facilitative (supports attention, clarity, connection) or competing (draws attention away from learning-relevant visuals, increases processing demands).	"Too much on screen"; "clear highlighting"; "step-by-step"; "pace too fast"; "helps follow"; "feels more personal"; "brings the lecture alive"; "face draws attention"; "split attention"; "better with fewer competing visuals".	Cognitive Theory of Multimedia Learning (CTML) (R. E. Mayer, 2005; R. E. Mayer & Fiorella, 2021); Social cues / instructor presence (Richardson et al., 2017; Stull et al., 2018; van Wermeskerken et al., 2018)
Cognitive Load – teacher	Cognitive Load – teacher (intrinsic, extraneous, germane)	Stakeholders describe cognitive demands during teaching. This includes intrinsic Cognitive Load (task/content complexity and essential orchestration demands), extraneous Cognitive Load (avoidable load from suboptimal design or operational/technical handling during instruction), and germane Cognitive Load (effort invested in developing effective instructional routines and sense-making to improve delivery).	Intrinsic: "complex to teach," "many elements to coordinate." Extraneous: "hard to teach while controlling," "too many operations," "reduces fluency." Germane: "learning to use it well," "developing routines," "getting better with practice."	Cognitive Load Theory (Sweller, 1988, 2010; Sweller et al., 1998b)

Cognitive Load – student	Cognitive Load – student (intrinsic, extraneous, germane)	Stakeholders describe cognitive demands during learning. This includes intrinsic Cognitive Load (content/task complexity and element interactivity), extraneous Cognitive Load (avoidable distraction/split attention or interface/design friction), and germane Cognitive Load (productive effort toward schema construction and integration).	Intrinsic: "complex to understand," "many things at once." Extraneous: "distracting," "hard to follow," "split attention." Germane: "made me think," "helped connect ideas," "deeper understanding."	Cognitive Load Theory (Sweller, 1988, 2010; Sweller et al., 1998b)
Motivation (SDT) – teacher	Motivation needs support – teacher (autonomy, competence, relatedness)	Stakeholders describe teachers' motivation in relation to basic psychological needs in the teaching situation, including autonomy (volition, meaningful choice, control over teaching process), competence (feeling effective/capable to teach with the setup), and relatedness (feeling connected/supported by colleagues, students, or the institution) – including both need support and need frustration (e.g., control, failure, isolation).	Autonomy: "I can do it myself", "control over delivery", "dependence on technicians reduces autonomy". Competence: "I feel capable / it's manageable", "too complex to operate", "reduces fluency". Relatedness: "support from team/colleagues", "shared practice", "isolated in production/teaching".	Self Determination Theory (Deci & Ryan, 1985; Niemiec & Ryan, 2009; Ryan & Deci, 2000a)
Motivation (SDT) – student	Motivation needs support – students (autonomy, competence, relatedness)	Stakeholders infer or anticipate students' motivation in relation to basic psychological needs in the learning situation, including autonomy (perceived learner control or meaningful choice), competence (perceived clarity, guidance, and manageable challenge supporting effectiveness), and relatedness (perceived connection with the teacher/peers and a sense of belonging) – including both need support and need frustration (e.g., controlling design, confusion, isolation).	Autonomy: references to learner control, pacing, interaction, agency, or lack of choice. Competence: references to clarity, scaffolding, comprehensibility, confusion, or "hard to follow." Relatedness: references to teacher presence, social connection, warmth, impersonality, or isolation.	Self Determination Theory (Deci & Ryan, 1985; Niemiec & Ryan, 2009; Ryan & Deci, 2000a)
Student agency (PICRAT)	Student agency (Passive / Interactive / Creative)	Stakeholders characterise students' relation to the technology in the learning activity as Passive (primarily receptive viewing/receiving with minimal learner control), Interactive (learners manipulate, explore, respond, or navigate in ways that shape what they do/see), and/or Creative (learners generate artefacts, outputs, explanations, or products using the technology).	Passive: "one-way", "students watch/consume"; Interactive: "students manipulate/explore", "control pace/navigation", "interact with model/environment"; Creative: "students produce/create", "build/make", "create artefacts/outputs".	PICRAT (Kimmons et al., 2020)

Teacher agency (PICRAT)	Teacher agency (Replace / Amplify / Transform)	Stakeholders characterise teacher use of the technology as Replace (substitutes existing practice without substantive change), Amplify (improves efficiency/clarity/reach without fundamentally changing pedagogy), and/or Transform (enables qualitatively different activity structures/roles not feasible previously)ю	Replace: "same as before but digital", "just recorded/streamed"; Amplify: "clearer explanations", "better visuals", "more efficient"; Transform: "enables new pedagogy", "changes task design".	PICRAT (Kimmons et al., 2020)

