Design and Technology Education: An International Journal

30.2

Design and Technology: An International Journal

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Jacqui Eborall, Membership Secretary
Tel: 01789 470007
email: membership@data.org.uk

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Editorial: New faces on Editorial Teams

Kay Stables, Goldsmiths, University of London, UK
Lyndon Buck, University of Southampton, UK

Having spent a considerable number of years with the Journal being navigated by just the two of us Editors, we are now growing the team and are pleased to introduce three new Associate Editors who have recently joined us. Over the years the focus of articles in the journal has grown from publishing largely articles focusing on design and technology education from early years to the end of formal schooling to a significant increase in the number of published articles from Higher Education. There has also been an increase in the range of topics being addressed, with an increase for example in Engineering Education, with topics around aspects such as makerspaces and, most recently, an inevitable mushrooming of focus on Artificial Intelligence. So, the team has expanded. Those with most interest in schools education may recognise two of our new team: Sarah Davies from Nottingham Trent University and Matt McLean from Liverpool John Moore's University. Those from Higher Education may recognise Gary Underwood from University of Southampton. All three joined the team last month as Associate Editors and are now have their feet well and truly under the table.

In addition, at the Editorial Board we have been discussing the need to increase the international make-up of the board and are now delighted to welcome three new members, each of whom was nominated by existing members of the Board. Our new additions are Donal Canty from Limerick University in Ireland, Wendy Fox Turnbull from Waikato University in New Zealand and Belinda Von Mengersen from the Australian Catholic University. We are very much looking forward to the new ideas and insights they will contribute.

Back to the current issue where we have four quite different and interesting research articles, a reflection article and a book review. Our associate Editors have been hard at work – Gary Underwood is one of the contributors to the book review and reflection article has been provided by Matt McClean. Whilst on the topic of these two contributions, we are keen to invite any of our readers to submit a reflection piece – or even propose a response to a reflection. Equally we are also always grateful for people interested in reviewing books of interest for journal readers. Just let us know!

And now to the articles. Following the reflection article are the abstracts of each research article, and following these are the full articles.

Welcome to Issue 30.2 of the Journal and we hope that you enjoy it!

Unsolved on Purpose: Reflections on the Rubik's Cube and the Curriculum and Assessment Review for D&T

Matt McLain, Liverpool John Moores University, UK

This reflection emerges from the dual stimuli of (a) recent conversations with the UK Department for Education (DfE) Curriculum and Assessment Review (CAR) team on design and technology (D&T) in the National Curriculum for England and (b) co-authoring the 'Key Pedagogies' chapter for the next edition of 'Learning to Teach Design and Technology in the Secondary School' (Hardy & Davies, n.d.) with my friend and colleague Sarah Finnigan. In the previous edition of the chapter (McLain, 2021), the chapter that I authored introduced the terms *ideating*, *realising* and *critiquing*, as alternatives to the familiar designing, making and evaluating (Figure 1). In the last edition (Hardy, 2021), I also described two key processes: *communicating* and *knowing*. But since publication I have thought long and hard about these and revised them to: *communicating*, *researching* (formerly knowing) and *satisficing* (Figure 2). The latter being the philosophical idea that in D&T we want learners to be making considered judgements about available options and selecting the optimal response in and for different contexts; in contrast to following a formulaic or predetermined path where there is one answer or solution (McLain & Finnigan, n.d.).

My choice to adopt the terms *ideating*, *realising* and *critiquing* was largely to disrupt and the challenge the overfamiliarity and acceptance of these fundamental yet widely misunderstood and apparently discrete activities – my thesis being that the acts of designing, making and evaluating are not linear and separate activities, which is written about extensively in academia, but conflated with assessment objectives in everyday classroom practice and thinking (both conscious and unconscious). The historic phenomenon is rooted in our current obsession with criterion referenced assessment for qualifications, where assessed items are categorised and awarded marks based on importance. For D&T, this unhelpfully simplifies processes that are inherently complex and nuanced, in the name of validity. Not a bad aim, you might say, but no political act is without its limitations and unintended consequences.

In relation to the recent discissions with the DfE for the D&T CAR, this has got me (along with another good friend and colleague, Dr Alison Hardy from Nottingham Trent University) thinking about theoretical frameworks for understanding D&T, to inform discussions with stakeholders including educators and policymakers on the ideas that underpin the subject; be it curriculum, pedagogy or assessment. (Look out for a future article from us both on this front.) In the midst of these musings, the metaphor of the ubiquitous 20th Century puzzle, the Rubik's Cube™, came into my mind. There was something wonderfully subversive about starting a discussion on curriculum design with a puzzle that most of us have either abandoned in frustration or solved by peeling off the stickers. The unsolved Rubik's Cube™ (Figure 3) as a metaphor for D&T education became just clever linguistic turn of phrase, but a challenge to our instincts as teachers and educators. We like things neat. We like things finished. But deep down we know that real learning, like a scrambled cube, is messy, unpredictable, and full of possibility. And progression does not follow a single, smooth trajectory.

The temptation in D&T has always been to "solve" the curriculum: to line up the colours, standardise the projects, and make the outcomes look good on display boards. The cube says: DON'T! It says that a rich D&T experience should resist uniformity. It should be complex, interconnected and yes, sometimes uncomfortable. That's where the learning lives.

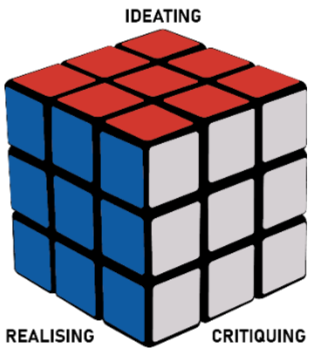

Figure 1. Three Fundamental Activities

Figure 2. Three Key Processes

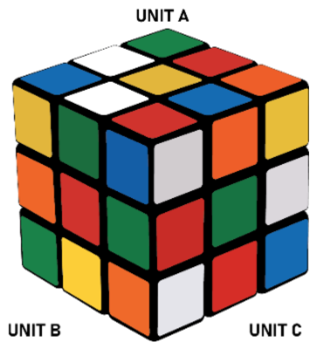

Figure 3. Unsolved Curriculum Model

The cube works because it captures the essence of our subject: interdependence. Twist one face and everything else shifts. Focus too much on "realising" (or *making*, if you prefer) and you risk neglecting "ideating" or "critiquing" (*designing* or *evaluating*). Overemphasise open-ended design and you may leave pupils without the skills to realise their ideas. The model reminds us that curriculum coherence is not about sameness, it's about balance. And let's be honest: balance is hard. The pressures of assessment, timetabling, and resource constraints push us toward the predictable, particularly when following the carousel timetabling that breaks units of learning into rigidly timebound chunks. It is easier to run a series of mainly making (or focused practical tasks) than to orchestrate a messy, iterative design project. But easy rarely equals educationally rich.

Here is the uncomfortable truth: an "unsolved" curriculum demands confidence. It asks teachers to embrace ambiguity, to plan for flexibility, and to trust processes that don't always produce tidy outcomes. For beginning teachers, that can feel terrifying. For experienced ones, it can feel like swimming against the tide of performativity and league tables. But the alternative (overly restrictive, homogenised schemes of work) risks stripping D&T of its soul. If every project looks the same, if every solution is pre-determined, then what are we really teaching? Not design. Not creativity. Just compliance.

In practice, the cube metaphor is not an excuse for chaotic or ad hoc planning. It is a call for intentional diversity. It asks us to plan across the three fundamental activities (ideating, realising, critiquing) and the three key processes (communicating, researching, satisficing), using the full repertoire of signature pedagogies: from designing and making, to mainly making, to mainly designing, to exploring technology and society. It's about sequencing restrictive and expansive approaches so that pupils experience both mastery and autonomy. And yes, that means resisting the seductive simplicity of the pervasive "skills first, creativity later" dogma. Learners can ideate, critique, and make from the earliest stages, if we scaffold intelligently. I think that Lev Vygotsky, the theorist who developed social constructivism and the zone of proximal development (ZPD), would approve.

The Rubik's Cube metaphor is more than a gimmick. It's a provocation. It asks us to stop chasing the illusion of a "solved" curriculum and start celebrating the productive tension of an unsolved one. Letting learners solve the 'problem' D&T learning in their own time and way. Because in D&T, the goal isn't to line up the colours, it is to keep turning the cube, exploring new configurations, and helping pupils see that complexity is not a problem to be eliminated but a reality to be embraced. To expose them to transformative ideas that apply on all walks of life (learning and work). So, the next time someone asks if your curriculum is "sorted," smile and say: *I hope not!*

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Abstracts

In this section we present the abstracts for each article published in this issue of the journal. As previously, the abstracts are arranged in the same order as the full articles. Across these articles valuable insight is presented through quite diverse aspects of design and technology education: from culturally relevant place-based learning with native American middle school students; to nurturing creativity in schools through makerspaces; to approaches that focus on assessable creative outcomes that prioritise design thinking processes; to the complexities and value of collaboration via a cross-cultural, virtual, design studio with a focal point on peer learning. The abstracts provide the ‘tasters’ for the articles. We hope the provision of the tasters is a useful addition to the journal and welcome feedback on the approach.

Designing Futures: Place-Based STEM Learning through Cultural and Spatial Innovation

Tilanka Chandrasekera, Oklahoma State University, USA
Tutaleni Asino, Carnegie Mellon University, USA
Nicole Colston, Oklahoma State University, USA

Abstract
This study examines how culturally grounded and immersive design pedagogies can enhance STEM engagement for Native American middle school students, integrating Place-Based Education (PBE), Culturally Relevant Teaching (CRT), and Problem-Based Learning (PBL). Utilizing Virtual and Augmented Reality (VR and AR) and 3D printing, the project aimed to boost student interest and engagement in STEM through culturally responsive, problem-solving modules. A Design-Based Research (DBR) methodology facilitated a co-design process with educators, community members, and students from three Oklahoma tribes (Citizen Potawatomie Nation, The Otoe-Missouria Tribe, and United Keetoowah Band of Cherokee Indians) to develop a curriculum incorporating local cultural narratives and environmental contexts. Findings show that place-based and culturally relevant pedagogies significantly enhance STEM education in tribal communities. Native educators effectively adapted the curriculum, integrating tribal origin stories and cultural practices into activities like architectural visualization and design thinking. Despite challenges such as irregular attendance and COVID-19 disruptions, the program successfully increased student engagement and motivation, particularly through hands-on hackathons. This research underscores the transformative potential of combining PBE, CRT, and PBL with advanced technologies to deepen students' connections to their heritage, enhance learning experiences, and strengthen STEM identities. Future plans include expanding professional development for educators and incorporating career narratives from Native American STEM professionals to further inspire students. Discussing these topics through the tangible contexts of architecture and interior design makes abstract ideas more engaging and accessible for students. As researchers committed to inclusive and community-centered educational design, our engagement with the three partner Tribal Nations stems from a longstanding collaborative relationship grounded in mutual respect. This partnership is guided by reciprocal learning, with communities benefiting through

access to emerging technologies, tailored curriculum, and STEM enrichment for their youth. This study highlights the importance of culturally responsive, place-based STEM education in preparing Native American students for future STEM careers.

Reclaiming Relevance: Positioning Design and Technology at the Heart of a Whole-School Creativity Framework

Andrew Rockliffe, Office for Standards in Education (Ofsted), UK

Abstract
Design and Technology (D&T) in the UK is approaching a crisis point, with declining enrolment, staffing shortages and increasing marginalisation in the curriculum. However, this paper argues that D&T is not a problem to be solved. Rather, it is a solution to be scaled. Positioned at the intersection of material practice, iteration and design thinking, D&T is uniquely placed to lead a whole-school strategy for embedding creativity as a set of teachable, observable competencies, not as an abstract ideal. This paper introduces a structured Creative Competency Framework, drawing on cognitive science, classroom research and cross-curricular theory. It outlines 15 core and meta-competencies, from divergent thinking and sequencing to translational and meta-cognitive awareness. Moreover, the paper demonstrates how creative competencies can be mapped onto existing D&T projects to reveal and develop their creative potential. Using a bespoke AI-powered tool, the paper presents trial analyses of two contrasting projects to show how creative depth can be made visible, measurable and actionable. Ultimately, the paper proposes a new standard for assessing creativity that is not merely based on outcomes, but is rooted in the thinking processes embedded in a task. Finally, the paper issues a call to practitioners to contribute to the refinement of this tool, with the aim of developing a bank of high-performing, creativity-rich D&T projects for shared use. The result is both a defence and a reinvention of the subject, repositioning D&T as foundational to a future-facing, creative curriculum.

Fostering Creativity in School Makerspaces: Principles and a Framework for Assessing Creativity-Supportive Design

Larysa Kolesnyk, University of South-Eastern Norway, Notodden, Norway
Brynjar Olafsson, University of South-Eastern Norway, Notodden, Norway
Camilla Groth, University of South-Eastern Norway, Notodden, Norway
Eva Lutnæs, Oslo Metropolitan University, Oslo, Norway

Abstract

School-based makerspaces are increasingly recognized as powerful contexts for fostering creativity, collaboration, and problem-solving. However, educational research on creativity has often prioritized individual traits or final products, underemphasizing the environmental conditions - physical, social, emotional, and cognitive - that shape creative engagement. This paper argues for re-centering Press, the environmental dimension of Rhodes' Four Ps model, as a central driver of creativity in educational makerspaces. Drawing on interdisciplinary literature from creativity studies, learning sciences, and educational psychology, the paper identifies six interrelated principles that characterize creativity-supportive learning environments: a supportive socio-emotional atmosphere, learner autonomy, inspirational stimuli, collaborative culture, teacher support and guidance, and equitable access to technology and resources. These principles are synthesized into the Creative Educational Environment Assessment Model, a prospective conceptual framework designed to evaluate and enhance makerspaces in ways that are context-responsive, equitable, and pedagogically robust. The model emphasizes process as well as product, incorporates intellectual resources as a dimension of creative support, and situates teacher capacity as a systemic driver. Intended as both a theoretical scaffold and a practical tool, the framework offers researchers, educators, and policymakers actionable guidance for transforming makerspaces into environments where creativity is structurally supported and democratically accessible.

Outputs of a Cross-Cultural Virtual Design Studio: EINSTUDIO – A Design Journey Across Countries

Barış GÜR, Gazi University, Turkey
N. Hande KUTBAY, Gazi University, Turkey
H. Güçlü YAVUZCAN, Gazi University, Turkey

Abstract

Following the COVID-19 pandemic, research on Virtual Design Studios (VDS) increased significantly, revealing mixed opinions about their limitations. This paper aims to present these contrasting views on VDS education, with a particular focus on peer-learning. While many studies argue that peer-learning diminishes significantly, or even disappears in VDS, others claim the opposite. The conceptual framework of this study explores the possible limitations of peer-learning in VDS and critically highlights how COVID-19-related anxiety may have influenced many of these opinions. The empirical study discussed in this paper is based on an Erasmus+ project titled *European Strategic Partnership Project: European Interactive Industrial Design Studio (EINSTUDIO*). Students and instructors from three different countries participated in EINSTUDIO. The project aimed to leverage recent developments in online and web-based communication to address the challenges of teamwork in cross-national teams. Accordingly, this paper investigates whether current virtual technologies support the implementation of cross-national design studios. Variables such as motivation, collaboration, cultural diversity, and the contribution of the e-learning infrastructure are examined through participants' self-evaluations. The findings indicate that although virtual peer-learning presents certain

limitations and cross-national collaboration poses even greater challenges, a more structured methodology, syllabus and close supervision, such as EINSTUDIO's semi-hybrid studio model, syllabus, and platform can help mitigate issues related to peer-to-peer communication and collaboration issues.

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Abstract

This study examines how culturally grounded and immersive design pedagogies can enhance STEM engagement for Native American middle school students, integrating Place-Based Education (PBE), Culturally Relevant Teaching (CRT), and Problem-Based Learning (PBL). Utilizing Virtual and Augmented Reality (VR and AR) and 3D printing, the project aimed to boost student interest and engagement in STEM through culturally responsive, problem-solving modules. A Design-Based Research (DBR) methodology facilitated a co-design process with educators, community members, and students from three Oklahoma tribes (Citizen Potawatomie Nation, The Otoe-Missouria Tribe, and United Keetoowah Band of Cherokee Indians) to develop a curriculum incorporating local cultural narratives and environmental contexts. Findings show that place-based and culturally relevant pedagogies significantly enhance STEM education in tribal communities. Native educators effectively adapted the curriculum, integrating tribal origin stories and cultural practices into activities like architectural visualization and design thinking. Despite challenges such as irregular attendance and COVID-19 disruptions, the program successfully increased student engagement and motivation, particularly through hands-on hackathons. This research underscores the transformative potential of combining PBE, CRT, and PBL with advanced technologies to deepen students' connections to their heritage, enhance learning experiences, and strengthen STEM identities. Future plans include expanding professional development for educators and incorporating career narratives from Native American STEM professionals to further inspire students. Discussing these topics through the tangible contexts of architecture and interior design makes abstract ideas more engaging and accessible for students. As researchers committed to inclusive and community-centered educational design, our engagement with the three partner Tribal Nations stems from a longstanding collaborative relationship grounded in mutual respect. This partnership is guided by reciprocal learning, with communities benefiting through access to emerging technologies, tailored curriculum, and STEM enrichment for their youth. This study highlights the importance of culturally responsive, place-based STEM education in preparing Native American students for future STEM careers.

Keywords

Culturally Relevant Teaching, Native American, Place-Based Education, STEM Education, Virtual and Augmented Reality

Introduction

Place-Based Education (PBE) is an instructional approach that emphasizes the concept of place to create authentic, meaningful, and engaging personalized learning experiences for students. When combined with Culturally Relevant Teaching (CRT), which integrates students' cultural references into all aspects of learning, it has the potential to enhance educational outcomes. This study aimed to explore whether integrating these two frameworks with Problem-Based Learning (PBL) to solve spatial design problems using technologies such as Virtual and Augmented Reality can improve students' interest in STEM education.

A project was developed that focused on an after-school program designed to increase STEM career interests and motivations among Native American middle-school students. Utilizing VR, AR, and 3D printing, students solved spatial design problems through culturally responsive, problem-based learning modules. A generative co-design process involving educators, community members, and students incorporated historical and contemporary cultural knowledge, targeting middle-school students and educators from three tribes in Oklahoma. The project established technology centers in the tribes, an inclusive curriculum, and community-defined hackathons. Research focused on the program's impacts on STEM career development, using mixed methods to evaluate student interest, motivation, and STEM identity. Findings and resources were made available online, contributing to the knowledge base on culturally responsive programs. The study employed a Design Based Research (DBR) Methodology aimed at improving educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in the real-world setting. The purpose of this study is to examine how the integration of Place-Based Education, Culturally Relevant Teaching, and Problem-Based Learning, supported by immersive technologies such as VR, AR, and 3D printing can enhance STEM engagement, cultural identity, and design thinking among Native American middle school students. The study shares findings from a multi-year, co-designed afterschool program conducted with three Tribal Nations in Oklahoma.

Literature Review

Place based education and Design pedagogy

Place-based education (PBE), also known as place-based learning, is an instructional approach that capitalizes on geography to create authentic, meaningful, and engaging personalized learning for students (Sobel, 2004). It hinges on the concept of using the local community and environment as a starting point to teach concepts in various disciplines, including language arts, mathematics, social studies, science, and more (Smith, 2002). The principles of PBE are founded on the belief that learning becomes profoundly relevant to students when it is concretely grounded in their own local experience, culture, landscape, and tradition (Gruenewald & Smith, 2008). This approach encourages exploration and connection to the local place, thereby fostering a sense of stewardship and attachment towards it (Theobald, 2004). The concept of place-based education holds substantial relevance in architectural and interior design. As architecture and interior design are disciplines deeply rooted in the physical and cultural context of places, PBE can enhance understanding and respect for the community's unique aspects and its relationship with the environment (Ardoin et al., 2019).

A place-based approach to design allows architects and designers to learn about the history, culture, social norms, and geographical features of a place, which can significantly influence their designs. For instance, the understanding of local materials, construction methods, climate, and cultural preferences can drive the selection of design strategies, materials, and technologies that are relevant, sustainable, and resonant with the local community (Lane & Johnsson, 2019). Furthermore, PBE is integral to understanding the physical and social characteristics of a place, contributing to the design of spaces that contribute positively to users' wellbeing and experiences (Vanclay et al., 2015). By understanding the nuances of a place, architects and designers can create structures and interiors that promote a sense of belonging, support cultural continuity, and enhance the lived experience.

Therefore, Place-based education can facilitate a more nuanced and engaged understanding of the local environment in architectural and interior design education, highlighting the cultural, historical, and physical aspects of a location and translating that understanding into designs that honor, reflect, and enhance the uniqueness of the place.

Culturally Relevant Teaching (CRT) and Culturally Relevant Design

Culturally relevant teaching, also known as culturally responsive teaching, is a pedagogical framework that integrates students' cultural references into all aspects of learning. It aims to make learning more relevant and effective for students by respecting and honoring their cultural backgrounds and experiences (Ladson-Billings, 1995).

In Language Arts and Literature, culturally relevant teaching suggests using texts and materials that reflect the cultural backgrounds of students. Teachers can integrate diverse authors and stories into the curriculum, enabling students to see themselves and their experiences represented in what they read and study (Lee, 2007). In Mathematics and Science, culturally relevant teaching implies incorporating real-world problems relevant to students' cultures or using culturally based examples to explain abstract concepts (Aguirre et al., 2013). For instance, a math teacher might use textile patterns from a community's cultural heritage to teach geometry, or an environmental science teacher might explore local environmental issues pertinent to the community (Leonard et al., 2010).

In Social Studies and History, culturally relevant teaching involves teaching history and social issues from various perspectives, including those of marginalized or underrepresented groups. It includes incorporating local and indigenous histories and allowing students to examine events from multiple viewpoints (Epstein, 2009). In Arts and Music, culturally relevant teaching encourages the exploration and appreciation of art forms from various cultures, particularly those represented in the classroom. It includes exploring diverse musical traditions, art styles, and cultural expressions, thereby validating students' cultural experiences and identities (Banks, 2019). Moreover, culturally relevant teaching is not limited to subject matter. It also pertains to teaching strategies, classroom dynamics, and assessment methods. It promotes cooperative learning strategies that align with communal cultures and includes assessments that value diverse ways of demonstrating knowledge and skills (Gay, 2018). Culturally relevant design (CRD) plays a critical role in the field of architecture and interior design. This approach emphasizes the importance of integrating cultural contexts and understanding into design processes and outcomes, enabling designs to reflect, respect, and honor the cultural backgrounds and experiences of the community (Banerjee & Loukaitou-Sideris, 2011).

CRD goes beyond the aesthetics of a design to incorporate meaningful elements of culture and tradition, facilitating a deeper connection between the people and the built environment (Champagne, 2015). It aims to create spaces that are not just functional but also culturally meaningful and comfortable. These designs often reflect the history, values, traditions, and lifestyle of the local community, thus forming a sense of cultural continuity (Tunstall, 2013). In architecture and interior design, CRD could involve incorporating traditional building materials and techniques, integrating cultural symbols and motifs, or designing spaces that reflect cultural practices and norms (Crysler et al., 2012). For instance, in a community with a history of textile production, designers might integrate textile patterns into the design elements of a building, or in a community with specific social gathering traditions, designers might create spaces that support these social activities (Tunstall, 2013). CRD also supports sustainability as it tends to be sensitive to local environments, using locally sourced materials and responding to local climate and ecological conditions. It acknowledges the deep connection many cultures have with their natural environment and seeks to maintain and strengthen this connection through design (Banerjee & Loukaitou-Sideris, 2011). Furthermore, CRD plays a significant role in design education. Incorporating culturally relevant perspectives into design education encourages students to respect and learn from diverse cultural knowledge systems and prepares them to design in a culturally responsive manner

Culturally Relevant Teaching and Culturally Relevant Design share a foundational principle: to honor, respect, and integrate the cultural backgrounds and experiences of the community into teaching and design practices (Ladson-Billings, 1995; Banerjee & Loukaitou-Sideris, 2011). CRT, in the pedagogical context, aims to make learning more relevant and effective by drawing on students' cultural knowledge and experiences (Ladson-Billings, 1995). Similarly, CRD in the context of architecture and interior design, aims to make designs more meaningful, functional, and comfortable for the community by incorporating cultural context and understanding (Champagne, 2015). Both CRT and CRD value the knowledge systems embodied within local cultures. CRT integrates these knowledge systems into pedagogy, acknowledging and validating them as a crucial part of the learning process (Aguirre et al., 2013). CRD, on the other hand, utilizes these knowledge systems in creating designs that reflect and honor the cultural practices, norms, and aesthetics of the community (Tunstall, 2013). Both CRT and CRD also share a commitment to fostering a sense of belonging and identity affirmation. CRT achieves this through creating an inclusive learning environment that validates students' cultural identities (Gay, 2018). Similarly, CRD creates spaces that reflect and affirm the cultural identity of the community, fostering a sense of cultural continuity and belonging (Crysler et al., 2012).

PBE and Culturally Relevant Design (CRD)

Place-Based Education (PBE) is a powerful pedagogical tool that can be particularly effective when applied to architectural and design contexts involving indigenous communities. Its emphasis on local knowledge and cultural sensitivity makes it an ideal approach for designing spaces that respect, reflect, and honor Native American cultures and environments (Demmert & Towner, 2003). Space provides a useful metaphor for teaching about culture and technology in STEM fields like design. Culturally relevant design is a critical aspect of architectural and interior design, especially in regions inhabited by indigenous populations. Since everyone experiences existing in physical spaces, using the concept of space allows students to better relate to and understand cultural influences and technological applications. Discussing these topics through the tangible contexts of architecture and interior design makes the abstract ideas more engaging and accessible for students. For Native American communities, the local environment, customs, history, and values have long been the basis of their architectural practices (Champagne, 2015). A place-based approach can help architects and designers grasp these intricate nuances, enabling them to create designs that not only meet functional needs but also resonate deeply with the community's cultural and spiritual sensibilities (Ardoin et al., 2019). The designs derived from this approach can be highly contextual, reflecting aspects such as local climate, available materials, traditional building methods, and cultural symbols and motifs. These designs are more likely to be sustainable, as they respect the ecological boundaries of the place, and culturally relevant, as they echo the community's heritage and values (Banerjee & Loukaitou-Sideris, 2011).

Culturally relevant design and Place-Based Education (PBE) share a conceptual similarity with Christopher Norberg-Schulz's idea of 'Genius Loci' or 'Spirit of Place.' Genius Loci, a term originating from Roman mythology, was revitalized by Norberg-Schulz in the context of architecture to express the unique, unrepeatable character of a place (Norberg-Schulz, 1980). Similar to PBE and culturally relevant design, the Genius Loci concept involves deeply understanding and appreciating the essence of a place – its history, culture, environment, and community – and reflects these aspects in architectural design. This is strikingly akin to the principles of culturally relevant design and PBE, which hinge on the meaningful integration of local community, culture, and environment into the learning process and design practices (Ardoin et al., 2019; Sobel, 2004).

Norberg-Schulz (1980) emphasized the importance of understanding a place in its totality – including its topography, climate, light, and tectonics – to capture its unique 'spirit.' This approach requires an understanding not just of physical characteristics but also the cultural and historical context of the location. Similarly, culturally relevant design adopts this contextual understanding, aiming to create designs that respect and reflect the local culture and community (Lane & Johnsson, 2019). PBE and the idea of Genius Loci both advocate for a sense of rootedness and a deeper connection to the place. PBE supports this through the educational process, promoting the exploration of local environments and cultural practices (Smith, 2002). In parallel, the Genius Loci approach in architectural design aims to evoke this sense of connection through built structures that embody the spirit of the place.

Moreover, both approaches value the unique knowledge systems embodied within local cultures. Norberg-Schulz's concept appreciates the indigenous understanding of place and its embodied experiences, while PBE promotes the integration of indigenous knowledge systems into pedagogy (Bang et al., 2014).

PBE and STEM education in Native communities

Place-Based Education (PBE) and culturally relevant learning are pivotal pedagogical strategies that can greatly enhance STEM (Science, Technology, Engineering, and Mathematics) education. PBE, with its emphasis on contextual learning rooted in the local environment and community, provides a tangible and relatable way to introduce complex STEM concepts (Smith, 2002). By utilizing local resources and issues, PBE transforms the abstract ideas often encountered in STEM into concrete examples that students can experience and investigate firsthand (Sobel, 2004). For instance, students can study local water quality to understand concepts in chemistry and environmental science or analyze the structure of a nearby bridge to learn about physics and engineering principles.

Culturally relevant learning, on the other hand, adds another layer to the effectiveness of STEM education. This approach recognizes and incorporates students' cultural knowledge and experiences into teaching and learning processes (Ladson-Billings, 1995). This inclusion of students' culture can enhance the understanding and relevance of STEM concepts. For instance, in a community with a rich history of textile production, a math teacher might teach geometry through the lens of textile patterns. This not only contextualizes mathematical concepts but also validates and integrates the community's cultural knowledge into the STEM classroom, fostering a greater sense of relevance and engagement among students (Aguirre et al., 2013).

Moreover, culturally relevant pedagogy in STEM also acknowledges the various ways in which different cultures engage with and understand STEM concepts. This can help to break down monolithic understandings of STEM and introduce students to a broader, more inclusive perspective (Bang et al., 2014). PBE has shown considerable potential in helping Native American students understand STEM (Science, Technology, Engineering, and Mathematics) concepts. Given the cultural significance of place in these communities, contextualizing STEM education within the local environment can help make these subjects more relatable, relevant, and engaging (Aikenhead, 2006). For example, studying local ecosystems or traditional building techniques can facilitate a deeper understanding of scientific concepts or engineering principles. Furthermore, this approach can promote a greater appreciation and application of indigenous knowledge systems within STEM, offering students a unique and culturally relevant perspective (Bang et al., 2014). This study aligns with calls from Indigenous scholars to center cultural identity and challenge systemic inequities in education (Nganga & Kambutu, 2024; Castagno & Brayboy, 2008). Hyscher’s (2024) work on culturally relevant virtual environments further illustrates how spatial design can foster Indigenous language learning, resonating with the approach in our modules.

Taken together, the literature highlights the educational potential of integrating culturally responsive pedagogy, place-based learning, and immersive technology. However, few studies have examined how these approaches intersect in the context of Indigenous design education, particularly through co-designed spatial problem-solving modules for youth. This study responds to that gap by combining PBE, CRT, and PBL within a Design-Based Research framework to explore how immersive design tools (e.g., VR/AR/3D printing) can support STEM engagement among Native American middle school students. By centering tribal narratives and community co-design, this research contributes a culturally grounded model that expands the boundaries of traditional STEM education.

Method

We employed a Design-Based Research (DBR) methodology, following an iterative process of design, implementation, research/evidence, feedback, and adjustment of program components. This approach aligns with Design-Based Research frameworks as described by Wang and Hannafin (2005) and Barab and Squire (2004), which emphasize iterative refinement through practitioner-researcher collaboration in real-world settings. This approach aimed to improve educational practices through collaboration among researchers and practitioners in real-world settings, leading to contextually-sensitive design principles and theories. DBR involves multiple iterations and evaluations, relying on prior research and theory while contributing to the development of teaching and learning theories and producing instructional tools that withstand everyday practice challenges.

The project staggered the participation of each Tribal Nation afterschool program over four years to enable the team to learn and improve the Project-Based Learning (PBL) modules and generative design process. Each program's participation began with a professional learning experience for afterschool educators in the summer prior to implementation. Afterschool educators and tribal elders collaborated to co-design culturally reflective modules specific to their Tribal Nation. Our project team coordinated the initial implementation of the program in the fall at each respective afterschool facility, followed by virtual support for the educators in the spring. This incremental training and support process was designed to prepare afterschool educators to implement the activities independently in subsequent years.

Over the course of the project, we hosted three summer workshops for afterschool educators at our home institution and sponsored 15 semester sessions of afterschool programs across three locations. Technology centers were established at each location to support the afterschool programs and mini hackathons. The afterschool program curriculum was made publicly available on the project website, including examples of digital cultural artifacts developed by the students.

The professional learning experience for afterschool educators included technical training on VR/AR technologies and curriculum, and collaboration to develop culturally explicit lesson plans. Each Tribal Nation nominated five individuals for a three-day summer workshop at our home institution. This workshop included training on software and curriculum modules, and collaboration with Tribal Nation educators to introduce culturally relevant themes and develop hackathon challenges. These workshops also facilitated meetings with current Native American undergraduates majoring in STEM fields to discuss college readiness and STEM career awareness from a near-peer perspective. Near-peer connections, where individuals learn from peers who are slightly more advanced in their knowledge or skills, are considered vital in educational settings. These connections foster a more relatable and less intimidating learning environment, as near-peers often share similar experiences and challenges with the learners. This can enhance motivation, engagement, and the overall learning experience (Authors, 2024)

For the afterschool STEM programs, the curriculum included seven modules targeted at middle school students aged 10-15. The project team coordinated the first semester implementation, with afterschool educators co-leading and participating in all sessions. In the following semester, afterschool educators led the program with the research team’s support. In subsequent semesters, the educators independently implemented the STEM program. In the final semester, teams of two educators and six students from each afterschool program were invited to the home institution to participate in a competitive hackathon as the project's finale.

All research involving minors was reviewed and approved by the Oklahoma State University Institutional Review Board (IRB). Informed consent was obtained from parents or guardians, and assent was secured from participating students, in coordination with tribal education departments to ensure cultural and procedural alignment. Tribal approval was also obtained through the respective tribal ethics committees and leadership of the tribes.

Developing Modules

The project used Problem-Based Learning (PBL) to encourage critical thinking, creative reasoning, and communication skills through innovative technologies such as VR, AR, and 3D printing. The curriculum included seven modules designed to help students learn problem-solving skills and retain information. Each afterschool program met once every two weeks for seven sessions during each fall and spring semester. Each week, students were introduced to a new module that was built on the previously completed one. The modules were designed to be hands-on experiences using examples of architecture and interior design situated in the local environment and community. The PBL format allowed the challenges to change each year by introducing different problems or incorporating specific Tribal Nation interests and concerns. The project leadership actively involved Native American afterschool educators and Tribal Nation elders and leaders in developing the cultural connections and problem areas, through both formal and informal consultations during summer workshops, afterschool programs, and annual hack-a-thon meetings.

The co-design of the curriculum modules supported the goal of making the curriculum relevant and unique to each Tribal Nation while also being replicable for other Tribal Nation afterschool programs. These educational resources served as a starting point for afterschool educators and students to explore traditional homes and spatial design in architecture specific to their Tribal Nation. Afterschool educators and project consultants identified age-appropriate, student-centered explorations of related concepts, such as structural materials, artwork, and community activities, to strengthen student cultural identity and inspire architectural visualizations. Tribal Nation elders were consulted in deciding the design problems and annual hackathon challenges.

The curriculum included experiential learning modules that began with cultural learning and then provided an immersive technology experience. Each module aimed to explore a different facet of indigenous culture through spatial design, allowing students to develop technological skills through PBL. Each module included an immersive (VR or AR) example tailored to the specific Tribal Nation. These immersive examples were developed to capture and present the genius loci of indigenous spatial structures, allowing students to experience and deconstruct these concepts before reconstructing them as novel spatial experiences.

Module 01: Basic Building Blocks: Sketching to Rendering – This module focuses on developing students' spatial reasoning skills through visualization. It introduces them to the fundamentals of architectural visualization, including the basics of sketching and architectural drafting. Using place-based learning, students draw inspiration from their local environment and community structures, learning to translate these familiar elements into visual representations. Culturally relevant pedagogy is integrated as students incorporate traditional Native American architectural elements and symbols into their sketches, fostering a connection to their heritage. This foundational knowledge sets the stage for more advanced design work in subsequent modules, providing students with essential skills for architectural and design projects.

Module 02: Virtuality: Using VR in Architectural Visualizations – This module introduces students to the exciting world of content creation through 3D modeling software and the use of VR as a powerful design tool (Figure 1 c). By designing their own dorm rooms, students tackle real-world design challenges that are relatable and relevant to their future educational experiences. This exercise also serves to instill the idea of college life and underscore the importance of higher education as a significant part of their future. Through this project, students incorporate culturally relevant designs and motifs from their Tribal Nation into their dorm room models, celebrating their cultural identity while learning technical skills. By visualizing their designs in a virtual reality environment, students gain a deeper understanding of architectural visualization and the parallelism between the design process and the scientific method.

Module 03: Virtual Realization: Modeling and Viewing a Building in VR – In this module, students create a virtual museum featuring their work. They begin by visiting and documenting a significant building in their Tribal Nation, such as a historical site or a culturally important structure. Using place-based learning, students gather data through 3D scanning, photography, and measurements to model the building in 3D software. The virtually recreated space serves as an interactive museum where students display their projects, enhancing their spatial thinking and technical skills. This module fosters a deeper connection to their cultural heritage by preserving and showcasing it in a modern, digital format, allowing students to contribute their work to a shared, immersive cultural resource.

Module 04: Virtuality to Physicality: 3D Printing – In this module, students transform virtual artifacts into tangible products using 3D printing, solving design problems through collaborative, team-based exercises. The focus of this exercise is on designing a light fixture (Figure 1 a). Students are introduced to the fundamentals of electricity and various types of lighting. They incorporate cultural elements into their light fixture designs, blending technical skills with cultural heritage. Place-based learning is emphasized as students draw inspiration from traditional Native American designs and motifs, creating meaningful, culturally inspired artifacts. This hands-on module not only teaches the technical aspects of 3D printing and electrical design but also encourages students to celebrate and integrate their cultural identity into their work.

Module 05: Empathic Design Process: Designing for Special Groups – This module introduces students to the concept of empathic design, emphasizing the Native American tradition of respecting elders. Students use an aging simulation suit (GERontologic Test suit) to experience the physical challenges faced by older adults, enabling them to develop thoughtful and practical design solutions. Place-based learning is incorporated as students consider the specific needs and cultural practices of their Tribal Nation's elders (Figure 1 b). Culturally relevant pedagogy is integrated as students design solutions that reflect traditional values of respect and care for elders, enhancing their ability to create innovative designs that improve accessibility and quality of life within their community.

Module 06: Augmented Living: Using AR in Design – This module challenges students to develop and enhance an everyday object using 3D modeling, with the final design presented through augmented reality (AR). Emphasizing anthropometric and ergonomic measurements, students learn to create designs that are both functional and user-friendly. Place-based learning is incorporated as students consider the specific needs and daily practices within their Tribal Nation. Culturally relevant pedagogy is integrated as students incorporate traditional designs and ergonomic considerations that reflect their cultural heritage, ensuring the objects they create are optimized for comfort, efficiency, and usability while honoring their traditions.

Module 07: VR+AR Mini-Hackathon – This team-based event tasked students with addressing a real-world issue within their Tribal Nation by utilizing the VR and AR technologies introduced in the preceding modules. These challenges were developed collaboratively with afterschool educators and tribal leaders, ensuring the projects were relevant and meaningful to the community. Emphasizing place-based learning, students engaged in projects that directly impacted their local environment and community. Culturally relevant pedagogy was integrated as students applied their technical skills to solve problems that reflected their cultural values and priorities, fostering innovation and collaborative problem-solving in a dynamic, high-energy setting. Additionally, tribal elders were invited to participate and work alongside the students, enriching the experience with their wisdom and cultural insights.

Fig 1. (a) 3D printed light fixture, (b) GERT Suite and Wheelchair use with VR, (c) A student using VR

Codesigning the Modules

While the initial framework for the modules was developed by researchers, the true strength of the curriculum lies in its co-design process. This collaborative approach involves working closely with educators and tribal leaders to ensure each module meets the specific needs of the students and the community. This collaborative process was conducted during the teacher workshops in the summer. According to Wang and Hannafin (2005), Design-Based Research (DBR) involves iterative analysis, design, development, and implementation, which is critical in creating contextually sensitive educational practices. This process often entails deconstructing and reconstructing entire modules to tailor them to local priorities and cultural contexts.

For some tribes, the modules are infused with unique cultural stories that serve as foundational themes, enriching the learning experience and helping students connect more deeply with the material. This integration of cultural narratives aligns with culturally relevant pedagogy, which Gay (2018) describes as teaching that uses the cultural knowledge, prior experiences, and performance styles of diverse students to make learning more appropriate and effective. In other cases, the modules are adapted to address specific requirements or goals identified by the tribe, ensuring the content supports the tribe’s broader educational and cultural objectives.

By prioritizing the co-design process, we ensure the curriculum is responsive and respectful to the diverse cultural landscapes of each Tribal Nation. This method fosters a sense of ownership among educators and students, making the learning experience more meaningful and effective. The collaboration between researchers, educators, and tribal leaders exemplifies a commitment to culturally relevant pedagogy and place-based learning, ultimately enhancing the educational outcomes for tribal students.

The following overarching research questions aimed to capture in qualitative terms the impact of a technology rich and culturally immersive environment on students' generative knowledge in terms of culture and career:

RQ1: How do afterschool educators access and use the spaces, practices, and resources for culturally relevant teaching and learning (i.e. technology center, curriculum, and website)?

RQ2: In what ways do blended cultural learning and technology-rich immersive experiences support students' abilities to translate Indigenous concepts into creative design experiences?

RQ3: How does visual storytelling impact participants' personal, social, and cultural worldviews in relation to their STEM education and career interests?

Findings

Our research focused on three key questions related to place-based learning, culturally relevant pedagogy, and the impact of visual storytelling on STEM education and career interests in tribal afterschool settings.

Educator Use of Cultural and Technological Resources: For our first research question, we aimed to understand how afterschool educators accessed and utilized spaces, practices, and resources for culturally relevant teaching and learning. In the first year, we assessed the STEM capacity and instructional comfort of educators through surveys, interviews, and planning meetings. We collaborated with tribal educators to enhance the afterschool computing space, introduce problem-based learning (PBL), and integrate cultural resources and tribal origin stories. This initial assessment revealed varied levels of experience and commitment to STEM education across the three partner tribal nations. In subsequent years, the implementation of the curriculum faced challenges due to irregular student attendance and program disruptions caused by COVID-19. However, we adapted to these changes and successfully implemented the curriculum. Native educators played a crucial role in integrating VR technologies, enhancing cultural learning through emerging technologies. Embracing 'kid-culture' and providing hands-on learning opportunities proved essential for student engagement. Moving forward, we planned to involve more educators in professional development and coordinate with the afterschool program to recruit a larger number of student participants.

Educators particularly valued the hands-on nature of the modules and the integration of tribal narratives. One participant noted that "students were more engaged when stories from our own community were part of the lesson." The ability to use VR tools and cultural content together made the sessions more relevant and sustainable for long-term use.

Translation of Indigenous Knowledge through Immersive Design: For our second research question, we explored how blended cultural learning and technology-rich immersive experiences supported students in translating Indigenous concepts into creative design experiences. We introduced generative design and culturally relevant pedagogy to afterschool educators and student researchers through an intertribal educator workshop. This workshop used space as a cultural metaphor, providing an opportunity to model generative design and explore pre-colonized societies. Involving elders, families, and cultural experts in design experiences was crucial for fostering intergenerational cultural exchange. The program revealed the need for curriculum modifications to create a fun environment with rewards for participation. Students engaged in activities such as scanning beadwork into a virtual museum and redesigning afterschool spaces during a hackathon. The creation of 3D objects was a significant motivator and confidence builder for students. Future iterations of the program were to focus on identifying cultural knowledge bearers and community-based problems, structuring the program into advanced and beginner groups, and providing resources for home use.

Students frequently incorporated elements like beadwork, traditional dwellings, and personal stories into their spatial designs. The act of scanning and transforming cultural artifacts into interactive digital forms not only increased confidence but also reinforced identity. One afterschool educator shared, “They saw their designs in 3D and said, ‘This is who we are.’”

Visual Storytelling and STEM Identity Development: For our third research question, we investigated how visual storytelling impacted students' personal, social, and cultural worldviews concerning their STEM education and career interests. The hackathon encouraged students to think critically and creatively about redesigning afterschool STEM program spaces, incorporating factors like space utilization, accessibility, and usability. Virtual and augmented reality technologies allowed students to explore emerging technologies and their practical applications in design and engineering. Empathic design principles taught students a human-centered approach to problem-solving. We faced challenges in collecting pre-post data due to varied student attendance and the impact of COVID-19. Moving forward, we planned to include video introductions by Native American STEM professionals and a career narrative activity to inspire students to think about jobs and careers. Revising the curriculum to include direct career connections and affective components would help develop STEM identity and emphasize the role of STEM-educated youth in addressing issues important to tribal nations.

Hackathon reflections revealed that visual storytelling helped students connect STEM activities to real-life cultural narratives. Students spoke about presenting projects to family members and elders, indicating an expanded sense of audience. This public-sharing context helped foster deeper meaning and long-term motivation to pursue STEM paths.

Summary

Overall, our research highlighted the importance of place-based learning and culturally relevant pedagogy in enhancing STEM education and career interests among tribal students. The transformative potential of technology-rich learning environments and the value of visual storytelling were crucial components in this educational approach.

Conclusion

This study aimed to explore the integration of Place-Based Education (PBE), Culturally Relevant Teaching (CRT), and Problem-Based Learning (PBL) to enhance STEM education for Native American middle school students. By utilizing technologies such as Virtual and Augmented Reality (VR and AR), as well as 3D printing, the project sought to improve students' interest in STEM education through culturally responsive, problem-solving modules.

Our findings underscore the importance of co-designing educational modules with input from educators, community members, and students to ensure the curriculum is culturally relevant and responsive to local needs. The iterative Design-Based Research (DBR) methodology facilitated continuous refinement of the program, enhancing its effectiveness and contextual sensitivity. By integrating cultural narratives and leveraging local environments, the modules fostered a deeper connection between students and their heritage, making learning more engaging and meaningful. The study revealed that incorporating place-based and culturally relevant pedagogies significantly benefits STEM education in tribal communities. Native educators played a crucial role in adapting and delivering the curriculum, which included problem-based learning activities that integrated tribal origin stories and cultural practices. This approach not only increased student engagement but also helped develop essential skills in architectural visualization, 3D modeling, and design thinking. Despite challenges such as irregular attendance and COVID-19 disruptions, the program successfully implemented its modules, demonstrating the potential of combining PBE, CRT, and PBL with advanced technologies to create a transformative educational experience. The hackathons and other hands-on activities proved particularly effective in motivating students and building their confidence in STEM subjects.

Moving forward, the project will continue to evolve, with plans to involve more educators in professional development and expand student participation. Emphasizing career connections and incorporating video narratives from Native American STEM professionals will further inspire students and strengthen their STEM identity. This study highlights the transformative potential of a culturally responsive, place-based approach to STEM education, supported by innovative technologies. By honoring and integrating the cultural heritage of Native American students, educators can create more relevant, engaging, and effective learning experiences that foster a sense of identity and belonging, while also preparing students for future STEM careers.

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Reclaiming Relevance: Positioning Design and Technology at the Heart of a Whole-School Creativity Framework

Andrew Rockliffe, Office for Standards in Education (Ofsted), UK

Abstract
Design and Technology (D&T) in the UK is approaching a crisis point, with declining enrolment, staffing shortages and increasing marginalisation in the curriculum. However, this paper argues that D&T is not a problem to be solved. Rather, it is a solution to be scaled. Positioned at the intersection of material practice, iteration and design thinking, D&T is uniquely placed to lead a whole-school strategy for embedding creativity as a set of teachable, observable competencies, not as an abstract ideal. This paper introduces a structured Creative Competency Framework, drawing on cognitive science, classroom research and cross-curricular theory. It outlines 15 core and meta-competencies, from divergent thinking and sequencing to translational and meta-cognitive awareness. Moreover, the paper demonstrates how creative competencies can be mapped onto existing D&T projects to reveal and develop their creative potential. Using a bespoke AI-powered tool, the paper presents trial analyses of two contrasting projects to show how creative depth can be made visible, measurable and actionable. Ultimately, the paper proposes a new standard for assessing creativity that is not merely based on outcomes, but is rooted in the thinking processes embedded in a task. Finally, the paper issues a call to practitioners to contribute to the refinement of this tool, with the aim of developing a bank of high-performing, creativity-rich D&T projects for shared use. The result is both a defence and a reinvention of the subject, repositioning D&T as foundational to a future-facing, creative curriculum.