Table 2

Meso-Level (organisational level) coding codebook for meaningful technology integration using Normalization Process Theory (May & Finch, 2009; May et al., 2009; Murray et al., 2010)

Code family (NPT construct)	Code (sub-construct)	Operational definition (apply when…)	Typical indicators in data
Coherence (sense-making)	Differentiation	Stakeholders articulate how the innovation differs from existing organisational routines, roles, and service models, clarifying what is "new" at institutional level.	"different from current practice"; "changes roles/workflows"; "not just another tool"; "shifts how provision is organised".
	Communal specification	Stakeholders describe collective work to build shared understanding of aims, expected benefits, target groups, and success criteria across stakeholder groups.	"shared vision"; "agreed purpose"; "alignment across units"; "common goals/criteria"; "what it is for".
	Individual specification	Stakeholders describe how specific roles/actors understand what they must do differently, including responsibilities, competencies, and boundaries.	"role clarity"; "who does what"; "responsibility allocation"; "my role would involve…".
	Internalisation	Stakeholders express perceived value/meaning of the innovation for the organisation (e.g., quality, equity, scalability), motivating why it should be integrated.	"worth it"; "adds institutional value"; "strategic relevance"; "benefits justify investment"; "fits mission".
Cognitive Participation (engagement)	Initiation	Stakeholders identify key actors/champions who drive and legitimise the integration process at organisational level.	"needs a champion/owner"; "leadership responsibility"; "who initiates"; "governance ownership".

	Enrolment	Stakeholders describe organising participation: recruiting units/roles, establishing coordination structures, and reconfiguring collaboration to do the work.	"coordination needed"; "cross-unit collaboration"; "new working group"; "role negotiation"; "handovers".
	Legitimation	Stakeholders express whether involvement is seen as appropriate and worthwhile for specific groups, including buy-in and mandate.	"why should we do this"; "is this our job"; "mandate"; "professional legitimacy"; "value for workload".
	Activation	Stakeholders describe sustaining engagement over time: maintaining participation, training momentum, and ongoing commitment beyond pilots.	"how to keep it going"; "sustained effort"; "ongoing training"; "maintain participation"; "avoid drop-off".
Collective Action (enactment)	Interactional workability	Stakeholders describe how the innovation works in day-to-day practice interactions and whether it fits operational workflows (e.g., scheduling, production, delivery, support).	"fits daily workflow"; "too complex in practice"; "operational friction"; "works smoothly in routine delivery".
	Relational integration	Stakeholders describe trust, accountability, and shared confidence in the innovation (e.g., quality assurance, reliability, credibility of outputs).	"confidence in quality"; "trust the process"; "accountability"; "quality assurance"; "reliability concerns".
	Skill-set workability	Stakeholders describe whether the right skills/capabilities exist and are allocated appropriately (training, role design, workload, division of labour).	"needs training"; "who has the skills"; "division of labour"; "workload capacity"; "capability gaps".
	Contextual integration	Stakeholders describe resourcing and organisational support (time, infrastructure, budgets, policies, support services), including commitments for scaling.	"need resources/time"; "budget/infrastructure"; "support services"; "policy/procedures"; "institutional investment".
Reflexive Monitoring (appraisal)	Systematisation	Stakeholders describe collecting and using information to evaluate the innovation (metrics, feedback loops, monitoring).	"evaluation plan"; "data/metrics"; "feedback collected"; "monitoring"; "evidence for decisions".
	Communal appraisal	Stakeholders describe collective evaluation processes and shared interpretation (committees, cross-role review, joint decisions).	"we evaluate together"; "committee review"; "shared reflection"; "collective judgement"; "joint decision-making".

	Individual appraisal	Stakeholders describe role-specific evaluation of effects on work (burden/benefits) and readiness to continue.	“for this role it…”; “benefits vs effort”; “manageable/not manageable”; “role-based judgement”.
	Reconfiguration	Stakeholders describe modifying the innovation or organisational arrangements in response to appraisal (adaptation, redesign, new procedures).	“we should change…”; “adapt workflow”; “revise procedures”; “iterate”; “reconfigure roles/resources”.