Keywords
Design and Technology Education, Creative Competency Framework, AI-Assisted Assessment, Curriculum Innovation, Creativity in Education, Cross-Curricular Pedagogy

Introduction
Design and Technology (D&T) education in the UK is facing an existential threat. Once a core part of the secondary curriculum, D&T has experienced a dramatic decline over the past decade. The number of qualified teachers has plummeted from over 15,000 in 2009 to just 6,300 in 2023, with forecasts suggesting that this number could fall below 4,500 within the next four years (Design and Technology Association, 2024). In addition, GCSE entries have reduced by 68% over the same period, and the subject missed its government recruitment target by 63% in 2023 alone (Cumiskey, 2024; The Guardian, 2024). There are now serious warnings that D&T may disappear entirely from the national curriculum unless decisive action is taken. In contrast, calls for the inclusion of creativity within education have never been louder. From curriculum reviews to employer demands, creativity is increasingly recognised as a critical competency for preparing young people to navigate an AI-driven,

rapidly changing world (Creative Industries PEC, 2024; Starmer, 2024). International policy discourse now regularly cites creativity, alongside problem-solving and collaboration, as a priority learning outcome for 21st-century learners (OECD, 2019; UNESCO, 2021). Despite these calls, creativity remains inconsistently embedded across the curriculum, often perceived as unteachable and rarely assessed with clarity or rigour (Craft, 2005; Lucas et al., 2013; OECD, 2019; UNESCO, 2021). Furthermore, in the absence of a shared pedagogical language or agreed markers of progress, opportunities for creative development and recognition can vary significantly between schools.

This paper argues that instead of D&T being treated as a curriculum casualty, it can be promoted as a strategic solution. Rooted in design thinking, iteration and real-world problem-solving, D&T provides a pedagogical model for embedding creativity as a teachable, observable set of skills (Razzouk & Shute, 2012; Kimbell, 2012; Holmes, Bialik & Fadel, 2019). Moreover, it is uniquely positioned to support cross-curricular collaboration, offering a framework that is inclusive, measurable and transferable. The paper presents a structured approach to teaching creativity, drawing on recent literature and classroom practice. By placing D&T at the centre of a whole-school creativity framework, this paper offers both a rationale for protecting the subject and a strategy for reinvigorating its role within a future-facing education system.

The Case for Creativity

Creativity is no longer simply a desirable enrichment activity, it is a core skill for a world defined by change, complexity and automation. Employers consistently rank creativity among the most valuable skills for future work, particularly in sectors where adaptability, problem-solving and innovation are essential (World Economic Forum, 2025; Nesta, 2018). In parallel, the growing influence of artificial intelligence (AI) has only heightened the need for human attributes that machines cannot replicate, such as empathy, imagination and non-linear thinking (Luckin et al., 2016; Holmes et al., 2019). Within education, the value of creativity extends beyond employability. It supports pupil well-being, cognitive flexibility and engagement. Creative thinking has been linked to improved executive functions, which underpins essential capabilities such as task management, self-regulation and collaboration (Luerssen, 2017; Pasarín-Lavín, 2023; Diamond, 2013). Rather than being luxuries, they are prerequisites for success across every subject. Despite these important ramifications, creativity is often misunderstood, inconsistently taught and rarely assessed. When it is addressed, it tends to be isolated within subjects such as art, music and drama, leaving subjects such as D&T to carry the burden of expectation without sufficient structural support (Harris, 2016; Lucas et al., 2013). This paper argues that D&T is not just one of the many creative subjects, it is uniquely placed to lead a new, integrated approach to teaching creativity as a set of observable, teachable and transferable skills.

Creative Competencies

Although creativity has long been recognised as a vital capacity in education (Craft, 2005; Lucas, Claxton, & Spencer, 2013), efforts to embed or assess it consistently have stalled due to a lack of clear frameworks, an agreed definition and practical assessment tools (Beghetto & Kaufman, 2007; OECD, 2019; UNESCO, 2021). One of the key reasons for this is the tendency to treat creativity as a singular entity, such as a trait that some pupils just ‘have’, or a vague disposition that defies planning and progression (Craft, 2005; Beghetto & Kaufman, 2007). This has left teachers with few tools for developing or measuring creative thinking in meaningful ways. By contrast, in subjects such as English, we routinely deconstruct complex competencies into structured learning pathways. For example, the ability to ‘write well’ is not treated as a single capability. Instead, it is broken into recognisable components, from phonics and spelling to grammar, sentence structure and tone, building towards more sophisticated meta-capacities such as voice, audience awareness and persuasive technique. Importantly, these components are explicitly taught, practised and assessed across years and key stages, providing rigorous progression and a shared pedagogical language that enables both teaching and accountability (Ofsted, 2022; Alexander, 2010).

This paper argues that creativity must be treated in the same way as the core subjects, as a structured, teachable process composed of interrelated core and meta-competencies. Only then can D&T be taken seriously as a cross-curricular priority and claim its rightful place as the pedagogical centre of that process. It is important to make the distinction that we do not teach English with the expectation that every learner will become a novelist or win a Pulitzer Prize. The purpose of teaching English is to develop a literate population, one that can communicate, interpret and construct meaning across all aspects of life and work. Although excellence can result, the goal is capability, not celebrity. The same principle must apply to creativity. It should not be reserved for the exceptionally gifted or treated as an optional enrichment activity. Instead, creativity must be recognised as a foundational capacity that, like literacy, is built from teachable, transferable components and integrated across the curriculum.

Much of the confusion in creativity research arises from outcome-based classifications such as ‘originality’ and ‘utility’, or the popular ‘Big-C/small-c’ distinction. However, these frameworks are often based on retrospective judgments rather than observable processes. For example, the invention of the transistor was initially seen as a minor innovation with limited use, yet it has become one of the most transformative technologies of our era. If creative value can shift so dramatically over time, then such classifications cannot offer a reliable basis for assessment. At this juncture, it is important to clarify what is meant by creativity, the definition of which remains contested across the literature (e.g., Craft, 2005; Runco and Jaeger, 2012). One reason for this definitional disparity is that creativity is usually inferred from the outcome, through asking the question ‘what is a creative product?’ rather than ‘what is creative thinking?’ In most curriculum subjects, disciplinary identity is derived from cognitive processes, not from outcomes. For example, mathematics is defined as ‘the study of numbers, shapes, and space using reason and usually a special system of symbols and rules’ (Cambridge Dictionary, 2024). Moreover, the solution to a mathematical problem is not mathematics itself, in the same way that getting the right ‘answer’ does not make someone a mathematician. Similarly, creativity should not be assessed by outcome alone. Instead, it should be understood as a structured, internalised process involving thought mechanisms such as abstraction, dual-perspective reasoning and narrative switching (Rockliffe and McKay, 2023). This reframing shifts the focus from evaluating products to recognising the thinking processes that generate them. Crucially, assessing creativity based solely on outcomes privileges those who are already confident, skilled or well-resourced enough to produce polished work, while overlooking others whose thinking may be deeply original but less visibly refined. This is not just pedagogically limited, it is inequitable and reduces creativity to performance rather than recognising it as a way of thinking that can be taught, observed and nurtured. Accordingly, in this paper, creativity is simply defined as a fluid and dynamic cognitive system that promotes the generation of alternative perspectives and inferences.

The framework presented in this paper reframes creativity as a structured, teachable set of cognitive and behavioural capacities, not as a mysterious talent. While creative insight may appear spontaneous, it is often underpinned by invisible mechanisms, such as abstraction, sequencing and narrative switching, which can be observed, developed and supported in educational settings (Lucas & Spencer, 2017). Teaching these competencies does not guarantee exceptional outcomes on demand, but it strengthens the underlying conditions in which creative thinking can flourish. Beyond creative performance, these capacities have broader educational value. Research suggests that the ability to think creatively supports emotional regulation, empathy, mental health and meaning-making (OECD, 2019; UNESCO, 2021; Kaufman, 2016). As learners build confidence in navigating ambiguity and generating ideas, they also develop resilience and agency, which are skills that are increasingly recognised as essential in contemporary curriculum frameworks. What is needed now is a clear framework for embedding creativity meaningfully within curriculums, pedagogy and assessment, not simply a renewed focus on creativity. D&T offers a ready-made environment in which creativity is not simply abstract. Instead, it is enacted through iteration, prototyping and problem-solving. Accordingly, D&T provides both the rationale and the mechanism for rethinking how creativity is taught and understood across education.

Origins of and Rationale for the Framework

The competencies presented in this framework were developed through a combination of classroom practice, cognitive theory and thematic analysis of creativity literature across education and design disciplines. Rather than adopting an existing taxonomy wholesale, the framework draws selectively from widely recognised cognitive models (such as divergent thinking and pattern recognition), embodied learning theory (Wilson, 2002; Shapiro, 2011) and studies on design-based education (Kimbell, 2012; Razzouk & Shute, 2012). Moreover, the framework is also a direct response to the under-theorised yet observable creative behaviours present in D&T classrooms. Recent studies (e.g., Rockliffe & McKay, 2023) have been central to establishing the theoretical foundation for this approach. In their earlier work, Rockliffe and McKay argue that creativity must be understood as a system of dynamic, interacting processes rather than a singular disposition. This perspective reinforces the need to reconceptualise creativity as a structured, developmental system of behaviours that can be observed, taught, and applied to purposeful outcomes rather than as a free-floating ideal.

The distinction between core and meta-competencies emerged from viewing creativity as a teachable system composed of interlinked behaviours. This framing was refined through iterative practitioner research led by the author, involving classroom design, project testing and ongoing reflection over multiple years of teaching practice. The 10 core competencies represent discrete, teachable cognitive behaviours that can be embedded, observed and practised. In contrast, the 5 meta-competencies are higher-order behaviours that emerge from the integration of multiple core competencies, often in response to complexity, challenge or creative disruption. It should be noted that the goal was not to create an exhaustive taxonomy. Rather, it was to develop a usable, classroom-focused model that supports curriculum planning, learner reflection and ultimately, assessment.

The Framework

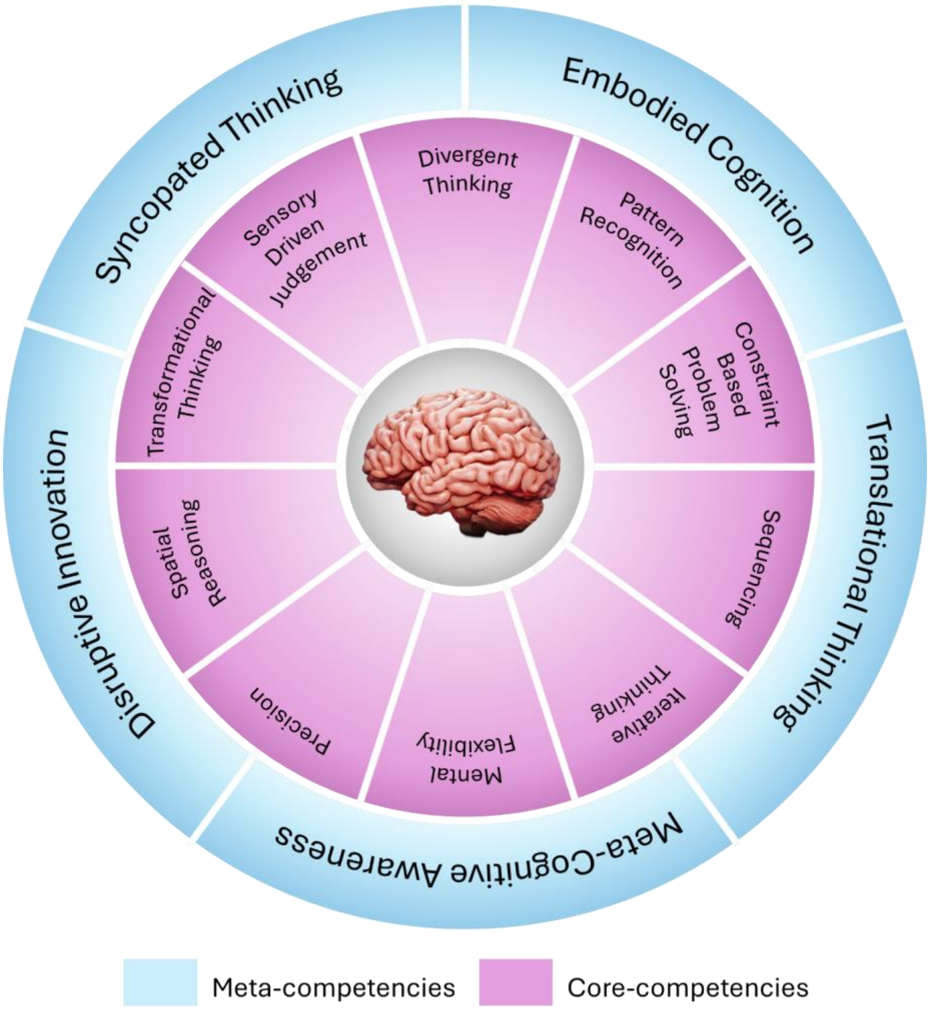

Figure 1. Creativity competency framework ('competency wheel') displaying the 10 core competencies and 5 meta-competencies

The Creative Competency Framework introduced in this paper (Figure 1) is the result of an interdisciplinary synthesis, drawing from cognitive science, design education and practitioner insight. It builds on established research into divergent thinking and problem-solving (Guilford, 1967; Runco & Acar, 2012), embodied cognition (Wilson, 2002; Shapiro, 2011) and design-based pedagogies (Kimbell, 2012; Razzouk & Shute, 2012). In particular, the framework reflects the view that creativity is not simply a singular disposition. Instead, it is considered a structured, functional process composed of interrelated behaviours that can be explicitly taught, practised and assessed. The competency wheel in Figure 1 visually represents the Creative Competency Framework developed through this research. While 'framework' refers to the structured set of interrelated skills and capacities, the wheel serves as its conceptual and practical model, offering both a taxonomic overview and a pedagogical tool.

This framework does not contradict the insights of earlier research into creative dualities, which describe inflection points (such as dual meanings or interpretations) that can form the basis of a new narrative (Rockliffe & McKay, 2023), it completes them. The competency wheel provides the underlying structure of the 'creative playground' where those dualities emerge. While earlier work observed the manifestations of creative thinking, such as the tension between logic and disruption or the ability to construct alternative narratives, it lacked a mechanism to explain how such thinking is activated and sustained. The current model fills that gap. In other words, the competencies are not endpoints, they are the cognitive and behavioural building blocks that enable flexible, dual-perspective thinking. Accordingly, the wheel can be perceived both as a set of skills and a cognitive ecosystem, in which complexity, ambiguity and innovation become both visible and teachable. Similarly, what earlier work described as 'creative logic' (Rockliffe & McKay, 2023), which is a mode of thinking that is structured yet non-linear, internally coherent yet often counterintuitive, finds form here in the competency framework. Rather than treating creative leaps as irrational or serendipitous, this model reveals the underlying structures that enable such leaps. It shows that creativity is not the absence of logic, but the application of a different type of logic that is built on flexibility, pattern recognition, abstraction and transformation. In this sense, the competency wheel can be read both as a taxonomy of skills and a map of the logical architecture of creative thought.

Core Creative Competencies

The framework presented in this paper draws on 25 years of Design and Technology (D&T) teaching experience, including 15 years in departmental leadership roles. While the author is no longer an active classroom practitioner, the framework's foundations lie in extensive practitioner research, developed over more than a decade through the design, delivery and refinement of curriculum projects. These were informed by emerging theory, tested across multiple cohorts and shaped by sustained reflection, peer discussion and professional judgement. The framework is also aligned with current cognitive science and creativity literature, allowing it to serve as both a retrospective synthesis and a future-facing tool. While not a formal empirical study, the framework represents a synthesis of lived pedagogical experience, supported by contemporary research and validated through reflective practice.

The core competencies were selected based on their frequency and visibility within successful creative tasks across multiple domains, especially within D&T. Each competency represents a discrete cognitive or behavioural process that can be taught, observed and practised within classroom projects. It should be noted that the aim was not to replicate existing creativity taxonomies. Rather, it was to develop a classroom-facing model that is both rigorous and practically useful for teachers (Lucas & Spencer, 2017; Craft, 2005; Treffinger et al., 2002).

- Divergent Thinking: The ability to generate multiple ideas, approaches or solutions to a problem (Runco & Acar, 2012).
- Pattern Recognition: The skill of identifying underlying structures, trends or relationships in information, materials or systems (Gabora, 2019).
- Sequencing: The capacity to organise steps, actions or information into a logical and functional order (Diamond, 2013). While related to pattern recognition, sequencing is active and generative. It involves constructing a logical or functional order, rather than identifying patterns that already exist.
- Iterative Thinking: The process of refining ideas or solutions through repeated testing, feedback and revision (Kolodner, 2002).
- Mental Flexibility: The ability to adapt thinking, shift strategies or consider alternatives when conditions change (Diamond, 2013).
- Precision: The skill of executing actions or decisions with care, control and accuracy (Kimbell, 2012).
- Spatial Reasoning: The mental ability to visualise and manipulate objects in three dimensions (3D) (Newcombe & Frick, 2010).
- Transformational Thinking: The conceptual skill of understanding how one thing can become another, such as from sketch to product or from flat sheet to 3D form (Razzouk & Shute, 2012; Kimbell, 2012). This differs from translational thinking, which focuses on changing the format or medium. Transformational thinking involves a deeper shift by reimagining the identity, function or state of an idea or object.
- Constraint-Based Problem Solving: The ability to generate solutions within given limits, such as time, materials, functionality or safety (Lawson, 2006).
- Sensory-Driven Judgement: Using tactile, visual and kinaesthetic feedback to guide decision-making (Shapiro, 2011; Wilson, 2002).

Meta-Competencies

The meta-competencies were derived by analysing instances in which multiple core competencies consistently co-activated during complex or novel creative tasks. This interpretive approach aligns with recent work identifying meta-competences as emergent outcomes of interrelated cognitive, process and social capacities in learning environments (Sotiriou et al., 2024). These higher-order behaviours often emerge when learners confront ambiguity, shift between modalities or subvert expectations (Sawyer, 2012). Rather than functioning as separate skills, meta-competencies signal integrative creative thinking, which is the type required for innovation, adaptability and reflective problem-solving (Beghetto & Kaufman, 2007; Gabora, 2019). Their inclusion ensures that the framework accounts for both foundational skills and the complex behaviours that arise from their combination.

- Syncopated Thinking: Deliberately disrupting expected patterns or rhythms to provoke new ideas or responses. Although 'syncopated thinking' is not a widely established term, it is introduced here to distinguish a specific form of creative disruption from more general divergent thinking. While both involve novelty, syncopated thinking is marked by cognitive surprise, which is a purposeful break from expectation designed to provoke alternative perspectives. This framing aligns with theoretical models that highlight the role of unpredictability, reframing and expectation violation in creative ideation (Boden, 2004; Kaufman, 2016).

- Embodied Cognition: Thinking through physical interaction, meaning when doing becomes a form of knowing (Wilson, 2002; Shapiro, 2011).
- Translational Thinking: Moving ideas across forms, such as from sketch to prototype or from verbal concept to material outcome (Shapiro, 2011; Wilson, 2002; Kimbell, 2012).
- Meta-Cognitive Awareness: Reflecting on one's own process and adjusting strategies consciously (Diamond, 2013; OECD, 2019; Lucas et al., 2013). Although iterative thinking also involves cycles of refinement, meta-cognitive awareness is distinct in that it centres on reflection and self-regulation by thinking about one's own thinking to improve future learning.
- Disruptive Innovation: Intentionally bending or breaking rules to challenge norms and invent new pathways (Kaufman, 2016; Boden, 2004). Unlike constraint-based problem solving, which thrives within set limits, disruptive innovation questions or transcends those limits, offering radically new approaches that can upend conventional solutions.

While the term syncopated thinking is original to this framework, it aligns closely in function with the concept of originality found in established creativity assessments, such as the Torrance Tests of Creative Thinking (Torrance, 1974) and the PISA Creative Thinking Framework (OECD, 2021). However, unlike 'originality', which is typically judged as a subjective feature of the output, syncopated thinking is framed as a cognitive behaviour. In other words, something that can be observed, scaffolded and taught. This behavioural framing offers greater pedagogical clarity, enabling teachers to recognise and foster this form of unexpected or disruptive thinking in varied classroom contexts. As mentioned previously, the meta-competencies were derived from combinations of the core competencies, as displayed in Figure 2. These combinations were established through reflective analysis of classroom projects and task design over multiple years of practice. Particular attention was paid to moments of cognitive challenge or breakthrough, where multiple core behaviours appeared to co-occur (such as iteration and constraint-based problem solving), resulting in disruptive innovation. These co-activations were repeatedly observed and triangulated with existing theory on creative cognition (Sawyer, 2012; Gabora, 2019).

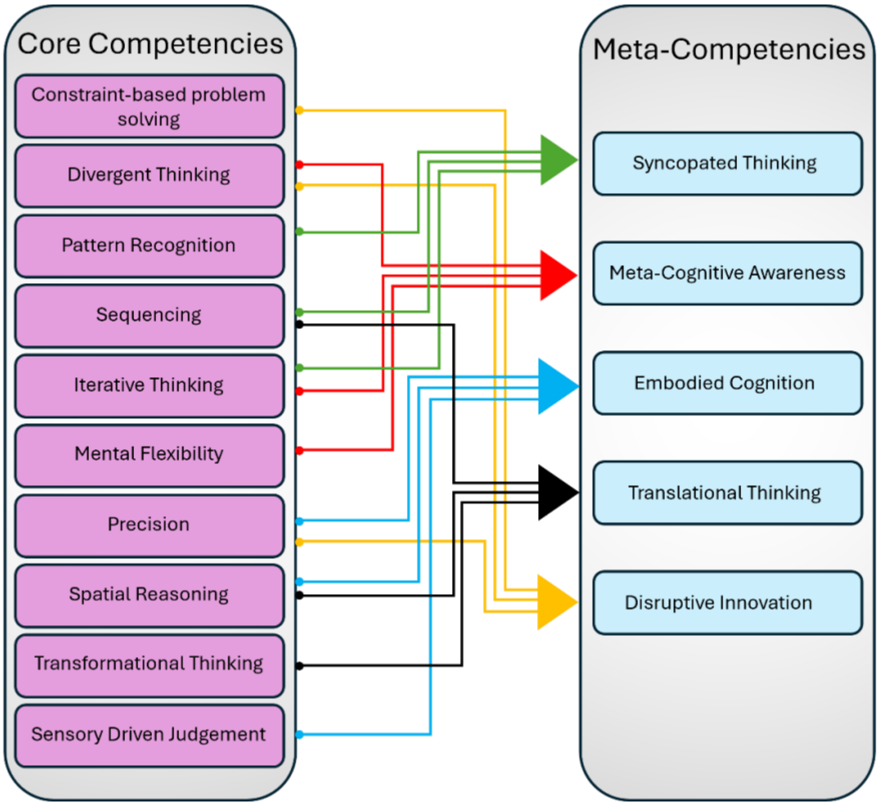

Figure 2. Mapping between the core competencies and the meta-competencies

Within the competency wheel, four competencies (iterative thinking, sensory-driven judgement, precision, and spatial reasoning) have particularly strong alignment with D&T practice. These capacities are rarely foregrounded in other subjects, yet they are core to the iterative, material-based and hands-on nature of D&T (Kimbell, 2012; Barlex & Trebell, 2008). Their prominence within the framework strengthens the case for D&T as a uniquely fertile environment for cultivating creative capacities, particularly those that are underrepresented or undervalued in more abstract or linguistically driven domains. In this way, the framework does not simply include D&T as one vehicle for creativity, it positions the subject as structurally central to its development and delivery.

Although this framework is applied here within the context of D&T, the creative competencies it maps are relevant across the entire curriculum. All subjects have a role to play in nurturing creativity. In particular, subjects such as mathematics (through pattern recognition, problem-solving, and abstraction) and English (through narrative construction, language play, metaphors and reflective thinking) offer rich opportunities to develop core and meta-level creative competencies (Beghetto, 2010; Craft, 2005). Embedding this framework within a whole-school approach to creative learning encourages consistency, coherence and collaboration, helping students to recognise, transfer and build on their creative capabilities across subject boundaries. While the framework provides a conceptual structure for understanding and supporting creativity, the next challenge lies in making it practical and scalable. Accordingly, the following section introduces an AI-assisted mapping tool that was developed using this framework. The tool allows teachers to analyse and evaluate creative competency coverage within any D&T project. In addition, it provides structured feedback that supports planning, reflection and whole-school alignment.