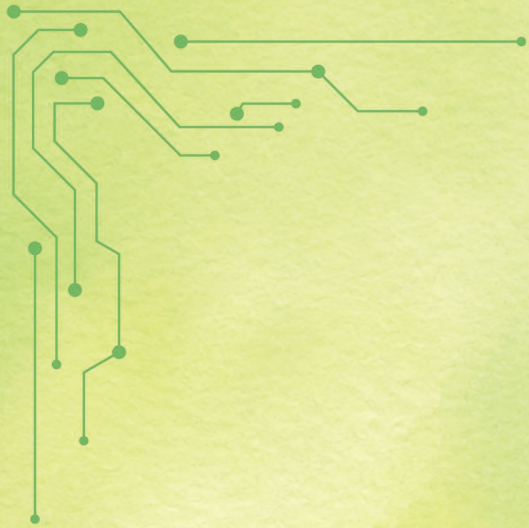
Appendix F (Chapter 6)

Table 1F

Ontological, epistemological, and axiological orientations across major learning theories

Learning theory / tradition	Ontology (view of reality and the learner)	Epistemology (view of knowledge and learning)	Understanding of the learning process	Role of the learner	Role of the teacher	Purpose and implied values
Behaviourism (Thorndike, 1913; Skinner, 1953)	Objectivist and empiricist; reality is external and measurable; the learner is a reactive organism shaped by environmental contingencies.	Knowledge consists of associations between stimuli and responses; justified through observable performance and reinforcement.	Conditioning through repeated practice and reinforcement until stable behavioural change occurs.	Respondent; imitator of modelled or reinforced behaviours.	Controller of contingencies; designer of reinforcement schedules and feedback.	Control, efficiency, and predictability; education aims at mastery of observable skills and compliance with standards.
Cognitivism (Atkinson & Shiffrin, 1968; Sweller, 1988; Mayer, 2001; Clark & Mayer, 2016)	Representational realism; mental structures and processes mediate interaction with an external world.	Knowledge is symbolic information stored and organised in memory; justified by accuracy and transfer of mental representations.	Acquisition, storage, and retrieval of information through attention, rehearsal, and schema formation; cognitive load must be optimised.	Active processor and organiser of information.	Designer of structured materials; manager of cognitive load through sequencing and signalling.	Clarity, structure, and optimisation; education aims at effective processing and durable retention of knowledge.
Constructivist and complexivist (Piaget, 1970; Davis & Sumara, 2006)	Experiential and emergent; reality is interpreted through interaction between the learner and the environment; systems	Knowledge is constructed through meaning-making; truth as *viability* rather than correspondence;	Reorganisation of prior understanding through exploration, reflection, and dialogue; learning occurs within	Active constructor and self-regulator; co-creator of knowledge.	Facilitator of inquiry; provider of rich, open tasks and scaffolds for reflection.	Autonomy, reflection, adaptability, and authenticity; education aims at sense-making and personal growth

	are adaptive and self-organising.	justified by coherence within experience.	complex adaptive systems.			within dynamic contexts.
Sociocultural and activity-theoretical (Vygotsky, 1978; Engeström & Sannino, 2010)	Non-dualist and relational; mind and world are co-constituted through social activity and tool mediation.	Knowing is socially mediated; knowledge is legitimate when enacted and recognised within cultural practices.	Participation and transformation within communities of practice; development through mediation, collaboration, and internalisation.	Participant developing identity and agency through guided participation.	Mediator of tools, dialogue, and social interaction; designer of collaborative activity systems.	Belonging, dialogue, equity, and collective agency; education aims at participation in and transformation of cultural practices.
Ecological and distributed-cognition (Gibson, 1979; Clark, 2008; Norman, 1993)	Situated and extended; cognition is distributed across minds, artefacts, and environments; learner and setting form one dynamic system.	Knowledge emerges through perception–action coupling and coordination with affordances and artefacts.	Adaptation to and exploitation of environmental affordances; learning as attunement and distributed problem-solving.	Perceiver–actor attuning to environmental possibilities.	Designer of environments and artefacts that offer meaningful affordances.	Sustainability, embodiment, and fit between mind and environment; education aims at adaptive interaction with tools and contexts.
Critical-pedagogical and pragmatist (Freire, 1970; Dewey, 1938)	Humanistic and transformative; reality is social and historical, open to reconstruction through dialogue and action.	Knowledge arises from reflection on experience and praxis; justified through its capacity to transform understanding and society.	Dialogical reflection leading to action (*praxis*); inquiry rooted in lived experience and communal problem-solving.	Reflective agent and co-creator of meaning; subject of emancipation.	Co-investigator; cultivator of critical awareness and moral responsibility.	Emancipation, democracy, and agency; education aims at social justice and reflective participation in collective life.





Acknowledgements

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