Introducing the Assessment Model: Purpose and Need

Despite the longstanding emphasis on creativity as a core educational aim, its assessment has remained inconsistent, informal and often anecdotal, particularly within D&T. While D&T is widely recognised as a site of creative activity, the absence of a structured model for evaluating creativity has undermined both its credibility and its curricular standing. The creative competency assessment model presented in this section addresses this gap directly. The model is built on the competency framework outlined previously and provides a systematic way of analysing how well any given D&T project activates the identified core and meta-competencies. The model focuses on identifying the creative processes embedded within the task itself. This shift enables teachers to assess the opportunities for creative thinking within a project.

The model serves several functions. At the classroom level, it helps teachers in designing, refining and reflecting on project-based learning. It also offers targeted feedback on where projects are strong, where they could be expanded and how they align with wider creativity goals. In this sense, it operates both as a development tool and as a professional dialogue aid, helping teachers to articulate the creative value of their practice in structured terms. At a wider level, the model also creates the conditions for a new, and long overdue, form of subject rigour. By identifying high-performing projects (i.e., those that score strongly across a range of creative competencies), a bank of benchmark tasks can be developed. These ‘standard projects’ would operate in a similar way to core texts in English or agreed case studies in History. For the first time, D&T would be able to present and promote a creativity model that is both defensible and scalable. Finally, by making creative demand visible, the model offers a pathway towards equity. Based on years of professional experience, it is evident that many D&T teachers already possess effective, instinctively strong projects that have remained undervalued because they do not easily fit into assessment rubrics or documentation frameworks. This tool gives them the language and structure to revalidate those projects and contribute to a broader, collective effort to define creativity on the subject’s own terms.

Training AI for Our Needs: Introducing Creativity-Focused Automation

As the pressure for measurable outcomes increases across all areas of education, the challenge of assessing creativity remains particularly acute. Traditional assessment systems struggle to capture the nuanced, often non-linear thinking that underpins creative work (Craft, 2005; Lucas et al., 2013). This is particularly true in subjects such as D&T, where outcomes are shaped by material constraints, iterative experimentation and hands-on processes (Kimbell, 2012; Hennessy & Murphy, 1999). To address this challenge, an AI-assisted assessment model capable of interpreting D&T project descriptions through the lens of the creative competency framework was developed and tested, as outlined in the ‘Model Development and Testing’ section. Unlike commercial AI tools that are designed to grade essays or generate feedback, this system does not impose external rubrics or generic scoring criteria. Instead, it has been specifically trained to work within a bespoke, teacher-authored framework that reflects the actual competencies involved in classroom creativity

(Luckin et al., 2016; Holmes et al., 2019). The model is designed to assess projects (not pupils) and map how well a task is likely to activate and support the development of specific creative competencies. In this way, AI is not a simple evaluator of performance. Instead, it is leveraged as a partner in curriculum planning, project development and pedagogical reflection.

At the heart of this approach is the principle that AI should be shaped by the values, priorities and domain-specific knowledge of teachers themselves, a model of human-in-the-loop co-design that is gaining increasing traction in educational technology (Selwyn, 2019; Rose Luckin, 2018). Moreover, the model is not preloaded with assumptions about what creativity 'looks like'. Instead, it interprets teacher-written project descriptions against an agreed framework that is rooted in cognitive science, design theory and professional classroom practice (Sawyer, 2012; Shapiro, 2011). This ensures alignment between pedagogical goals and automated output and enables a level of precision that general-purpose tools cannot achieve. Ultimately, the broader aim of this work is to reduce workload and increase access to expert thinking, not to replace human judgement. By training AI to perform the repetitive, logic-based analysis of creative project structures, teachers are freed to focus on the subtleties of context, engagement, delivery and differentiation. In other words, the tool becomes a mirror that reflects back the embedded creative value in a task and helps to identify areas for extension or refinement. The following section presents a brief account of how the model was developed, tested and refined, and how it can be used to support both project-level planning and wider efforts to standardise high-quality creative experiences across schools.

Model Development and Testing

The model was developed through an iterative design process, refined through repeated testing against a sample set of anonymised D&T project descriptions using the creative competency framework as the evaluation lens. Each cycle involved reviewing outputs for alignment with expected competency patterns and adjusting the tagging logic accordingly. While exploratory, this approach demonstrated the practical viability of using the framework to guide automated analysis of project work. The assessment tool was developed using OpenAI's GPT-based large language model, guided by a custom prompt structure and the identified competencies. The model was trained to interpret plain-language project descriptions and then map them against the set of 15 creative competencies (10 core and 5 meta) defined earlier in this paper. The tool was initially calibrated using a sample set of D&T projects. The second exemplar project was analysed in two phases: first with an unstructured description, and again after revision to surface more embedded competencies. This allowed for the adjustment of both the AI prompt structure and teacher guidance materials.

The assessment output was designed to include the following:

- A mapped rating of each creative competency (✅ / ➖ / ❌)
- A percentage-based coverage score
- Commentary on missed opportunities or underdeveloped areas
- Suggestions for enhancing project design

To maintain alignment with the competency framework, the model does not evaluate student outcomes. It assesses the creative affordances embedded in the project structure itself, rendering it a planning and reflection tool, rather than a grading mechanism.

Ongoing testing focused on three key performance indicators:

1. Accuracy: Are core competencies correctly detected when clearly present?
2. Sensitivity: Can the model recognise nuanced or implicit creative behaviours?
3. Consistency: Does the same project yield repeatable outputs under similar conditions?

These iterations established the model's reliability as a teacher-facing design tool, ready to support both reflective practice and standardised project development. Moreover, it represents a working example of how domain-specific frameworks and AI can be aligned to produce high-level educational tools. The completed prompt (tool) ready for insertion in ChatGPT is as follows:

> You are an educational assistant trained to analyse Design & Technology (D&T) projects for creative competency coverage.
> There are 15 creative competencies in total: 10 core and 5 meta. Each is rated as:
> ✅ = Strongly Present (1 pt)
> ➖ = Partially Present (0.5 pt)
> ❌ = Not Evident (0 pt)
> Interpret competencies as follows:
> - Use ✅ only when the competency is clearly and intentionally supported.
> - Use ➖ if the behaviour is implied, somewhat supported, or likely present but not central.
> - Use ❌ when the competency is not present or relevant.
> - If student behaviours like revision, reflection, or design choice are described informally, consider awarding ➖.
> Return a full mapping and a total score out of 15.
> Start with: **Core Competency Mapping: X%**
> Then present a 4-column table with:
> [Number/Letter] | [Competency Name] | [Rating] | [Notes]
> Follow with a short summary and suggestions for enhancement.
> End your response here. Do not include follow-up offers, extensions, or additional questions.
> Follow with a short summary and suggestions for enhancement.
> After your final suggestion, include this footer exactly as written:
> "© Rockliffe 2025 | Creative Competency Mapping Tool v1.0"
> The 15 competencies are:
> 1 Divergent Thinking – generating multiple ideas or solutions
> 2 Pattern Recognition – recognising patterns, structures, or relationships
> 3 Sequencing – following or creating logical order
> 4 Iterative Thinking – revising or refining based on testing or feedback

5 Mental Flexibility – adapting to changes or new challenges
6 Precision – accurate measuring, cutting, assembly
7 Spatial Reasoning – visualising and manipulating in 3D
8 Transformational Thinking – turning ideas from one form into another (e.g., sketch → model)
9 Constraint-Based Problem Solving – working within limits (materials, time, function)
10 Sensory-Driven Judgement – using tactile or visual feedback in making decisions
a Syncopated Thinking – disrupting patterns or norms to provoke new ideas
b Embodied Cognition – thinking through physical doing and making
c Translational Thinking – shifting ideas across modes (words ↔ images ↔ materials)
d Meta-Cognitive Awareness – reflecting on and managing one's own process
e Disruptive Innovation – breaking rules or conventions to challenge assumptions
Please upload your project description to begin.

User notes: For optimal consistency and accuracy, the AI tool was developed and tested using GPT-4. Teachers using free-tier or earlier versions may experience variation in output quality. Where possible, use GPT-4 or an equivalent model when applying the mapping tool to ensure alignment with the framework. The text is only supplied in a reduced font size to ease cutting and pasting (ChatGPT can equally understand any sized font). Functionally, it is better to copy the complete prompt into a word document, then simply upload it to ChatGPT using the inbuilt 'Add photos and files' feature. Finally, ChatGPT defaults to American English conventions, including the use of the Oxford comma, which appears in the prompt for consistency and clarity.

Practical Implementation of Creative Competency Mapping Tool

To evaluate the practical application of the creative competency mapping tool, two D&T projects were selected: a simplistic Birdhouse and a highly structured and intentionally layered project (Jacob's Ladder). These examples serve as a proof of concept, demonstrating how the model responds to real-world classroom tasks and how the visibility of the creative process, not just the product, affects assessment outcomes. What follows is a comparative analysis based on the tool's mapping output.

Project 1. 'Birdhouse'

Description for the mapping tool:

'This project involves students designing and constructing a birdhouse using basic hand tools. They must measure, cut, and assemble parts, then test the design to ensure weather protection and entry points for specific bird types.'

Mapping tool results for Project 1:

Core Competency Mapping: 60%

#	Competency Name	Rating	Notes
1	Divergent Thinking		Some idea generation is implied in design decisions for entry types.

#	Competency Name	Rating	Notes
2	Pattern Recognition	✗	No evidence of recognizing patterns or relationships.
3	Sequencing	✓	Clear procedural order in measuring, cutting, assembling.
4	Iterative Thinking	–	Testing for weather protection implies some revision.
5	Mental Flexibility	✗	No explicit adaptation to challenges mentioned.
6	Precision	✓	Accurate measuring and cutting are central.
7	Spatial Reasoning	✓	3D visualization and construction are required.
8	Transformational Thinking	✗	No mention of transforming concepts across media or forms.
9	Constraint-Based Problem Solving	✓	Design must meet constraints (tools, materials, bird type, weather).
10	Sensory-Driven Judgement	–	Possibly present in assembly or finishing but not explicitly stated.
a	Syncopated Thinking	✗	No disruption of norms or creative provocation indicated.
b	Embodied Cognition	✓	Physical making and tool use strongly support this.
c	Translational Thinking	✗	No shifting across representational forms described.
d	Meta-Cognitive Awareness	✗	No mention of reflection or process management.
e	Disruptive Innovation	✗	Traditional project with no rule-breaking or new approaches.

Total Score: 9 / 15

Summary and Suggestions for Enhancement:

This birdhouse project supports fundamental D&T skills, particularly in precision, spatial reasoning, sequencing, and constraint-based problem-solving. It also incorporates some iterative and sensory-driven thinking, though these are not explicitly emphasized.

To strengthen creative competency coverage:

- Add a brainstorming phase to broaden Divergent Thinking.
- Encourage Meta-Cognitive Awareness through journaling or process logs.
- Include sketching or prototyping to support Translational and Transformational Thinking.
- Pose open-ended design challenges to foster Syncopated or Disruptive Innovation.

Project 2. 'Jacob's ladder'

Description for the mapping tool:

This project involves pupils constructing a working version of a Jacob's Ladder, which is a kinetic, cascading toy made from six interlinked wooden blocks and 15 strips of cotton tape. The activity is completed in two distinct phases: material preparation and final assembly.

Introduction and Demonstration: The teacher begins by demonstrating the Jacob's Ladder's movement and explaining its mechanics. Pupils are shown the coin trick (but not how it works), sparking curiosity. They are encouraged to research independently or deduce the trick's logic.

Phase 1: Material Preparation

Pupils will:

- Accurately mark, cut, and finish six identical timber blocks.
- Measure and attach cotton tape in a fixed pattern using PVA adhesive.
- Compare textures and effectiveness of adhesive bonding.
- Record tactile feedback and visual observations of tape placement.

Phase 2: Final Assembly (3D Puzzle Challenge)

Before any instruction, pupils are challenged to assemble the prepared tape-adhered blocks based on observation. Most will attempt linear arrangements, others may intuit the tower structure.

Then:

- A teacher demonstration shows the final sequence without verbal instruction.
- Pupils replicate the 3D manipulations based on visual cues.
- Errors in folding or alignment lead to a feedback-revision cycle before the glue sets.
- Pupils are encouraged to test variants and discuss changes that improved function or movement.

Exploration, Disruption & Reflection

Once built:

- Pupils revisit the coin trick and attempt to explain it.
- Small groups brainstorm alternative uses, display ideas or new tricks.
- Pupils choose one of the following challenges:
    - Modify the toy to perform a new unexpected function.
    - Design a variant that changes how the pattern operates.
    - Translate their process into a comic strip, video, or storyboard.

End-of-project meta-cognitive prompts:

- 'What surprised you during this project?'

- 'How did your approach 'shift' after encountering difficulties?'
- 'What did your hands learn that your head didn't know at first?'

Mapping tool results for Project 2:
Core Competency Mapping: 90%

# / Letter	Competency Name	Rating	Notes
1	Divergent Thinking	✅	Pupils brainstorm new functions and display ideas, encouraging multiple solutions.
2	Pattern Recognition	✅	Recognising and interpreting the tape layout and Jacob's Ladder mechanics.
3	Sequencing	✅	Clear emphasis on ordered steps in marking, cutting, and assembly.
4	Iterative Thinking	✅	Feedback-revision loop during final assembly; reflective writing after tape application.
5	Mental Flexibility	✅	Encouraged to shift strategies during assembly and trick analysis.
6	Precision	✅	Accurate measuring and cutting required; adhesive placement noted.
7	Spatial Reasoning	✅	Solving a 3D puzzle based on visual cues alone.
8	Transformational Thinking	✅	Translating visual instructions into functional assemblies.
9	Constraint-Based Problem Solving	✅	Limited materials and sequence structure; working within tight parameters.
10	Sensory-Driven Judgement	➖	Tactile feedback noted but not central to decision-making.
a	Syncopated Thinking	✅	Encouraged to disrupt expected patterns and invent variations.
b	Embodied Cognition	✅	Physical manipulation essential to problem-solving.
c	Translational Thinking	✅	Translation of process into comics, video, or storyboards.
d	Meta-Cognitive Awareness	✅	Strong reflective prompts and mini reflection task.
e	Disruptive Innovation	➖	Some elements (e.g., trick modification) push toward innovation, though not deeply explored.

Summary and Suggestions for Enhancement

This project robustly supports a wide spectrum of creative competencies, especially in core domains like sequencing, iterative thinking, and spatial reasoning. The integration of visual, tactile, and reflective strategies demonstrates a strong design for nurturing creative fluency.

To enhance further:

- Increase emphasis on Sensory-Driven Judgement by integrating more activities where students make design choices based on tactile or visual feedback (e.g., choosing tape types or wood textures).
- Deepen Disruptive Innovation by formally prompting students to identify and challenge a convention of the toy or its operation in more radical ways.

Comparative Analysis of Project Results

The contrast between the Birdhouse and Jacob's Ladder projects provides a clear demonstration of how the creative competency framework distinguishes between surface-level engagement and deeper creative opportunity. While both projects involve making, measuring and construction, and could be seen as equivalent in traditional D&T assessment models, their competency profiles tell a different story. The Birdhouse project scored well on technical and spatial competencies but lacked iterative challenge, reflection and cognitive flexibility. In contrast, the Jacob's Ladder project engaged a far broader spectrum of core and meta-competencies, including embodied cognition, transformational thinking and syncopated reasoning. This divergence was not due to student outcomes or subjective quality. Rather, it was engendered through differences in task structure, cognitive demand and embedded learning opportunities. The comparison illustrates that creativity can be planned for and scaffolded, not simply left to chance. Moreover, it is evident that even modest shifts in project design can significantly enhance a task's creative potential.

The high score for the Jacob's Ladder (Figure 3) project suggests that it would be a worthy candidate for addition to the standard projects. This project has been used extensively across a wide range of educational settings, consistently delivering high levels of engagement, practical skill development and inclusive success. However, under the current curriculum framing, it has often been seen as a 'skills unit' that is primarily valued for its focus on hand tool use (e.g., accurate sawing and assembly) rather than as a site for creativity or design thinking. Questions such as 'Where is the design element?' or 'Where is the creativity?' have resulted in its marginalisation within schemes of work focused on externally justifiable outcomes.

Figure 3. Jacob's Ladder manufactured by a Year 7 pupil

However, when viewed through the lens of the creative competency framework, the true value of the Jacob's Ladder project became clear. It draws upon a wide range of core and meta-cognitive behaviours, including sequencing, spatial reasoning, precision, embodied cognition and transformational thinking. In addition, it allows for diverse learners to experience success in ways that are often inaccessible in more abstract design tasks. Importantly, it also serves as a powerful example of how many D&T teachers already possess a bank of effective, well-loved projects that may not align neatly with current documentation, but which their professional experience tells them 'work'. This framework provides a means of revisiting and revalidating those projects, not by reworking them entirely, but by recognising the cognitive and creative value already embedded within them. In doing so, it offers teachers both the language and structure needed to reposition their best practice within a creativity-led curriculum.

This tool is part of an ongoing developmental study aimed at mapping creative competencies in D&T education. While it currently focuses on 15 core and meta competencies, its structure is intentionally open to refinement. Future versions may expand to incorporate:

- D&T-specific competencies, such as technical fluency, material awareness and design communication
- Nuanced capabilities, including performance, audience engagement and emotional affect. This would be particularly relevant to tasks involving surprise, storytelling or physical demonstration
- Wider learning dimensions, such as collaborative dynamics, iterative design culture and learner agency

These additions would allow the tool to increase the creative richness of D&T classrooms more fully. However, despite these potential enhancements, further testing and analysis is required before incorporating them into the model. This ensures that any refinements are evidence-based and aligned with authentic teaching practice. These examples demonstrate the tool's capacity to differentiate between projects based on the creative processes they embed, not on their outcomes. By making invisible thinking visible, the model empowers teachers to critically assess and elevate their practice. It also affirms that creative depth can be built into even the simplest of projects, and that many such projects already exist within teachers' repertoires. What is now needed is broader classroom testing, refinement based on teacher feedback and the development of a shared bank of creativity-rich, high-competency projects. Through these steps, D&T can become a national exemplar of how creativity can be taught, measured and embedded with clarity and rigour.

Postscript: Contributing to an Emerging Catalogue

This paper introduces a proposed framework for embedding creativity across the curriculum, with D&T positioned as a core site for its delivery. The creative competency mapping tool is presented here as a prototype, a structured but adaptable means of evaluating how D&T projects develop creative thinking in pupils. At this stage, the framework is not formally validated and should be viewed as part of an ongoing research process. As such, the author would like to invite fellow D&T practitioners to explore the tool in their own contexts. If you are willing, I would be very interested to receive feedback on its clarity, relevance or usefulness, particularly in relation to how it supports curriculum planning or cross-curricular dialogue. If you choose to map one of your existing projects and it performs well, especially if it appears to match or exceed the creative depth demonstrated in the Jacob's Ladder benchmark project, I would be delighted to hear from you. With permission, I hope to begin developing a catalogue of projects that may inform future proposals for standardised, creativity-rich D&T tasks across Years 7, 8, and 9. If you would like to contribute, please send your mapped results, a short summary of your project or any feedback to: [dtmappingtoolsubmissions@gmail.com].

Future Directions: Towards Assessment, Automation, and Accountability

While this paper has focused on defining and testing a framework for embedding and mapping creative competencies within D&T, the next stage in this research must involve the development of a corresponding assessment framework. If creativity is to be treated with the same seriousness as literacy or numeracy, it must be supported by structured, reliable and scalable forms of evaluation. Current approaches to assessing creativity, such as the Torrance Tests of Creative Thinking (TTCT), or frameworks developed by OECD (2019) and Lucas, Claxton, and Spencer (2013), offer useful conceptual groundwork but often remain either too abstract for practical classroom use or too reductive to capture real creative process. What remains missing is a model that links assessment to what actually happens in the classroom, in terms of observable behaviours, transferable processes and curriculum-embedded tasks. Therefore, future research should explore how each of the identified core and meta-competencies in this framework can be assessed both formatively and summatively, using a combination of qualitative and quantitative indicators. This may include the development of observation rubrics, student self-assessment tools, peer review protocols and performance-based measures that are aligned with the cognitive and embodied realities of D&T. Crucially, any such framework must balance rigour with flexibility, ensuring that assessment supports rather than constrains creativity.

In parallel with this, the work presented here opens up the potential for the development of AI-assisted tools that can significantly reduce teacher workload. By automating aspects of competency mapping, generating structured feedback and offering project-level analysis, these tools could embed creativity-focused assessment into daily practice without adding to planning or marking demands. This dual pathway of grounded frameworks alongside intelligent automation represents a vital step in making the development of creativity both meaningful and manageable for educators. Importantly, this paper also serves as a practical demonstration that creativity can be assessed without reducing it to product quality, artistic flair or subjective aesthetic judgement. Instead, it uses project mapping through a structured competency framework to show how identifying the cognitive and behavioural processes activated during a task offers a more inclusive, transparent and transferable model of creative development rooted in what students do, not merely what they produce. More significantly, this framework has the potential to reframe educational accountability in the context of creativity. Currently, when pupils fail to demonstrate creativity, the implicit assumption is often that they lack imagination or innate talent, meaning responsibility is placed on the learner. However, in subjects such as English, if a student struggles with sentence structure, the responsibility lies with the teacher, not the pupil. This framework applies that same standard to creativity. By clearly defining what creative thinking involves and how it can be taught, it enables teachers and schools to be accountable for developing creativity, not just rewarding it when it appears. This marks a fundamental shift from a view of creativity as an individual gift to a structured, teachable capacity embedded in a system designed to support all learners.

Finally, as the framework continues to be tested and refined, an important area for future development lies in mapping how different combinations of competencies can engender distinct forms of creative thinking. This could be represented as an 'outer ring' to the existing competency wheel that identifies patterns or typologies that emerge when certain cognitive behaviours interact. For example, the pairing of iterative thinking with constraint-based problem solving could underpin technical creativity, while divergent thinking combined with syncopated thinking might drive more disruptive or narrative-led outcomes. Such a development would deepen the explanatory power of the model and support a more nuanced understanding of how creativity manifests across domains and disciplines. Moreover, because the framework's structure is grounded in observable cognitive behaviours rather than subject-specific outcomes, it remains adaptable across educational phases (from primary to higher education) and into workplace training and professional development. In doing so, it directly responds to calls from both education and industry for transferable models of creative competency that can be developed, applied and assessed across learning and professional contexts (OECD, 2019; World Economic Forum, 2023)

Conclusion

This paper has proposed a new way of thinking about both D&T and creativity itself. Instead of presenting creativity as a nebulous ideal, it is redefined as a structured set of observable, teachable competencies, as captured in the creativity competency framework (also referred to as the competency wheel). This model positions D&T not as a marginalised subject, but as a pedagogical leader capable of driving systemic innovation across the curriculum. The development and trialling of the creative competency mapping tool demonstrates how these abstract capacities can be made visible, actionable and assessable. This is not achieved through subjective impressions or the quality of final products. Rather, it is through the cognitive and behavioural processes embedded in pupils' work. Hence, the competency framework becomes a practical instrument for designing learning, supporting assessment and fostering professional dialogue.

Crucially, this reframing of creativity shifts it from being an innate trait of the few to a shared educational responsibility. It enables accountability that is empowering rather than punitive, offering educators a common language to recognise, nurture and refine creativity in everyday practice. For D&T teachers, it offers both recognition and rigour, affirming their intuitive, often under-acknowledged contributions while equipping them with tools for systematic planning and reflection. More broadly, the framework serves as a prototype for how artificial intelligence (AI) can support, rather than supplant, human judgement in education. By aligning intelligent tools with domain-specific pedagogies, the paper demonstrates how technology can extend professional expertise, reduce workload and promote equitable access to creative learning. What has been developed here is a working proof of concept, not a finished product: a new logic for teaching creativity and a compelling call to reimagine curriculum relevance in an age of complexity, collaboration and AI.

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Fostering Creativity in School Makerspaces: Principles and a Framework for Assessing Creativity-Supportive Design

Larysa Kolesnyk, University of South-Eastern Norway, Notodden, Norway
Brynjar Olafsson, University of South-Eastern Norway, Notodden, Norway
Camilla Groth, University of South-Eastern Norway, Notodden, Norway
Eva Lutnæs, Oslo Metropolitan University, Oslo, Norway

Abstract
School-based makerspaces are increasingly recognized as powerful contexts for fostering creativity, collaboration, and problem-solving. However, educational research on creativity has often prioritized individual traits or final products, underemphasizing the environmental conditions - physical, social, emotional, and cognitive - that shape creative engagement. This paper argues for re-centering Press, the environmental dimension of Rhodes' Four Ps model, as a central driver of creativity in educational makerspaces. Drawing on interdisciplinary literature from creativity studies, learning sciences, and educational psychology, the paper identifies six interrelated principles that characterize creativity-supportive learning environments: a supportive socio-emotional atmosphere, learner autonomy, inspirational stimuli, collaborative culture, teacher support and guidance, and equitable access to technology and resources. These principles are synthesized into the Creative Educational Environment Assessment Model, a prospective conceptual framework designed to evaluate and enhance makerspaces in ways that are context-responsive, equitable, and pedagogically robust. The model emphasizes process as well as product, incorporates intellectual resources as a dimension of creative support, and situates teacher capacity as a systemic driver. Intended as both a theoretical scaffold and a practical tool, the framework offers researchers, educators, and policymakers actionable guidance for transforming makerspaces into environments where creativity is structurally supported and democratically accessible.

Keywords
Makerspace, creativity assessment, environment, education, pedagogy

Introduction
School makerspaces have gained substantial traction in recent years, offering technology-rich environments that emphasize hands-on, student-led, and project-based learning through the act of making (Blikstein, 2014; Korhonen et al., 2022; Gravel & Puckett, 2023). These spaces are specifically designed to teach and foster essential 21st-century skills—such as critical thinking, collaboration, problem-solving, technological proficiency, and creativity—skills that are critical for the evolving job markets of the future (Binkley et al., 2011; Larsson & Miller, 2012; Piirto, 2011). Creativity, which involves generating and evaluating possibilities by connecting information in new ways or finding viable alternatives to problem solutions (Beghetto, 2020), lies at the heart of both the concept of 21st-century skills and maker-centered learning (Clapp et al., 2016). As the maker movement has entered the educational context (Davies & Seitamaa-

Hakkarainen, 2024), school makerspaces offer unique opportunities for students to develop their creative capacities. Makerspaces thus also provide us with a context for assessing creative environments, and for studying how environments can be better equipped to facilitate teaching for developing creative capacities.

General creativity research has disproportionately emphasized individual traits (e.g., persistence, divergent thinking), cognitive processes (e.g., ideation, iteration), or the originality of products. Far less attention has been devoted to the environmental conditions, the Press in Rhodes' (1961) Four Ps framework, that shape, enable, or constrain creative engagement. This imbalance is not a mere oversight; it limits both our theoretical understanding of creativity and the capacity to design inclusive, equitable, and effective learning environments that could support sharing creative ideation and communication.

Existing approaches to creativity assessment further reflect this gap. While assessment of creativity (typically summative) and assessment for creativity (typically formative) have their place in educational design (Bolden et al., 2019; Beghetto & van Geffen, 2024), both approaches often operate without a robust framework for understanding the interplay between environmental factors and learner agency. Without such a framework, efforts to evaluate creativity risk overlooking the socio-emotional, material, and cultural contexts that influence participation and innovation.

In school makerspaces, environmental factors are often assumed rather than intentionally designed. Access to advanced tools or open-ended tasks is not, on its own, a guarantee of creativity, (Niinimäki et al., 2025). Instead, creativity emerges when physical, social, emotional, and cognitive dimensions of the environment are deliberately aligned to foster curiosity, collaboration, and risk-taking (Kumpulainen & Kajamaa, 2020). Treating the environment as a constitutive force rather than a passive backdrop requires both conceptual clarity and practical strategies for design and evaluation (Juurola et al., 2022) Especially the theoretical influence of embodied learning has directed researchers' attention to the environment when it comes to its affect on the learning activities in the classroom, especially in the creative subjects (Hughes & Morrison, 2020). However, little research has been focusing on the environment's effect on creativity and how to design learning environments for enhancing creativity in students.

This paper responds to the need of strategically designing learning environments to enhance creativity in students by re-centering Press as a primary lens for both understanding and improving creative engagement in school-based makerspaces. In doing so, it addresses two central research questions:

- What role does the learning environment - encompassing physical, social, emotional, and cognitive factors - play in fostering student creativity within school-based makerspaces?
- What principles can be derived from interdisciplinary research to guide the design and assessment of creative learning environments?

To answer these questions, we synthesize theoretical insights from creativity studies, learning sciences, and educational design to articulate a set of interconnected principles for cultivating creativity through environmental design. These theoretical principles are summoned in our prospective Creative Educational Environment Assessment Model, a flexible, evidence-informed framework designed to guide educators, researchers, and policymakers in fostering and assessing creative learning environments. By advancing this model, we aim to contribute both to the scholarly discourse on creativity and to the practical transformation of makerspaces into environments where creativity is structurally supported, equitably accessible, and meaningfully assessed.

Re-centering environment: Theoretical Foundations and Empirical Gaps in Creativity Research

Creativity remains a cornerstone of contemporary education, increasingly valued for its role in preparing learners to navigate the demands of a rapidly evolving world. In educational design, particularly within school-based makerspaces, creativity is often viewed as both a pedagogical aim and an indicator of meaningful engagement (Olafsson, 2022). While extensive research has explored learner characteristics, cognitive processes, and final outputs, the environmental dimension, and especially its assessment, has received significantly less theoretical and empirical attention in educational contexts (Jordanous, 2016). In educational contexts, creativity has traditionally been viewed through the lens of individual traits such as motivation or divergent thinking, or cognitive processes like problem-solving and iteration (Runco & Jaeger, 2012). Evaluative tools often center on final outputs, using instruments such as the Consensual Assessment Technique (CAT) (Amabile, 1982) or domain-specific rubrics. However, this person-process-product emphasis has led to a skewed understanding of creativity that overlooks the contextual affordances and constraints embedded within learning environments (Beghetto & Kaufman, 2007; Henriksen et al., 2019).

Too frequently, the learning environment is treated as a static backdrop or a neutral container for activity, despite robust evidence from the learning sciences suggesting otherwise. However, situated, embodied, and socio-material learning theories challenge this assumption (Schilhab & Groth, 2024). Situated Learning Theory (Lave & Wenger, 1991) asserts that knowledge and skills are developed through active participation in specific cultural and material contexts, highlighting how learning is inherently relational and situated. Similarly, socio-material perspectives (Fenwick, 2013) argue that cognition and creativity emerge from dynamic interactions between individuals, tools, artefacts, and spatial configurations. These approaches shift the focus from creativity as a purely internal phenomenon to one shaped by the interplay of material, social, and symbolic factors (Keune & Peppler, 2018; Mehto & Kangas, 2023).

From this perspective, the environment is not simply a backdrop but a constitutive element of creativity itself. The concept of affordances (Gibson, 1979) from ecological psychology, that has formed a basis for embodied cognition theories and related learning theories underscores how learners perceive opportunities for action based on what their environment offers. Whether or not students pursue creative pathways is deeply influenced by how accessible and supportive their physical and social context is. This is echoed in Hutchins' theory of a shared socially distributed cognition (Hutchins, 1995) and Vlad Glăveanu's distributed creativity concept (Glăveanu, 2014) that similarly demonstrates that thinking—including creative ideation and problem-solving—is not confined to the mind but is distributed across tools, representations, and social interaction which has formed a basis for embodied cognition theories and related learning theories, ns. These theoretical foundations support the embodied view on learning that the environment actively mediates creative engagement, shaping what learners notice, value, and attempt.

While several theoretical models have been developed to define creativity, there is still a lack of sufficient attention to concrete environmental aspects. Where environmental considerations are addressed, they are often treated broadly or inconsistently. Among existing frameworks, we find Rhodes' definition of the environment—captured in the concept of Press—to be the most developed to date. For this reason, we use it as the starting point for our model. Rhodes (1961) conceptualised creativity through four interrelated components: Person, Product, Process, and Press, each highlighting a distinct facet of creativity. In the educational context, each of these components can be targeted and assessed independently to yield a more comprehensive understanding of creative development. The Four Ps model is a comprehensive framework that has been used extensively to contextualize creativity in a variety of disciplines and enables a detailed analysis of how these elements interact to stimulate or hinder creativity. A significant advantage of the 4P model is its applicability in educational settings, particularly for facilitating creativity among students. Studies suggest that integrating the 4P framework into teaching practices can enhance creative outcomes in students by recognizing the importance of personal attributes, process methodologies, environmental factors, and product evaluations in nurturing creativity (Jiang et al., 2020; Liu & Chang, 2017).

The Person dimension of Rhodes (1961) creativity framework considers the traits, characteristics, and behaviours that are typically associated with creative individuals. For instance, research from the Centre for Real-World Learning (CRL) has identified five core habits linked to creativity: inquisitive, persistent, imaginative, collaborative, and disciplined (Spencer et al., 2012). These characteristics have been validated through extensive field trials. The core habits can be used to plan, execute, and assess different aspects of teaching and learning (e.g., Lutnæs, 2018) and can serve as indicators of creative potential in students.

Several tools have been designed to measure individual creative capacities through tests that focus on cognitive and expressive aspects, such as the Critical Thinking Assessment Test (CAT) and the Abreaction Test (Geist et al., 2018; Carbonell-Carrera et al., 2017). However, such tests assume that creativity is a domain-general trait that can be measured. However, many researchers have described creativity as domain-specific (e.g., Baer, 2010), and the link between creativity and personality can differ across domains.

The Product refers to the tangible outputs of the creative process, with a commonly accepted definition of a creative product as something that is both novel and task-appropriate (Runco & Jaeger, 2012). In educational makerspaces, the emphasis is generally on ideas that are new to the individual, rather than on groundbreaking contributions to a field. One of the most widely used methods for evaluating creative products is the Consensual Assessment Technique (CAT), which relies on expert evaluations to rank the creativity of students' work (Amabile, 1982). The products are compared to other products within a group rather than an ideal. This model has proven effective across multiple fields (Plucker et al., 2019), but determining who qualifies as an "expert" remains an ongoing challenge.

In the Rhodes model, the Process dimension refers to the sequence of cognitive and collaborative steps involved in creative thinking (Batey, 2012; Beghetto, 2020). For example, Beghetto (2020) outlines a seven-step process, from problem identification through to evaluation. In a makerspace setting, each stage can be assessed to understand how students generate, refine, and share creative ideas. However, understanding the creative process should not lead to overplanning and assessing but to developing what the students already have and do (Beghetto, 2020).

When we shift our focus from individuality, products, and process to the surrounding context, it becomes clear that creativity is not an isolated phenomenon. Creativity is a response to needs in society and/or builds on other creative constructs. Typically, workplace environments are evaluated based on features that support or inhibit creativity (Sundquist et al., 2025). This is the final dimension, Press (environment), in Rhodes' model. The psychological climate that is conducive for creativity has been measured in organizational settings (Ekvall, 1996; Amabile et al., 1996; Dul & Ceylan, 2011) and home environments (Harrington et al., 1987). However, the interplay between the individual and environment in creativity assessment in school makerspace remains largely unexplored (Abdulla Alabbasi, et al., 2025; Runco & Acar, 2024)

The neglect of environmental factors that affect creativity is particularly evident in research on educational makerspaces, which are often idealized as inherently creative spaces. While these settings offer access to materials, tools, and open-ended tasks, such provisions alone do not guarantee deep or sustained creative engagement (Sälzer & Roczen, 2018). Instead, factors such as classroom layout, peer interaction, emotional safety, and the presence of cognitive scaffolds play crucial roles in determining whether and how creativity emerges (Kumpulainen & Kajamaa, 2020).

A recent scoping review by Soomro et al. (2023) offers empirical confirmation of this imbalance. They analyzed 34 peer-reviewed studies related to creativity in STEAM education, and the authors found that the majority of studies focused heavily on the Person, Process, and Product dimensions (Soomroo et al. 2023). Further, none utilized established tools to measure environmental variables such as social norms, spatial affordances, or access to emotional support (Table 1). This empirical gap limits our understanding of how creativity is enabled or constrained by environmental conditions.

Table 1. Method for creativity assessment and corresponding aspect of creativity
From: Makerspaces Fostering Creativity: A Systematic Literature Review (based on Soomro et al., 2023)

S. No	Creativity assessment method	Aspect of creativity	References
I	The creative solution diagnosis scale (CSDS)	Product	(Cropley & Cropley, 2004; Cropley et al., 2011; Timotheou & Ioannou, 2021)
II	Critical thinking assessment tests (CAT)	Person	(Geist et al., 2019; Harris et al., 2014)
III	The abreaction test	Person	(Carbonell-Carrera et al., 2019; Saorín et al., 2017)
IV	The Torrance test for creative thinking (TTCT)	Process	(Noh, 2017; Torrance, 1972)
V	Rubric-based assessments of creativity	Process	(Lille & Romero, 2017 ; Clark et al., 2018)
VI	Summative assessment of prototypes	Product	(Fleischmann et al., 2016)

VII	Export jury assessment	Product	(Chekurov et al., *2020*)

Treating Press as an influential component of creativity aligns not only with theoretical developments but also with growing awareness of how equity, inclusion, and access intersect with creative learning. Heredia and Tan (2021) have shown that minoritized learners often face invisible barriers in makerspaces, ranging from unfamiliarity with technical tools to social exclusion from collaborative groups. These experiences cannot be fully understood or addressed without considering the environmental and cultural conditions of the learning setting.

Press, in this context, becomes a valuable analytical and design tool. It allows practitioners to interrogate how different elements of the environment—emotional safety, teacher mediation, physical accessibility, or intellectual scaffolding—shape the conditions for participation. By centering Press, educational design can move from a narrow focus on individual aptitude or project outputs toward a systems-level approach that recognizes creativity as co-produced by learners and their environments.

Designing Creative Learning Environments in School-Based Makerspaces: Principles for Practice

The evaluation and enhancement of school-based makerspaces require a balanced consideration of pedagogical theory and practical application (Korhonen et al., 2022). Makerspaces have been consistently positioned as fertile grounds for integrating STEAM learning while fostering creativity, critical thinking, collaboration, and problem-solving (Kay & Buxton, 2023; Bertrand & Namukasa, 2022). These environments provide not only access to technical tools but also opportunities for social interaction and experiential learning, aligning closely with constructionist principles. For instance, Eldebeky and Hughes (2025) illustrate how a laser cutter station in a school makerspace can advance subject-specific learning and career readiness, especially when collaborative engagement between students is prioritized.

Motivational factors also play a crucial role in shaping the success of makerspace-based learning. Positive emotional experiences have been shown to enhance students' self-efficacy and situational interest, ultimately improving project performance (Vongkulluksn et al., 2018). These findings echo Bandura's social cognitive theory, which highlights the central role of affective experiences in shaping learners' perceptions of competence. Consequently, makerspaces should be designed not only as technical workspaces but also as emotionally supportive environments that promote well-being, confidence, and sustained engagement.

Assessment in makerspaces must go beyond conventional academic metrics. Traditional measures are often insufficient for capturing the full spectrum of learning in these complex, project-based contexts. Alternative approaches, such as collaborative problem-solving rubrics and structured reflective practices, have emerged as more effective tools for understanding student learning dynamics. Herro et al. (2018) offer a framework for assessing collaborative problem-solving behaviors among primary students, showing how task-specific observation can illuminate critical social and cognitive processes. Similarly, Rosenheck et al. (2021) advocate for embedded, student-centred assessment tools that produce nuanced evidence of learning, adapted to the distinctive qualities of maker pedagogy.

The role of the teacher is central in realizing the potential of school makerspaces. Stevenson et al. (2019) argue that structured pedagogical frameworks not only increase teacher confidence but also strengthen the integration of maker-based approaches across the curriculum. Well-prepared teachers can facilitate richer student experiences, ensure equitable participation, and connect makerspace activities to broader educational goals.

Drawing together these insight points to a multi-dimensional framework for designing creative learning environments in makerspaces one that addresses emotional engagement, collaborative practice, innovative assessment, and sustained teacher development, while accounting for the social and physical conditions that nurture creativity.

Such environments thrive when they foster a supportive atmosphere in which students feel welcomed, valued, and encouraged to take intellectual risks. A positive emotional climate, underpinned by peer support and inclusive engagement, builds trust and creative confidence (Baeten et al., 2012). They also benefit from promoting freedom and autonomy, allowing learners genuine control over project design and execution. Autonomy-supportive teaching nurtures intrinsic motivation, aligning work with personal interests and sustaining creative persistence (Vansteenkiste et al., 2012; León et al., 2015).

Equally important is providing inspiration and stimulus through challenging tasks, diverse perspectives, and curated environments that spark curiosity and innovative thinking (Bieraugel & Neill, 2017). A collaborative culture enhances this by encouraging peer-to-peer interaction, feedback exchange, and joint problem-solving, embedding collaboration as a core skill.

Within this culture, teacher support and guidance remain pivotal. Educators provide strategic feedback, encourage experimentation, and supply the intellectual resources necessary for translating ideas into viable outcomes (Belland et al., 2016). Finally, equitable access to technology and resources ensures that all students can participate fully, with inclusive provision of tools, materials, and training aligning with the broader goal of high-quality, equitable education (Andrews & Boklage, 2023).

From this evidence base, six interrelated principles are embedded that we can use for guiding the creation and evaluation of creative learning environments in school makerspaces. These six principles were identified through a thematic synthesis of key concepts recurring across interdisciplinary literature on creative learning environments, particularly in the context of school-based makerspaces. While not derived from a formal systematic review, they reflect converging theoretical insights and practical considerations highlighted in recent studies.

A **supportive atmosphere** underpins all creative engagement. This is characterized by peer support, a strong sense of inclusive community belonging regardless of background or skill level, and encouragement to take intellectual and creative risks. When students feel welcomed, included, and safe to explore new ideas, they are more likely to participate actively, share their perspectives, and persist through challenges, ultimately fostering both creativity and academic success.

Freedom and autonomy empower students to take ownership of their creative work. This includes having control over project management, the authority to make key creative decisions, and the autonomy to pursue personal interests. Such freedom builds intrinsic motivation, responsibility, and resilience—qualities essential for sustained creative practice.

Inspiration and stimulus ensure that students are exposed to diverse ideas and physical and digital materials, that they are invited to tackle challenging tasks that promote skill growth, and that they are provided with physical spaces designed to spark creativity. These conditions stimulate curiosity, expand creative repertoires, and encourage learners to approach problems from multiple perspectives.

A **collaborative culture** strengthens creativity through shared endeavor. Opportunities for joint projects, an open exchange of ideas and feedback, and recognition that working with others enhances creative outcomes are all vital. This culture builds collective intelligence, strengthens problem-solving, and fosters a sense of shared ownership over the creative process.

Teacher support and guidance provide the intellectual scaffolding necessary for sustained innovation. Educators play a crucial role by helping students develop their creative ideas, remaining available to answer questions, and encouraging experimentation with novel approaches. This guidance also encompasses the provision of intellectual resources required for making informed technical design decisions—supporting students in navigating the complexities of tool use, materials selection, and process optimization. By combining pedagogical insight with technical expertise, teachers enable learners to integrate conceptual thinking with practical execution, ensuring that creative ambitions can be translated into functional, high-quality outcomes.

Finally, **access to technology and resources** ensures that students are equipped with the tools, materials, and training they need to realize their ideas. Equitable access to resources, combined with opportunities to learn how to use them effectively, is fundamental to fostering inclusion, enabling diverse forms of creativity, and levelling the playing field for all learners.

Taken together, the six guiding principles - supportive socio-emotional atmosphere, freedom and autonomy, inspiration and stimuli, collaborative culture, teacher support and guidance, and equitable access to technology and resources - offer a theoretically grounded foundation for reimagining creative learning environments in school-based makerspaces. Developed from interdisciplinary literature and established theory, these principles address the pedagogical, social, and material factors that shape creative engagement.

The challenge, however, lies in moving from a conceptual framework to a practical tool that can inform decision-making in diverse school contexts. Without a structured model to guide application, such principles risk remaining abstract ideals. Makerspaces are complex, context-dependent settings in which creativity emerges from the interplay of multiple environmental conditions - requiring an approach that reflects this interdependence and supports context-sensitive adaptation.

In response, this paper introduces *the theoretical foundations for a prospective Creative Educational Environment Assessment Model*. This model operationalizes the six principles into a flexible yet structured tool that is intended to enable educators to identify strengths and gaps, pending empirical validation in future iterations. Its design is deliberately adaptable to diverse institutional and cultural contexts, while retaining the coherence necessary for systematic evaluation.

Figure 1 illustrates the proposed framework, mapping the six principles and their interrelations as an integrated, system-oriented approach to assessing and enhancing creative learning environments in school-based makerspaces.

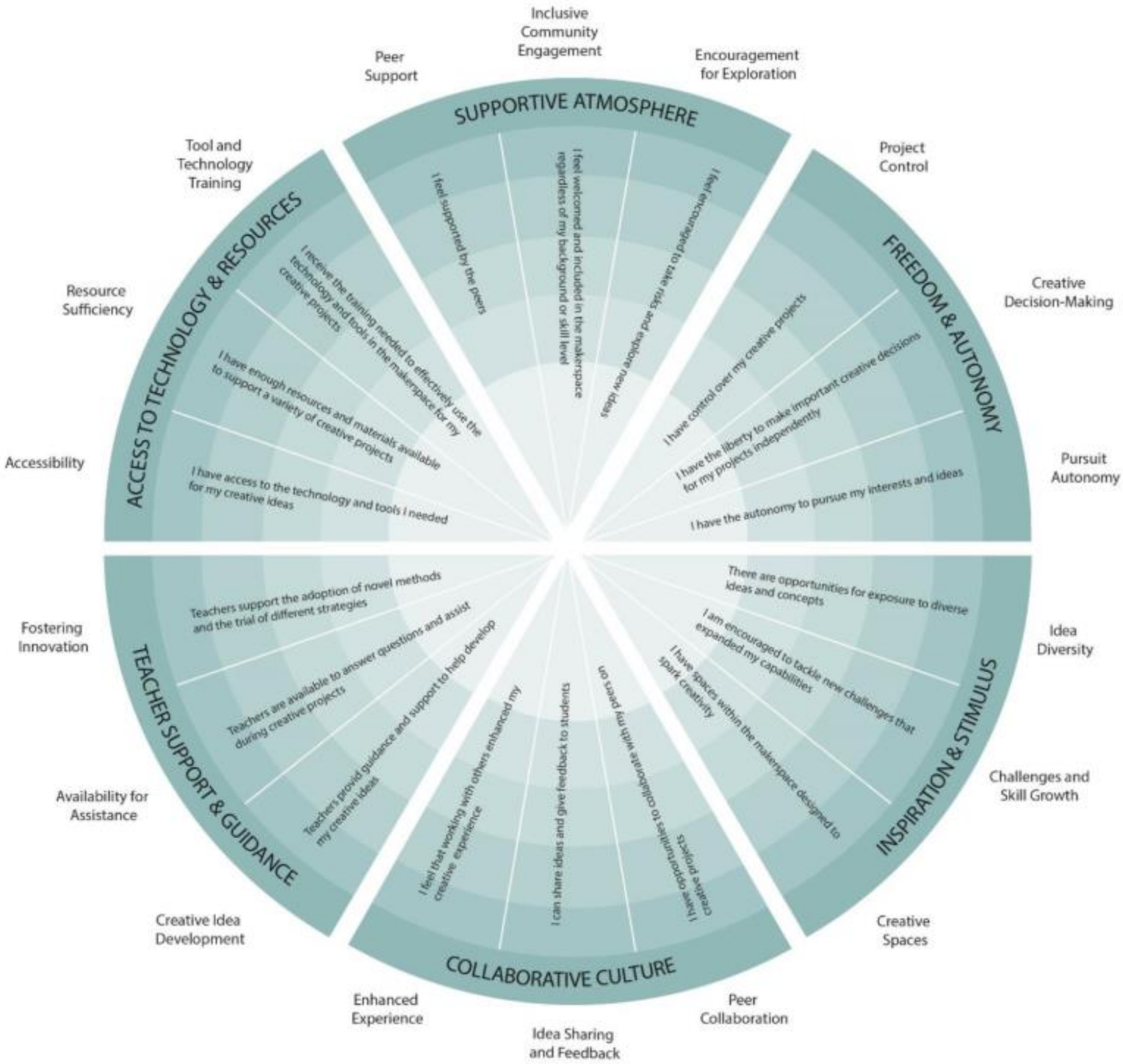

Figure 1. The creative educational environment assessment model (the CEEA Model)

Discussion

The articulation of the six principles within the Creative Educational Environment Assessment Model marks an important step towards bridging theory and practice in makerspace-based education. The model advanced herein extends existing theoretical and empirical work by articulating a comprehensive framework for the support and evaluation of the environment (Press) within makerspace classroom contexts. Although the environment has long been recognized as a critical dimension of creativity (e.g., Rhodes), it has remained comparatively underexplored in both empirical research and the domains of educational design and assessment (see Table 1). The model proposed in this article seeks to address this lacuna by conceptualizing press, thereby offering educators a robust framework through which to cultivate creativity across disciplinary domains, while simultaneously furnishing creativity scholars with a systematic instrument for the empirical examination of press as a constitutive factor in creativity. In this context, a model serves both as a conceptual scaffold, organizing theoretical insights into a coherent whole, and as an operational tool that educators, researchers, and policymakers can adapt to specific institutional and cultural contexts (Borko & Livingston, 1989).

The framework is deliberately systemic, recognizing the interdependence of its domains. Autonomy, for example, gains practical meaning only when embedded in a climate of trust and supported by pedagogical scaffolding (Amabile, et al.,1996). Similarly, access to advanced tools becomes transformative when paired with teacher expertise that enables students to use them creatively (Vygotsky, 1978; Turakhia et al., 2023). This interconnectedness positions the model as a network of mutually reinforcing conditions rather than a sequence of isolated variables.

The 'Teacher Support and Guidance' domain explicitly integrates intellectual resources, such as domain-specific knowledge, design reasoning strategies, and problem-solving heuristics, as key enablers of student decision-making. Without such scaffolding, even well-equipped makerspaces may fall short of their creative potential.

Institutional context represents another key structural element. As Gravel and Puckett (2023) note, teachers often operate across 'systemic distances' between policy mandates, curricular constraints, and their own pedagogical goals. The model must therefore be adaptable to a wide spectrum of school environments, acknowledging how local priorities, time structures, and accountability pressures affect the enactment of creative learning. Incorporating context-sensitivity into the model's architecture ensures that it functions as a flexible framework rather than a rigid template (Fidan & Balcı, 2017).

Equity is embedded as a structural priority. The model calls for evaluating not only participation rates but also the quality of engagement—whose voices are heard, who drives decisions, and who feels confident to experiment (Bourdieu, 1986; Heredia & Tan, 2021). Access, in this sense, extends beyond physical tools to include mentorship, knowledge, and encouragement.

Assessment within the model places equal emphasis on process and product, acknowledging that creativity in makerspaces unfolds through iteration, collaboration, and reflection (Valgeirsdottir & Onarheim, 2017; Schön, 1992). Recommended instruments include design journals, collaborative problem-solving rubrics, and reflective interviews to capture the full arc of creative engagement.

Finally, the model situates the teacher's capacity as a central driver of system performance. Teachers mediate both technical affordances and social climate, requiring pedagogical skill, technical expertise, and strategies for fostering agency, inclusivity, and productive collaboration (Wiggins & McTighe, 2005; Turakhia et al., 2023). Professional development is therefore integral to the model's operation.

A central challenge in model design is achieving a balance between theoretical robustness and practical feasibility. If too abstract, the model risks becoming an aspirational checklist with little direct application; if overly prescriptive, it may fail to accommodate the contextual variations that define real-world makerspaces. The process of model-making must therefore be iterative, refining structure and indicators through cycles of empirical testing and practitioner feedback, so that the final framework reflects both research evidence and the lived experience of educators and students.

In sum, the Creative Educational Environment Assessment Model offers a structured yet adaptable framework for assessing and enhancing creativity in school-based makerspaces. This model will need to evolve through participatory design with educators and learners, ensuring that it remains both conceptually grounded and adaptable to the diverse realities of school-based makerspaces. Its ultimate value will lie in providing a framework that can guide reflective practice, inform policy, and support the intentional cultivation of creativity as a sustained, inclusive, and context-responsive process.

Conclusion

This paper has argued for re-centering the role of environment – Press – as an influential element in the design and evaluation of creative learning within school-based makerspaces. Through the articulation of six interconnected principles – supportive socio-emotional atmosphere, learner autonomy, inspirational stimuli, collaborative culture, teacher support, and access to technology and resources – we offer a coherent framework for interpreting, designing, and cultivating conditions where creativity can meaningfully flourish.

These principles are not presented as a prescriptive checklist, but as a reflective guide for educational stakeholders seeking to embed creativity into learning environments. Together, they collectively form the foundation of the Creative Educational Environment Assessment Model. The model offers researchers a theoretically robust yet adaptable framework for interrogating how environmental variables shape creative engagement, enabling assessment that attends to both process and product.

For educators, it provides actionable guidance for structuring inclusive, risk-permissive, and intellectually stimulating spaces where creativity can flourish. For policymakers, it serves as a blueprint for developing infrastructures and accountability systems that recognize creativity as an emergent, ecological process rather than a discrete, individual trait.

By positioning the environment as an active, designable component of creative learning, the framework promotes an ecological view of creativity — one that integrates spatial, social, emotional, and cognitive dimensions in the service of equitable participation. Crucially, the model is intended not as a static prescription but as a living tool, adaptable to diverse contexts and responsive to the evolving realities of schools.

The next phase of this work will involve empirical testing of the model across varied school makerspaces to evaluate its validity, reliability, and adaptability. At this stage, the interdependencies between principles and their relative influence on creative outcomes remain hypothetical and warrant empirical exploration. Results from these studies, together with refinements informed by practitioner feedback, will be presented in a subsequent publication. There are a variety of ways in which educators and researchers can use and develop the model introduced in this article. Through an iterative process, the framework aims to provide a durable yet flexible scaffold for research, policy, and practice, supporting the intentional cultivation of creativity as a sustained, inclusive, and context-responsive educational priority.

Future testing of the model will involve exploratory case studies in school makerspaces, including teacher-led assessments, observational studies of classroom dynamics, and student reflections. These iterative cycles will be used to refine the model's applicability and sensitivity to diverse contexts.

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Outputs of a Cross-Cultural Virtual Design Studio: EINSTUDIO – A Design Journey Across Countries

Barış GÜR, Gazi University, Turkey
N. Hande KUTBAY, Gazi University, Turkey
H. Güçlü YAVUZCAN, Gazi University, Turkey

Abstract
Following the COVID-19 pandemic, research on Virtual Design Studios (VDS) increased significantly, revealing mixed opinions about their limitations. This paper aims to present these contrasting views on VDS education, with a particular focus on peer-learning. While many studies argue that peer-learning diminishes significantly, or even disappears in VDS, others claim the opposite. The conceptual framework of this study explores the possible limitations of peer-learning in VDS and critically highlights how COVID-19-related anxiety may have influenced many of these opinions. The empirical study discussed in this paper is based on an Erasmus+ project titled *European Strategic Partnership Project: European Interactive Industrial Design Studio (EINSTUDIO*). Students and instructors from three different countries participated in EINSTUDIO. The project aimed to leverage recent developments in online and web-based communication to address the challenges of teamwork in cross-national teams. Accordingly, this paper investigates whether current virtual technologies support the implementation of cross-national design studios. Variables such as motivation, collaboration, cultural diversity, and the contribution of the e-learning infrastructure are examined through participants' self-evaluations. The findings indicate that although virtual peer-learning presents certain limitations and cross-national collaboration poses even greater challenges, a more structured methodology, syllabus and close supervision, such as EINSTUDIO's semi-hybrid studio model, syllabus, and platform can help mitigate issues related to peer-to-peer communication and collaboration issues.

Keywords
design pedagogy, virtual design education, virtual design studio, cross-cultural studio,

Introduction
The studio course is widely regarded as the core and most intensive component - the backbone - of undergraduate design curricula, including architecture (Özorhon & Sarman, 2023), urban design and planning (Peimani & Kamalipour, 2022), interior design (Kurt Çavuş & Kaptan, 2022), product and industrial design (Toprak & Hacıhasanoğlu, 2019; Fleischmann, 2020), graphic design, and fashion design (Fleischmann, 2020). Studio work applies theoretical knowledge from lectures to practice-oriented, real-world projects (Kumar et. al., 2021), and is characterised by hands-on learning, individualised instruction, and frequent feedback exchanges (Fleischmann, 2020). It relies heavily on face-to-face interaction and iterative processes, which led many educators to be sceptical of online studios even before the pandemic (Fleischmann, 2021). However, Fleischmann (2021) describes the COVID-19 shift as a "sink-or-swim" moment, noting that both educators and students adapted more effectively than expected.

Although VDS dates back to the early 1990s, they became essential during the pandemic as programmes had to rapidly transition to remote or hybrid models (Iranmanesh & Onur, 2021). This abrupt change spurred increased research interest in VDS, yielding mixed perspectives on its strengths and weaknesses. A Google Scholar search for "Virtual Design Studio" returns an average of 71 results annually between 2000 and 2019, but this number surged to 197 in 2021, with continued growth in subsequent years (see Figure 1). While VDS initially gained traction in the late 1990s, it remained a relevant topic through the 2000s and 2010s before experiencing renewed prominence in the early 2020s.

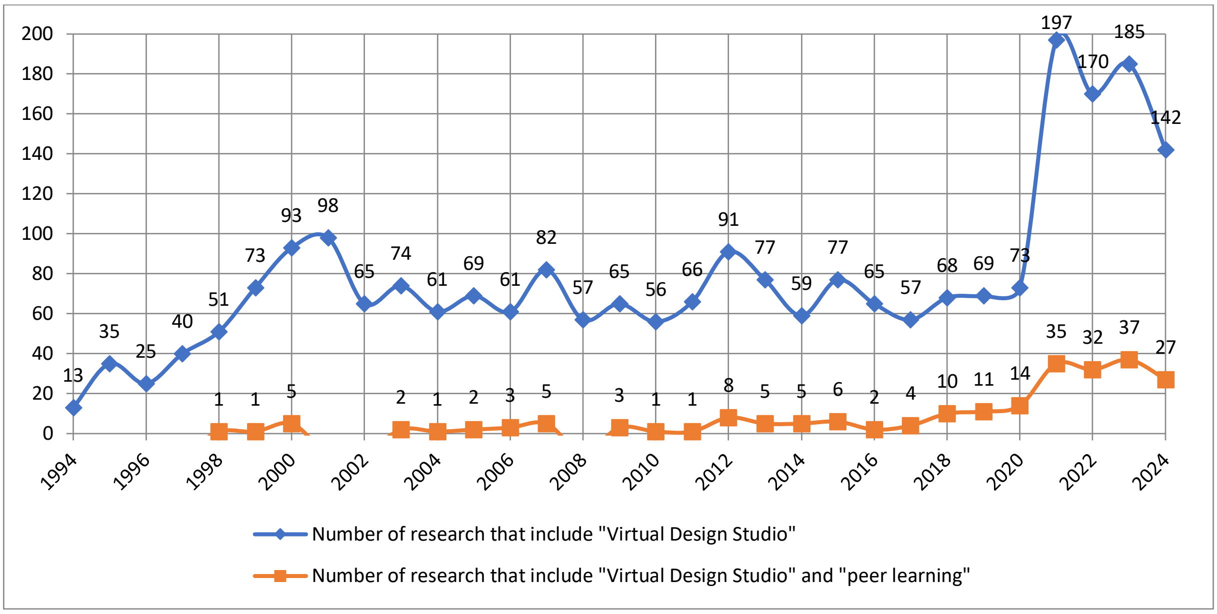


Figure 1. Google Scholar search results per year that include VDS and peer-learning

A key issue in recent VDS studies is peer-learning. As shown in Figure 1, peer-learning has become a prominent topic in VDS pedagogy since 2018, with 19–20% of publications between 2021 and 2024 addressing it. Although earlier results retrieved through these keywords include some extra-pedagogical articles and conference papers, most are relevant to design education literature. Traditional studios were seen as physical environments where students interacted, inspired one another, and informally exchanged knowledge and practices (Perolini, 2019). Consequently, peer-learning remains a significant and debated theme in VDS literature, with mixed views on its effectiveness.

Jones (2022) highlights that the complexities of studio-based learning have only recently gained scholarly attention, particularly regarding social dynamics, informal learning, and hidden curricula. As such, peer-learning in VDS remains an emerging research field. The following chapter reviews key findings from existing studies and presents a conceptual framework defining the studio and VDS. Given this paper's specific focus on cross-national collaboration and peer-learning via VDS, subsequent sections describe the implementation of the Erasmus+ project EINSTUDIO as a case study. Students' reflections and perceptions are presented as the study's primary findings.

Conceptual Framework and Literature Review: Studio

The studio course, rooted in craft-based disciplines, is considered the core of the curriculum. Typically held once or twice a week for half a day or longer, it requires a shared physical space and emphasises experiential, collaborative learning. It is usually delivered to small groups and refers not only to the course itself but also to the physical, social, and cultural environment where real-world design problems are addressed under the guidance of expert practitioners (Jones et al., 2021; Crowther, 2013; Taşlı Pektaş, 2012; Johns & Shaw, 2006). Contemporary studio pedagogy in design schools follows a Bauhaus-inspired model, itself rooted in the École des Beaux-Arts tradition of the 19th century. Students engage in realistic design problems (Taşlı Pektaş, 2012), with an emphasis on craftsmanship and apprenticeship through direct tutor-student interaction (Thoring et al., 2020).

Studios are tutor-centred (Cao, 2019), and tutors are often practitioners with little formal pedagogical training (Fleischmann, 2020). This distinctive interaction makes the studio the hallmark of design education—rich, complex, experiential, contingent, often messy, and difficult for newcomers and non-designers to grasp (Jones, 2022). Project briefs are typically open-ended, with no single correct answer (Fleischmann, 2020). As such, the studio learning model is problem-based, constructivist, explorative, and creative, often shaped by productive ambiguity (Jones et al,. 2021).

Studios involve critical feedback loops, commonly known as "crits," which support iterative design processes (Fleischmann, 2020; Goldschmidt et al., 2010). A crit is feedback from a tutor, helping students generate and evaluate concepts through dialogue, gestures, and other forms of interaction. However, studio learning is not limited to crits. Students also engage in self-learning and peer-learning (Lotfabadi & Iranmanesh, 2024), creating knowledge both independently and collaboratively (Corazzo et al., 2023). Peer-learning in studios is often described as having a “beehive effect,” where the collective energy of students—whether working individually or in groups—stimulates shared learning (Blevis et al., 2007).

This unique pedagogy depends on people, identities, networks, interactions, material surroundings, atmospheres, and moments of serendipity (Corazzo et al., 2023). Donald Schön’s concept of design as a reflective practice is frequently cited to capture the complexity of studio learning (Kaya Pazarbaşı, 2019). Students learn by reflecting on the behaviours of tutors and peers, as well as their prior knowledge. Although highly experiential and context-dependent—making it difficult to objectify—the studio remains central in design education due to its adaptable, signature pedagogy (Jones, 2022).

Hapticity, Kinaesthetic and Spatial Perception in Studio

Studios in product or industrial design programmes are similar to other design studios but are distinctly oriented towards mass production (Bodur & Akbulut, 2022). They emphasise experiential prototyping using full-scale models and usability testing (Tzeng, 2011). Consequently, in addition to visual, verbal, and written communication, tactile interaction—referred to as hapticity—plays a key role (Düzenli et al., 2018). Hapticity, or the sense of touch, is supported by kinaesthetic awareness—bodily sensations related to movement and spatial orientation (Özdamar et al., 2021). Haptic perception provides feedback on qualities such as texture, hardness, elasticity, temperature, weight, shape, stickiness, wetness, and viscosity, often more effectively than visual input (Minogue & Jones, 2006).

While haptic and kinaesthetic experiences are also essential in disciplines like architecture, urban design, interior design, and fashion or textile design (Özdamar et al., 2021; Atkinson et al., 2013), their application varies across fields. For instance, fashion designers choose fabrics by touch (Atkinson et al., 2013), while kinaesthetic experiences include sensing object weight or walking along inclined paths (Özdamar et al., 2021). Some of these sensory elements—such as recommended walkway gradients or sleeve lengths—can be quantified. However, many remain subjective, like the feel of tarmac versus gravel, the coldness of steel versus plastic, or the softness of silk compared to linen.

Hands-on learning in Studio

Haptic feedback and kinaesthetics are integral not only to the designed object but also to the learning experience. While vision and sound often suffice for communication, haptic feedback enhances perceptual quality (Bruns et al., 2007; Başdoğan et al., 2000), and spatial comprehension of objects or people on a screen remains limited (Davis et al., 1994). This issue persists in remote design education, particularly in architectural studios, where it is often underemphasised (Özdamar et al., 2021). Similarly, auditory perception is influenced by spatial variables, especially vibration. For instance, touching an object or hearing its pitch when struck helps distinguish between chrome-plated plastic and polished steel.

Haptics supports hands-on learning: physical interaction with materials and tools is a powerful educational method that fosters practical skills (Minogue & Jones, 2006). Thus, being hands-on is not merely about sensing tactile qualities, but about engaging in a distinct learning mode. Minogue and Jones note that the term "hands-on" reflects the role of touch as an active, discovery-based sense, with many tactile metaphors embedded in everyday language. Learning by touch feels more real than learning by sight alone (Jones et al., 2005).

Proximities and Synchronicity in Studio

Design education has long been associated with a physical space that simulates professional practice through tools, materials, and surroundings (Wragg, 2019; Petrova, 2021). Many instructors still view physical studio spaces as essential, yet this reliance also highlights their limitations—physical and geographical constraints, limited resources, and unequal access for students (Lagier, 2003; Huang et al., 2017). COVID-19 prompted a narrow focus on physical elements—surfaces, surroundings, and tools—since these became suddenly inaccessible. However, this perspective often lacked a deeper understanding (Jones, 2022).

Jones proposes that studio is defined by three dimensions: time, space, and being. Simply translating traditional studio to VDS by addressing time and space superficially overlooks deeper forms of engagement. He argues that *time* refers to the level of synchronicity, *space* involves more than physical proximity, and *being* concerns readiness to learn, connect, and contribute. Physical proximity is frequently conflated with social or temporal closeness—an assumption challenged during the pandemic when many participated online via limited tools. Yet studio has never been fully synchronous or socially cohesive; students may share a space yet remain disconnected, or contribute meaningfully even when absent. As Jones summarises, social proximity is not strictly tied to physical or synchronous presence.

Peer-learning in Studio
In studio, students interact with both instructors and peers, learning to express ideas verbally and visually while considering others' perspectives, which deepens their understanding (Petrova, 2021). Studio is a semi-public, social space where critique is shared, and peer support fosters a sense of community (Lotz et al., 2018). This signature pedagogy exposes students to multiple viewpoints (Kemp & Grieve, 2014). While critique traditionally flows from tutor to student, peer-to-peer critique is increasingly recognised as a key mode of knowledge-building, socially constructed through interaction and collaboration (Gray, 2013). Students learn from and with each other in both formal and informal ways (Coorey, 2016).

Sidawi's findings, cited by Lotz et al. (2015), highlight that peers often have a more positive influence than tutors, whose feedback can inhibit creativity. Peer-learning is broadly defined as the exchange of knowledge, ideas, and experiences among students (Zamberlan & Wilson, 2015), and many feel more comfortable seeking or offering help to peers (Coorey, 2016). Coorey argues that growing student numbers and increasing curricular demands make peer-learning increasingly important, helping alleviate the challenges educators face in balancing theory and technology instruction. Peer-learning can be informal or more structured, such as peer tutoring or monitoring (Zamberlan & Wilson, 2015), and also includes collaborative or team-based learning (Coorey, 2016). This paper adopts an informal understanding of peer-learning, encompassing unstructured, horizontal interactions, often occurring in small groups. Teamwork, in this context, is a concentrated form of peer-learning. Referring to Johnson & Johnson's earlier research, Coorey noted that peer-learning is traditionally believed to require face-to-face interaction. This paper critically examines whether physical proximity is truly essential for effective peer-learning, and whether such arguments remain valid in the context of VDS.

Teamwork in Studio
Collaboration, negotiation, and teamwork across disciplines are now essential elements of design practice (Tessier & Carbonneau-Loiselle, 2023), reflecting the shift from solitary design to team-based approaches (Tessier, 2021). Teamwork, whether face-to-face or virtual, is widely used in design education to simulate professional practice (Demir, 2016; Britton et al., 2017; Itkonen, 2009; Ünal et al., 2022). According to Tessier & Carbonneau-Loiselle (2023), teamwork involves activities that could be done alone, those requiring peer input, and those only achievable collaboratively. These foster skill development in communication, self-expression, adaptability, organisation, and problem-solving. Teamwork encourages creativity (Igbinenikaro et al., 2024), facilitates idea exchange (Demir, 2016; Patel, 2024), and enhances output quality through diversity (McLeod et al., 1996). Patel argues that collaboration fosters deeper engagement than peer-learning in individual settings.

Despite its benefits, teamwork presents challenges, including differing work ethics, conflicts, and unequal participation (Friis, 2015; Meseguer-Dueñas et al., 2016). Effective communication is essential but often underdeveloped in students (Salas et al., 2008). In VDS, the lack of informal interaction heightens the need for structured peer engagement (Lotz et al., 2015). Tools like Miro support connection and task coordination (Petrova, 2021).

International studios introduce further complexities. Ethnic diversity may cause distrust, communication barriers, or social division (Friis, 2015; McLeod et al., 1996; Cooper, 2009). Language and time zone differences complicate collaboration (Marchman, 2002; Sadecka, 2014). While diverse teams can enrich learning, students often feel more comfortable in homogeneous groups (Friis, 2015). Some institutions now implement intentionally global, virtual studios. For example, Northumbria's Global Studio connected students from the UK, USA, Australia, and Korea via video conferencing, with logistical issues like differing academic calendars (Bohemia, 2010). Similarly, the UNSW–Waseda studio (2020–2022) operated fully online using Miro and Concept Board (Pernice et al., 2023). Though these tools supported critique, analysis, and international collaboration, they also limited contextual understanding and peer-learning due to technical constraints.

Teamwork in Virtual Studio

Cochrane et al. (2008) define a virtual team as one with shared goals, interdependent work, and geographically dispersed members. Earlier research highlights that VDS enables students to work across time and place, and combining synchronous and asynchronous tools enhances satisfaction by improving decision-making, participation equity, and analytical depth compared to face-to-face teamwork (Resta & Laferrière, 2007). While instructor leadership is necessary in VDS, this mirrors face-to-face studios. Gül et al. (2008) found that over half of students struggled with remote teamwork, citing the lack of in-person interaction. They stressed the need for systems that manage tasks, schedules, file sharing, and communication in VDS, along with encouraging peer-to-peer critiques. Though virtual tools have significantly advanced since their study, some criticisms still apply, likely due to insufficient hierarchy, leadership, and organisational skills among student teams. As Friis (2015) noted, whether in-person or virtual, lack of hierarchy can lead to discomfort and conflict. Effective teamwork in VDS requires utilising multiple tools (Taşlı Pektaş, 2015).

Mixed views on peer-learning and teamwork are prevalent. Some argue fully virtual studios hinder informal interaction, peer-learning, active engagement, and collaboration (Süner Pla Cerdà et al., 2025). Peer collaboration is often seen as ineffective (Alnusairat et al., 2020), lost (Grover & Wright, 2023), declined (Iranmanesh & Onur, 2021), or disrupted (Hepburn & Borthwick, 2021). Wang (2025) suggests mutual engagement in design education—particularly in architecture—is rooted in physical presence, while virtual tools merely support basic idea exchange. Many researchers favour blended models. However, some findings are heavily shaped by the psychological effects of COVID-19, with newer studies often building on pandemic-era observations. Since students reported disengagement during forced VDS periods (Gümüş Çiftçi et al., 2021), overgeneralising its limitations without accounting for COVID-related anxiety risks misrepresenting how virtual proximity affects peer-learning. It remains unclear whether VDS inherently limits peer-learning and teamwork, or whether sudden, unprepared transitions caused perceived losses.

While many experienced VDS during the pandemic, others studied it beforehand. The Open University in the UK offers key pre-COVID insights. Lotz et al. (2018) noted the lack of a clear definition for quality learner-generated content via peer-learning. Referencing Kutay Güler's 2015 work, they observed that online social-network-supported design studios fostered more active communication, and peer critiques were especially valuable. The same study of Lotz et al. presents the Open Design Studio; an online portfolio and communication space that allows sharing and viewing posts, making discussions on each other's work. Their study presents the Open Design Studio, a platform for sharing work and facilitating discussions, in which numerous peer critiques occurred, enabling informal peer-learning. Lotz et al. argued that while other researchers criticise peer-feedback in such virtual networks with not fostering learning-oriented communication, others find such conversation community-building. Though not fully remote, the Open Design Studio demonstrated how online social tools can foster virtual peer-learning. Lehto et al. (2014) also emphasised that both in-class and extracurricular discussions enhance intercultural competence. Similarly, Salman et al., (2017) argued that structured discussion prompts in VDS simulate face-to-face engagement by maintaining connections with tutors and peers. In a prior study, Lotz et al. (2015) claimed that meaningful social interaction and peer-learning in online studios are not only possible but are actively pursued by students. Cuthbertson & Falcone (2014), however, contended that simply posting on a platform doesn't ensure commitment. Jones's (2022) model is explanatory to lack of commitment issues; the studio presence in terms of being there and ready to contribute is central to engagement. While commitment levels may vary, disengagement occurs both in virtual and face-to-face.

Hepburn & Borthwick (2021) contrasted synchronous learning—rich in real-time interaction—with asynchronous models where students engage independently. They compared two VDS setups: one offering live feedback to the whole class and another with individual responses. Nearly a third of students felt neither model fostered cohort engagement. While most found tutor support sufficient, synchronicity was found slightly favorable, yet notable number of students felt otherwise. One student mentioned that they felt disconnected and they struggled to collaborate and have sense of ambition, communication or accountability without physically proximite interactions. One argued that working in student-teams is more favorable in VDS because even in teamwork it has been rather *lonely*. Another felt difficult to stay motivated in asynchronicity. These views suggest that commitment isn't solely tied to synchronicity or physical presence, yet they still have an impact. Hepburn & Borthwick warned that asynchronicity can reduce creativity. Conversely, Neubauer & Wecht (2021) argued that mandatory synchrony restricts flexibility, making VDS less adaptable. They concluded that learning improves when presence is distributed across time and platforms. Across many studies, a recurring question persists, as exemplified in Petrova's (2021) findings: 83% of students disagreed that VDS could replace in-person studios. One explanation cited was that in-person communication feels more effective than "talking to a camera." Yet "better" remains undefined. Is virtuality truly synonymous with distance? Despite students being able to see and hear tutors closely, virtual settings are often equated with detachment—raising critical questions about how students perceive presence

Dependency of Peer-learning to Kinaesthetics, Spatial Perception, Proximities and Synchronicity

Two concepts are key to understanding how social proximity relates to virtuality: kinaesthetic empathy—knowledge gained by placing oneself within another's movement experience (Artpradid, 2023) - and spatial perception - the ability to comprehend shape, distance, position, motion, and spatial relations in three dimensions, even with limited sensory input (Kaya, 2021; Gérard, 2020). Although underexplored in design research (Kwon & Iedema, 2022), both are well discussed in acting and dance literature. Kinaesthetic empathy refers to sensing movement while observing it—perceiving speed, effort, and bodily changes as if performing the action, without physical motion (Artpradid, 2023). This capacity relies on spatial perception, as understanding movement extends beyond vision to include spatial awareness.

The complexity of proximity issues in VDS is not merely about being physically apart but rather about the limitations of spatial perception imposed by current technologies—namely, two-dimensional displays and the assumption that audio alone can simulate spatial sound perception. Moreover, spatial perception in VDS affects not only object awareness but also how tutors and peers are perceived. Since social interaction is shaped by observable behaviour (Shao et al., 2020), reduced spatial perception diminishes the quality of observation. While the link between social interaction and proximity is well researched, fMRI studies show the brain processes physical and social distance similarly, both influencing how people conceptualise events, individuals, or ideas (Shao et al., 2020). As Shao et al. summarise: whether distance is social or physical, what is farther feels more abstract, and what is nearer, more concrete. Exploring whether social proximity is similarly constrained by interface-based spatial perception as by physical distance is beyond this paper's scope but presents a promising avenue for future research. Nonetheless, the discussion aligns with Jones's view: proximity is not solely a matter of physical space.

Educational Equality of Virtual Design Studio

From a practical perspective, regardless of how advanced social media and virtual platforms become, students and instructors remain physically social beings, with campuses providing rich social infrastructure. Viewing VDS as the sole pedagogy creates drawbacks that are irrational now considering the COVID-19 crisis educational limits have passed. However, VDS offers unique benefits. Since this paper focuses on peer-learning, these advantages are briefly noted: VDS promotes individualism and independent learning (Saghafi et al., 2012). It equips students with crucial technical skills increasingly essential in professional design (Mariotti & Niblock, 2023). With digital design tools used more in VDS than in face-to-face education, students gain skills better suited for a digital-first world (Rodriguez et al., 2016). Another benefit, noted in literature, is the collaboration of multiple universities rather than replacing traditional studios. Cross-university studios, not necessarily international, expose students to diverse perspectives (Rodriguez et al., 2016) and cultural and geographical diversity, enhancing productivity (Tucker & Abbasi, 2012). Beyond financially limited students mentioned by Kvan (2001), those with reduced mobility, illnesses, social anxieties, or facing force majeure can participate in VDS with less difficulty. Thus, despite challenges, two facts remain: VDS expands educational access, and some collaborations—such as cross-national projects—are only feasible via VDS.

Brief History of Virtual Design Studio

To conclude this chapter, it is important to highlight key milestones in VDS. The concept dates back to the early 1990s, initially as an experiential, collaborative tool to overcome geographical barriers in architectural education (Kvan, 2001). Early VDS initiatives emerged alongside advances in computer-aided design (CAD) and the internet, mainly enabling asynchronous collaboration, such as MIT's early distributed design studio experiments (Kolarevic et al., 2000). Some of the earliest projects include Distance Collaboration in 1992 (University of British Columbia and Harvard), Virtual Village and VDS in 1994 (Wojtowicz, 1995), and the Virtual Design Studio Project involving the University of Hong Kong, MIT, and the University of British Columbia, which used then-nascent tools like email, file transfer servers, and 2D CAD software to facilitate overseas design exchanges (Kvan, 2001). Due to hardware and software limits, real-time collaboration was restricted, and the technology was costly and complex for large classes (Kvan, 2001). The late 1990s and early 2000s witnessed multiple VDS approaches: design teaching via email, remote TV lectures, the Design Pinup Board, MIT's innovative collaboration systems, cross-university/national projects, file uploading, chat, whiteboards, self-learning materials, and hybrid face-to-face/VDS methods (Saji et al., 2008). The Design Studio 2.0 concept then emerged, emphasizing web tools to enhance reflective design learning (Iavarone, 2021). From the mid-2000s, web tools supported studios, with social networks often serving as VDS mediums. The UK's Open University, led by Nigel Cross, exemplifies this era and its researchers are pioneers in VDS literature (Heyik & Erdoğan, 2022). The 2010s witnessed many VDS projects globally beyond the US, UK, and Far East; some failed, others evolved. Despite over two decades of existence by 2019, VDS was not widespread until the pandemic due to access barriers. Approaching the 2020s, fiber optics, 4G, cloud computing, big data (Bieringa et al., 2021; Cui et al., 2023), improved video codecs reducing bandwidth (Galteri et al., 2020), and WebRTC—an open-source browser video framework (Zeidan et al., 2014)—enabled plugin-free conferencing. Zoom, leveraging WebRTC, became emblematic during lockdowns, despite earlier tools like Skype and WebEx. These advances propelled VDS from experimental to mainstream pedagogy. In the past decade especially, video conferencing tech became cheaper, accessible, and commonplace (Iranmanesh & Onur, 2021). Today, even those with low purchasing power can access video-enabled phones.

Modern VDS combines synchronous and asynchronous tools. Platforms like Zoom, Miro, Prezi, and Teams support communication, while CAD software enables collaborative design (Komarzyńska-Świeściak et al., 2021). Social media such as YouTube, Facebook, Discord, and WhatsApp also back VDS (Schnabel & Ham, 2014; Iranmanesh & Onur, 2021; Karaca Şalgamcıoğlu & Genç, 2021). Although VDS has taken many forms since early attempts (Kvan, 2001), the core of design education—realistic project themes and crits—remains as in traditional studios. Key differences between VDS and face-to-face studios lie in Sense of Place (Kusumowidagdo & Prihatmanti, 2022), spatial perception, and lack of haptics and kinaesthetic feedback. These affect culture, community type, space flexibility, technology, learning styles, evaluation methods, and whether course content and outcomes are physical (Saghafi et al., 2012). Emerging technologies like augmented reality (AR), virtual reality (VR), and extended reality (XR) offer potential to reduce these gaps. Although first applied in VDS in the early 2000s, AR/VR/XR are not yet widespread in distance education. These technologies enable immersive interaction with 3D models, enhancing reduced spatial perception in VDS (Tan et al., 2022; Crolla et al., 2024). However, due to the high cost of necessary hardware and software, their use remains experimental. A paradigm shift is likely once these become widely accessible. Meanwhile, blending VDS with face-to-face delivery is the simplest way to minimize VDS's major drawbacks and is gaining attention (Saghafi et al., 2012; Komarzyńska-Świeściak et al., 2021). Yet, instructors often resist losing familiar face-to-face methods (Peacock & Cowan, 2016), while younger students and instructors view virtual environments as routine (Resta & Laferrière, 2007). In some respects, rushing to blended approaches is status quo; attributing VDS limitations solely to missing sensory experiences shows a technology-dependent path, while blaming physical proximity reflects a resigned acceptance of current drawbacks.

Methodology

This chapter outlines the aims, implementation, and data collection methods of EINSTUDIO, a cross-national Erasmus+ undergraduate VDS project. In the broader context of educational transformation, projects like EINSTUDIO support the European Commission's (2020) goals of enhancing digital literacy and collaboration in higher education. Such cross-cultural design education fosters technical skills, promotes professional development in multicultural settings, encourages critical thinking, deepens diversity awareness, and advances sustainable, scalable education models for a digital-first, interconnected world (Rodriguez et al., 2016).

EINSTUDIO was launched after COVID-19 lockdowns ended and operated as a semi-hybrid VDS. It is ‘semi-hybrid’ rather than ‘hybrid’ because teams, composed of cross-national members, worked collaboratively; each member met proximate peers and tutors face-to-face but only encountered overseas participants virtually. Peer-learning occurred via five types of proximities and synchronicities: scheduled virtual class meetings, virtual private meetings, face-to-face class meetings, face-to-face private meetings, and an online discussion board. While class meetings were synchronous, others were occasional. This complex, semi-hybrid, semi-proximate, and semi-synchronous peer-learning model distinguishes EINSTUDIO from other studies and forms the focus of this research. Participants included tutors and students from Gazi University (Turkey), University of Beira Interior (Portugal), and University of Alicante (Spain).

The study’s scope centres on whether EINSTUDIO’s infrastructure, curriculum, and learning design effectively support cross-cultural peer-learning in VDS. Accordingly, the research primarily measured motivational outcomes. In psychology, self-reports are often preferred for assessing motivation (Touré-Tillery & Fishbach, 2014) through percieved quality (Kirchmer & Kim, 2023). Therefore, EINSTUDIO’s outcomes were analysed through student self-reports, offering rich insight into motivational effects from the students’ perspective, though limited to their viewpoint alone.

Infrastructure

EINSTUDIO utilised a web-based e-learning platform supporting both synchronous and asynchronous interactions, accessible via any preferred web browser. The platform features a blog for posting texts and media, replying, accessing a library of downloadable documents, and viewing various design and manufacturing YouTube videos embedded by instructors. It also includes an interactive schedule and team-based subfolders for uploading and managing tasks. Integrated with Zoom, the platform offers private video conference rooms accessible through or independently of the system. Teams held numerous private meetings for collaboration alongside general classroom sessions with all participants.

The main page links to ten sections: assessments, syllabus, schedule, studios involved, labs and libraries, applications, users, files, my homework, and group homework. Students have access to seven; applications, users, and group homework are tutor-only to manage infrastructure, accounts, and submissions.

The homepage (Figure 2) serves as a one-page, blog-like discussion board where all participants can share and comment. Instructors posted announcements, teaching materials, and community-building content, while students were expected to share progress and asynchronously communicate via texts, images, or videos. However, students rarely engaged here, resulting in an unexpected loss of peer-learning. This suggests that, given easy access to synchronous tools and popular asynchronous apps like WhatsApp, students pay less attention to public asynchronous interactions.

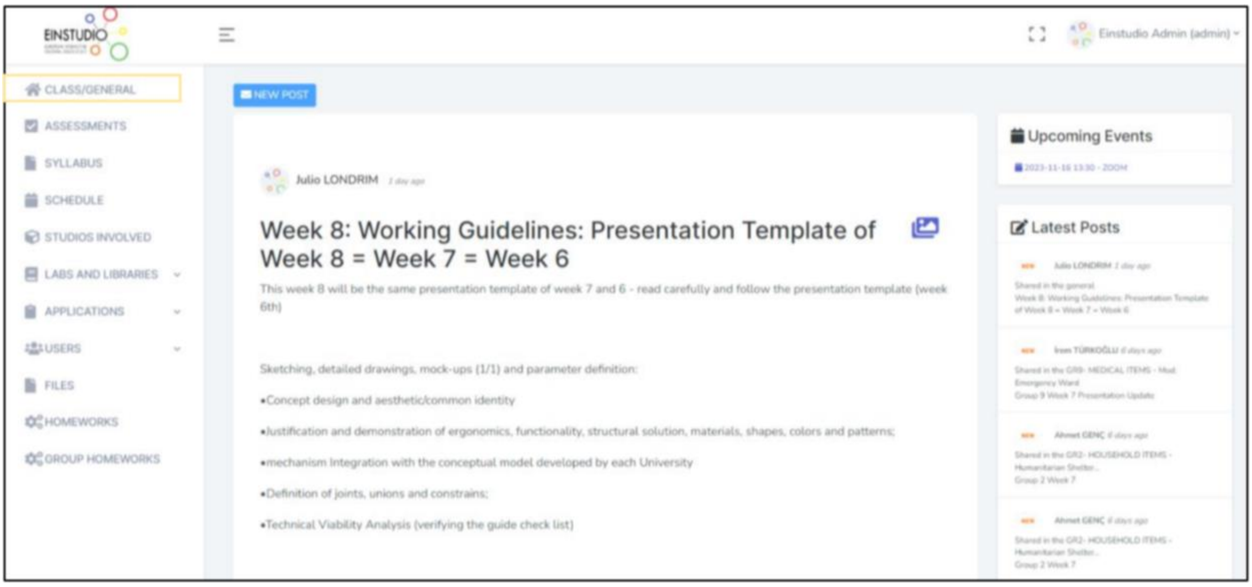


Figure 2. Main page of the EINSTUDIO platform (instructor sign-in)

The Assessments, Syllabus, and Schedule pages are simple one-page sections outlining upcoming tasks and events. As EINSTUDIO integrates Zoom and supports multiple simultaneous meetings, teams scheduled private meetings as well as the routine class meetings. While these private meetings were primarily limited to team members, tutors were occasionally invited to provide critiques or observe, with prior notice. Most meetings, however, remained closed to tutors. The remaining platform sections support scheduling or joining private or class meetings, uploading homework (Figure 3), and accessing pre-uploaded library materials.

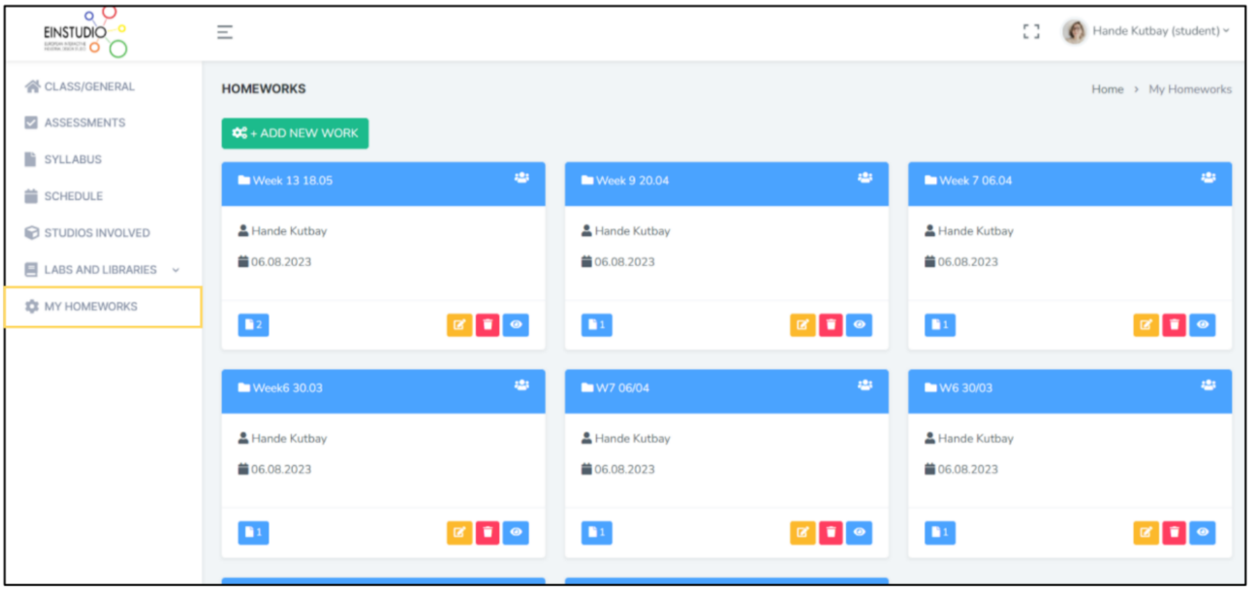


Figure 3. Homework page of the EINSTUDIO platform (student sign-in)

Syllabus

The course spanned 15 weeks and included 12 virtual crit sessions (Figure 4), up to 12 optional face-to-face crits per team, and three semi-hybrid juries (Figures 5). Attendance in virtual classes was mandatory, while face-to-face crits remained optional. All teams worked on the same general brief: designing the interior of a predefined minimum space (a 20-foot container) and six pieces of furniture sharing a unified design language. To complete the project, students were required to collaboratively decide on forms, colours, surfaces, textures, and usability—necessitating peer-to-peer critiques and intra-team decision-making.

Figure 4. A team of students taking crits from the tutors while whole class attending

Teams were expected to meet at least weekly, though many met more frequently. However, some struggled with coordination and required tutor intervention. During the first four weeks, teams conducted varying levels of research, ideated, and developed concepts through sketches. In week five, they participated in a semi-hybrid jury—local students met tutors face-to-face while remaining connected to the broader class via Zoom. Weeks six to eight focused on refining designs through sketches and mock-ups, culminating in an interim jury presentation in week nine. From weeks ten to thirteen, teams developed CAD and large-scale models aimed at implementation. The final jury, held in week fourteen, was semi-hybrid; some tutors traveled to attend in person. Week fifteen concluded with a synchronous exhibition across all participating universities.

Figure 5. Tutors watching a prototype being tested by the presenting team in another country

Sampling

A total of 85 design students from three partner universities participated in the study: 39 from Gazi University, 35 from the University of Beira Interior, and 11 from the University of Alicante. The cohort included second- and third-year undergraduate design students. Eleven instructors from these institutions—each experienced in VDS—facilitated the course. Students applied voluntarily, were interviewed, and selected based on their English proficiency and genuine motivation, excluding those seeking participation for unrelated reasons such as language practice or course avoidance. Prior to the project's launch, instructors met face-to-face to build collaborative rapport, while students from different countries interacted only virtually. Eleven teams were formed, each composed of seven to eight students: three or four from Gazi University, three or four from the University of Beira Interior, and one from the University of Alicante, assigned randomly.

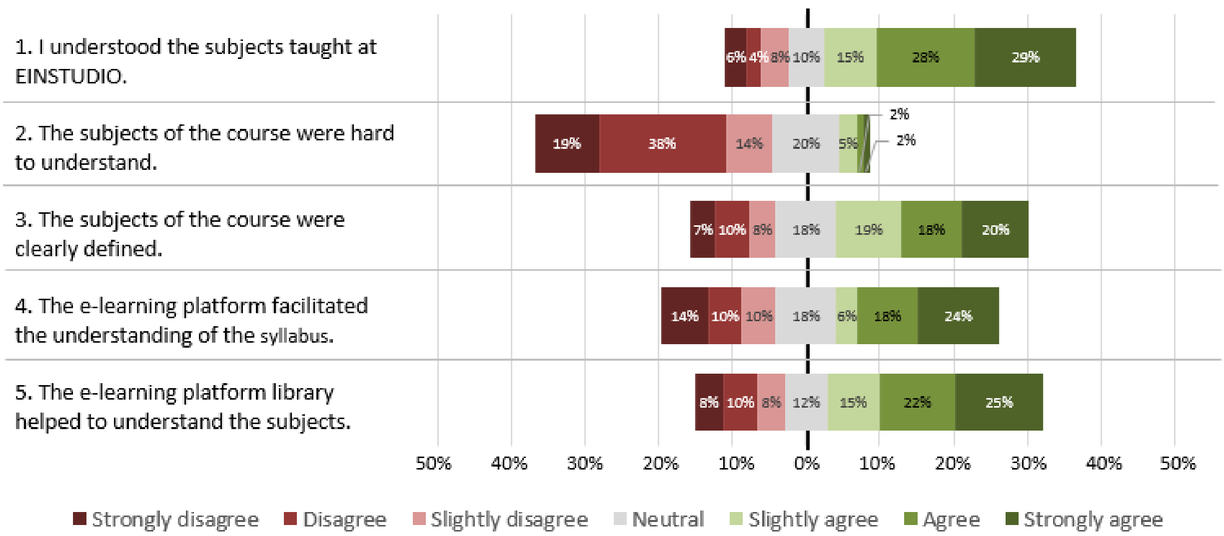
Data Collection and Analaysis

At the end of the semester, students were invited to complete an online survey. Participation was voluntary, and responses were anonymous. A total of 53 students completed the survey, representing 62% of EINSTUDIO participants. The survey included 43 seven-point Likert scale items. Based on recommendations from EINSTUDIO's quality-assurance partners, most statements were positively worded, with a few negatively framed to detect response bias. An additional open-ended question asked students to reflect on their overall experience. Each closed-ended item and its response distribution is presented in diverging bar charts in the next chapter. The open-ended responses were excluded, as they did not offer significant explanatory or complementary insights. Survey outcomes are discussed in the Discussion chapter, supported by instructor observations.

Findings

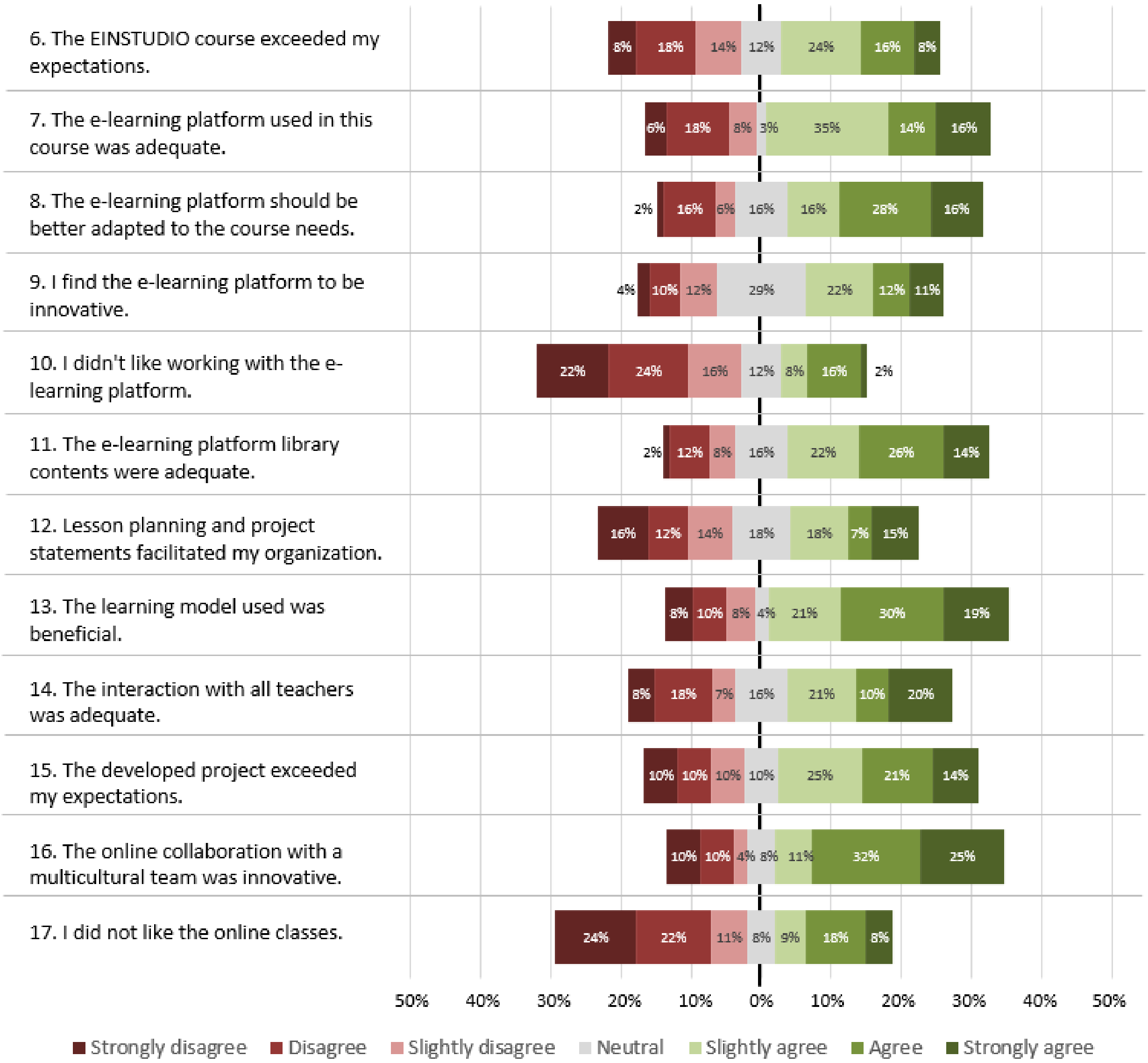
The first set of survey questions examined whether respondents had difficulty understanding the course's concepts, terminology, and theoretical content, and whether the e-learning platform supported their comprehension. While presenting the findings textually, the answers *slightly agree*, *agree* and *strongly agree* were merged, and vice-versa regarding the negative responses; detailed frequencies are given in the diverging bar charts.

Table 1. Frequency of responds to the survey questions 1-5



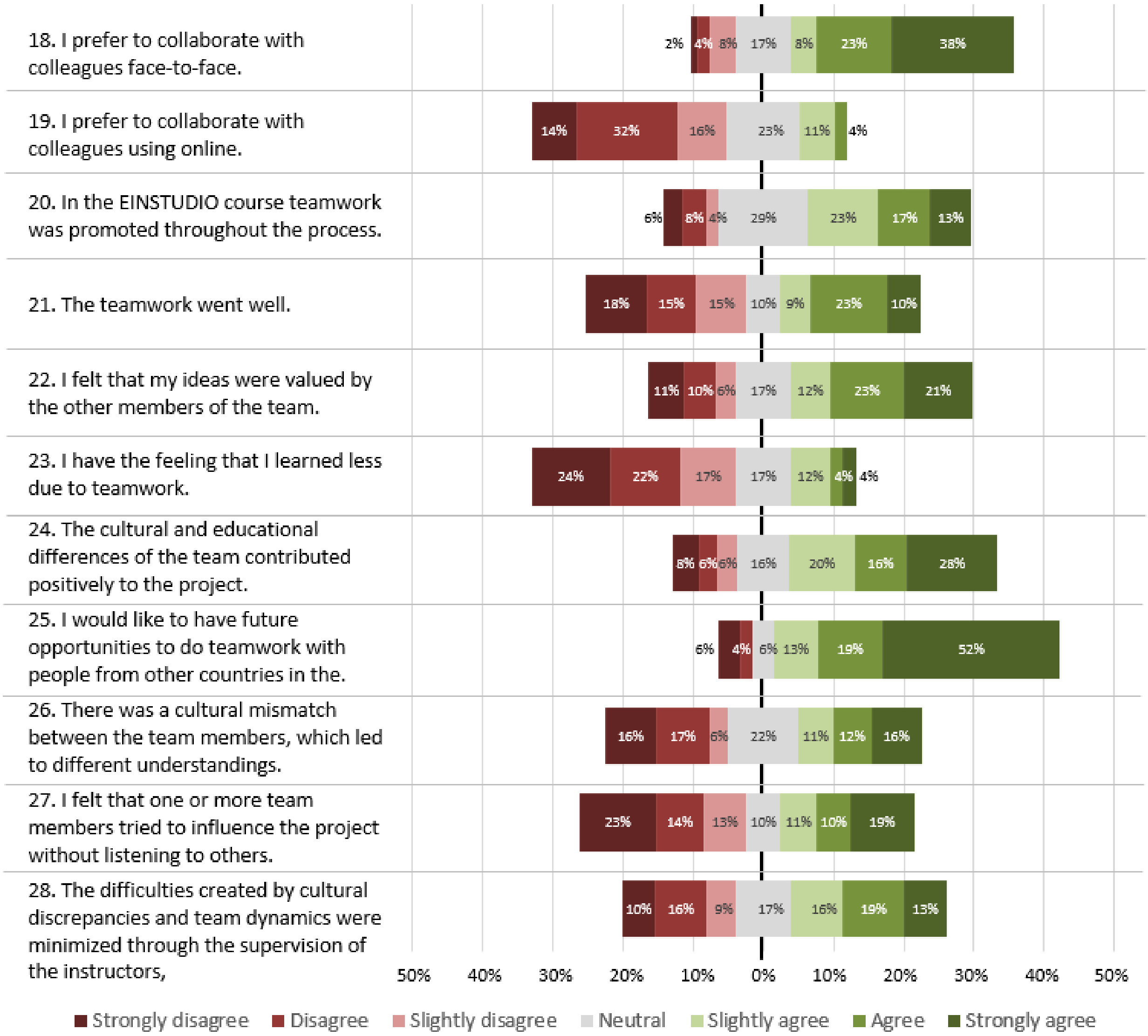
As illustrated in Figure 6, responses generally leaned toward agreement that the subjects were understood and the e-learning platform was supporting. However, 18% of students reported difficulties in understanding the content, and 25% indicated that the subjects were not clearly defined (questions 1 and 3) despite only 9% of the respondents found the subjects hard (question-2). Additionally, although fewer in number, a notable portion of respondents did not find the e-learning platform or its content helpful (questions 4 and 5).

Table 2. Frequency of responds to the survey questions 6-17



The next set of questions (Figure 7) further explored the perceived effectiveness of the e-learning platform and the overall learning model. In overall, respondents were positive about the e-learning platform in various means. While 65% agreed the e-learning platform was adequate (question 7), 60% also saw room for improvement (question 8). Additionally, 62% reported enjoying working with it (question 10), and 62% found the library function of the e-learning platform and uploaded content sufficient (question 11). Notably, 70% found the EINSTUDIO learning model beneficial (question 13), and 68% viewed cross-national collaboration via VDS as innovative (question 16). Despite these positive assessments, 35% still expressed dislike for attending virtual classes (question 17), and only 14% disagreed with a preference for face-to-face collaboration (question 18, Figure 8). In contrast, 62% disagreed with a preference for online collaboration (question 19, Figure 8), indicating a general tendency to favor in-person interaction despite the model's perceived benefits.

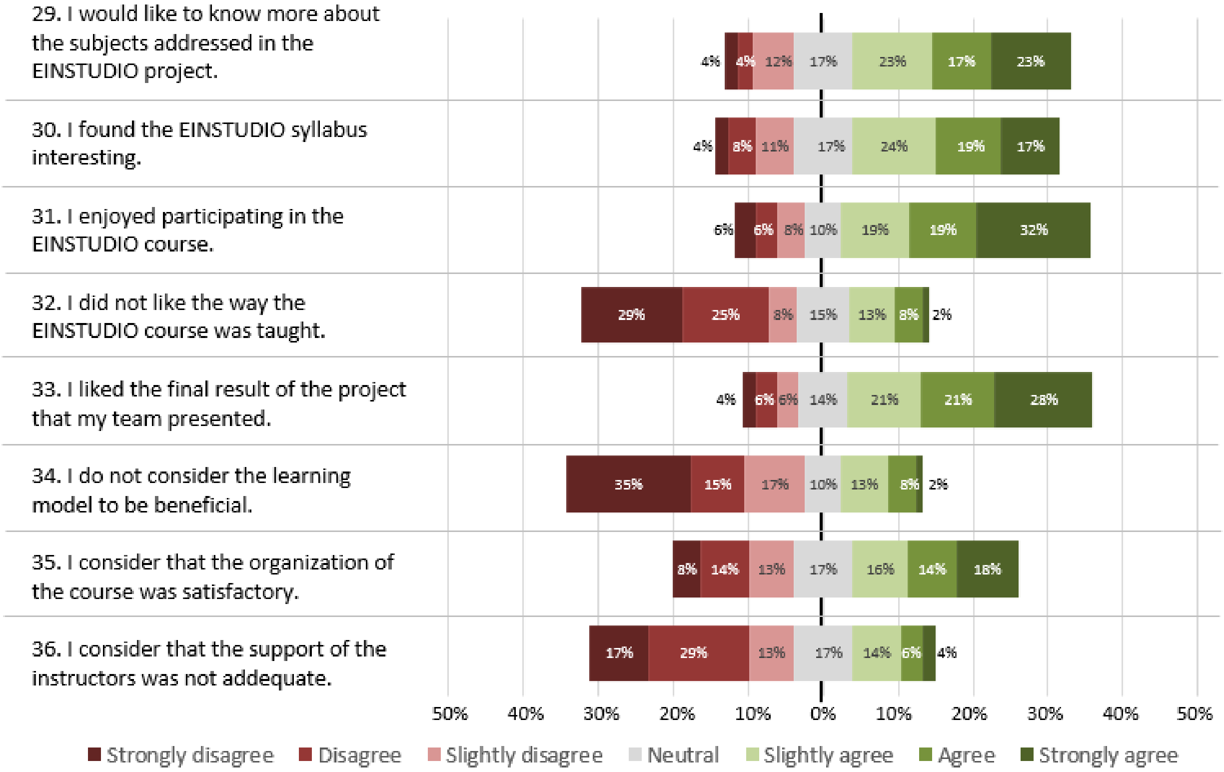
Table 3. Frequency of responds to the survey questions 18-28



The next set of questions (Figure 8) examined teamwork and cross-national collaboration. Overall, respondents were mixed or slightly negative regarding teamwork effectiveness: 48% responded negatively and 42% positively (question 21). Responses were equally split on whether cultural misunderstandings occurred (39% positive; 39% negative, question 26), and 50% disagreed that some members tried to dominate others, while 40% agreed (question 27). 48% felt instructors supported them in resolving team issues, compared to 35% who disagreed (question 28). Although a majority felt their opinions were valued, 27% disagreed and 17% remained neutral (question 22). Notably, 63% disagreed that teamwork hindered their learning (question 23), and 64% agreed that cultural and educational diversity was beneficial (question 24). A strong majority (84%) expressed interest in future cross-national studios, with 52%

strongly agreeing (question 25). Additionally, 53% agreed that EINSTUDIO's model supported teamwork, while 18% disagreed (question 20).

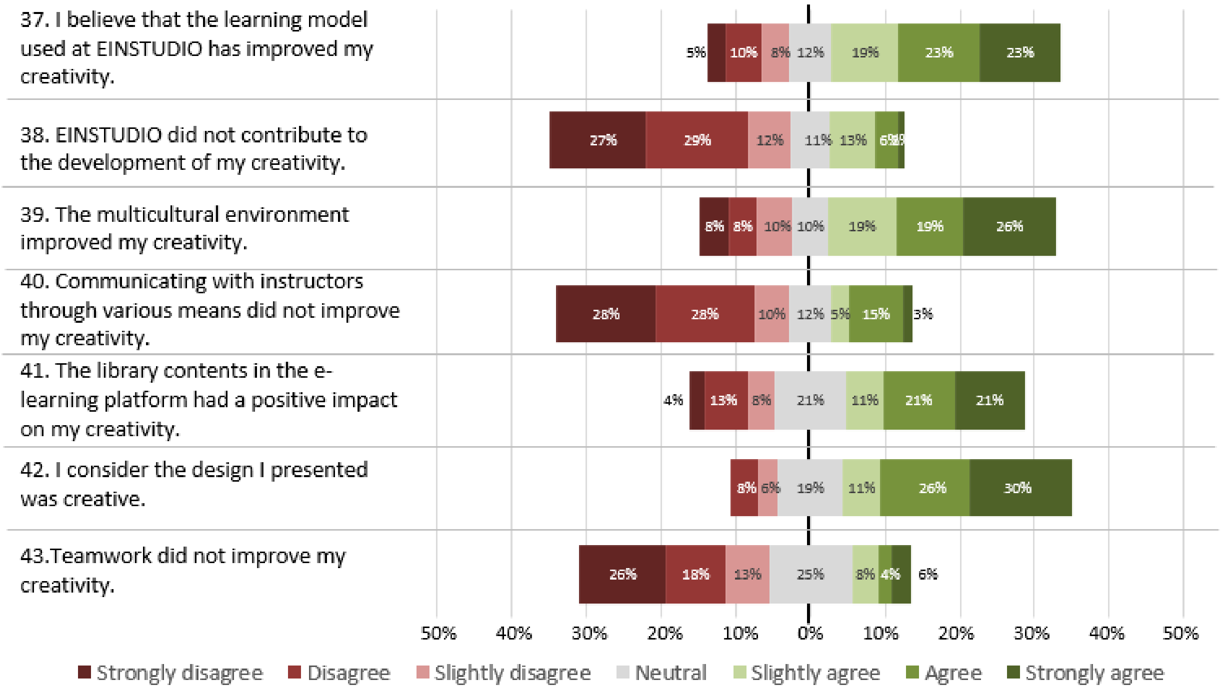
Table 4. Frequency of responds to the survey questions 29-36



The questions in Figure 9 evaluated participants' enjoyment of the course in terms of its content, syllabus, learning model, final designs, and instructor support. Overall, responses indicated a positive experience: 63% expressed curiosity to learn more about the EINSTUDIO Erasmus+ project (question 29), 60% found the syllabus interesting (question 30), and 70% enjoyed participating (question 31). Only 14% reported dissatisfaction with their team's final work (question 33). Additionally, 62% and 67% disagreed with negatively worded statements in questions 32 and 34, indicating they found the learning model both enjoyable and beneficial. However, 35% disagreed that the course was well-organized (question 35), representing the highest level of criticism across questions 29–36.

The final set of closed-ended questions examined how EINSTUDIO's semi-hybrid model, cross-cultural team structure, and e-learning platform influenced creativity (Figure 10). A majority of respondents found the cross-cultural and semi-hybrid aspects beneficial, with 64–67% agreeing with positively stated items (questions 37 and 39). Although fewer participants found the platform's library and content supportive of creativity, 53% still responded positively (question 42). Only 23% agreed that the semi-hybrid crit system failed to enhance creativity (question 40), suggesting that most viewed the model as beneficial. While 18% believed teamwork did not foster creativity (question 43), this is slightly lower than the 23–26% who disagreed that the cross-national setting and overall model supported creativity (questions 37 and 39), indicating that the team structure may have posed minor creative challenges. Notably, 66% disagreed with the negatively phrased question 38, the inverse of question 37, suggesting a low rate of careless or contradictory responses. As no significant inconsistencies emerged in other reversed items, the overall reliability of the responses is considered high.

Table 5. Frequency of responds to the survey questions 37-43



Discussion

Overall, half to two-thirds of the respondents agreed with the positively stated questions and disagreed with the negatively stated ones, evaluating their experience as either greatly or slightly satisfactory. On the other hand, findings indicated that the EINSTUDIO model negatively impacted the learning of some students—while not the majority, a notable portion of respondents, up to 18%, reported difficulties. Since it is expected that some students face more challenges than others in any type of class, it is impossible to clearly define how EINSTUDIO negatively affected their learning. However, considering that only 9% of respondents agreed that the course subjects were hard to understand, it is reasonable to infer that the other 9% of respondents, who did not find the subjects difficult but still had trouble, experienced a negative impact. Remarkably, more students disliked the VDS sessions compared to those who did not find the e-learning platform, semi-hybrid learning model, cross-national team structure, and syllabus beneficial. Furthermore, the majority preferred face-to-face collaboration over online interactions. The findings also show that cross-cultural teamwork was slightly more criticized compared to teamwork overall, indicating that issues with peer-learning in VDS were not strongly linked to cultural, educational, or social differences.

Task Sharing Versus Collaborating

Quoted directly from their statements during courses and informal dialogues, instructors provided feedback indicating that the overall quality of peer-learning in VDS could be improved by monitoring teams' communication issues more closely, transferring some members between teams when necessary, and ensuring equal contribution from all members. One instructor particularly suggested holding more virtual meetings outside of regular class hours to analyze student teams and prevent poor organization that might reduce efficiency. During the VDS sessions and face-to-face dialogues, it was observed that students often, both privately and sometimes publicly, asked instructors for help regarding collaboration issues. They reported that some members attended private meetings significantly less frequently. Almost all teams struggled with scheduling, not only due to time zone differences but also because of extracurricular commitments such as other homework and exams. Scheduling issues were more significant during the early phases, until students got to know each other better. Additionally, some students expressed concerns about not being valued within their teams, and the workload distribution was often unequal. Although only a few in number, some students struggled with fluent English and required continuous translation support. Consequently, these students were often socially distant, regardless of their willingness to contribute. It is therefore understood that some students experienced social anxiety when speaking a foreign language during teamwork and critiques, even though they had demonstrated sufficient English proficiency during the selection process.

Considering these issues, decision-making became more difficult for some teams. Anxiety about being valued, expressing themselves fluently, and fear of disagreements led many students to mistake teamwork for mere task-sharing instead of engaging in peer-to-peer critiques. Early in the course, students rarely evaluated each other's sketches and instead divided furniture design tasks individually. They avoided comparing designs until repeatedly encouraged to critique peers. This avoidance and misunderstanding of collaborative design caused significant struggles in developing a cohesive design language. Colors, styles, shapes, materials, and purposes were mismatched for a long time; however, most teams overcame these issues by the project's end. Ultimately, nearly all teams managed to create furniture sharing a common style (Figures 11, 12, and 13). Accordingly the major driver of peer-learning in this course was the requirement to collaboratively design a cohesive product family

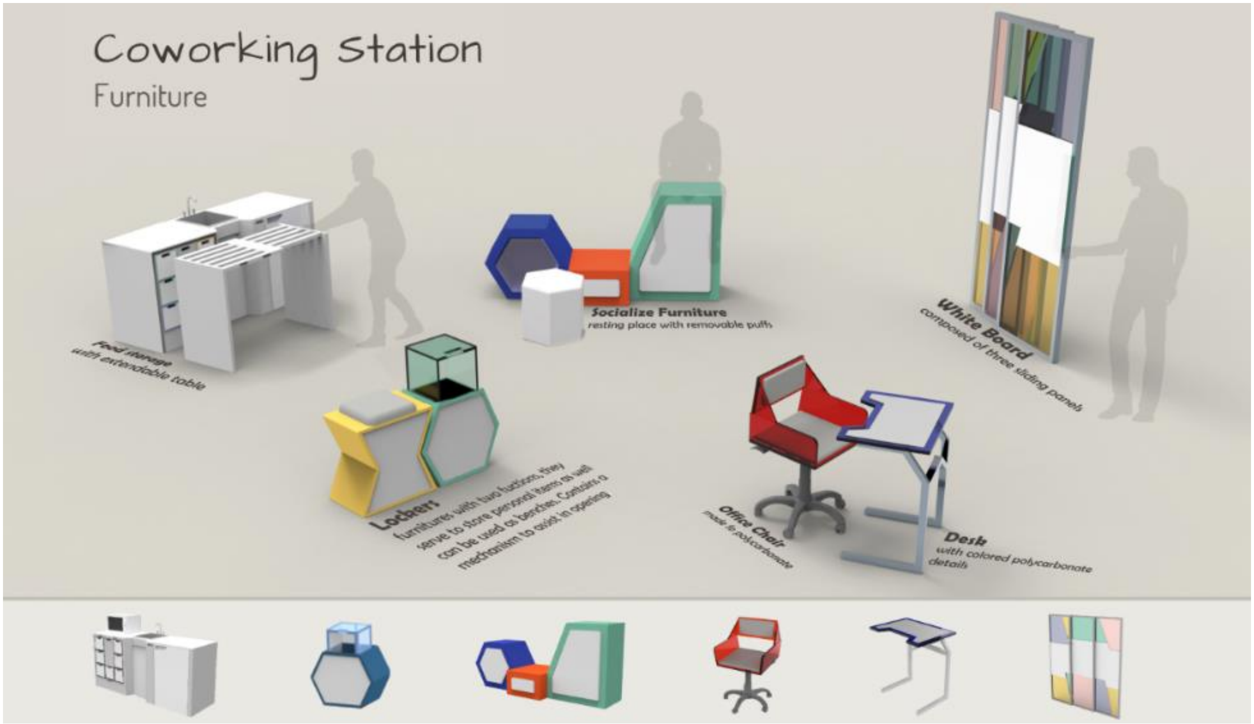


Figure 6. Co-working furniture pieces by individuals in a team

Figure 7. Medical furniture pieces by individuals in a team

Figure 8. Laboratory furniture pieces by individuals in a team

Conclusion

The post-2021 surge in VDS research created a widespread perception that physical distance undermines the quality of peer-learning. However, the anxiety stemming from the abrupt transition to online education limited a nuanced understanding of its actual challenges. Given that this unplanned shift negatively impacted student engagement (Gümüş Çiftçi et al., 2021), future research should critically reassess COVID-19-era claims that VDS inherently limits peer-learning (Alnusairat et al., 2020; Grover & Wright, 2023; Iranmanesh & Onur, 2021; Hepburn & Borthwick, 2021). While hybrid studio models have been shown to alleviate some of these issues, several studies also suggest that online-only studios can support peer-learning effectively. This paper argues that remaining limitations are more closely related to the absence of haptic and kinaesthetic feedback, and restricted spatial perception due to current display and audio technologies, rather than physical distance per se.

Although previous studies recommend teamwork or strategic student matching to enhance peer-learning in VDS, these strategies pose considerable challenges. This study finds that, without close tutor supervision and design constraints that necessitate collaboration—such as the requirement to develop a shared design language—teams tend to reduce teamwork to mere task division, foregoing collaboration, brainstorming, and decision-making via peer-crits. Multicultural teams, particularly those involving cross-national collaboration, introduce additional complexities that can hinder peer-learning. Nevertheless, engagement with culturally diverse partners remains one of the key benefits of VDS, as was evident in its earliest implementations in the 1990s. Based on student self-reports, EINSTUDIO's infrastructure and semi-hybrid model helped mitigate many challenges of virtual teamwork and cross-national collaboration. Despite its complexity, cross-culturality appeared to be a motivating and enriching element for most students.

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Book Review:
Studio Properties: A Field Guide to Design Education

Derek Jones, James Benedict Brown, Elizabeth Boling, James Corazzo, Colin M. Gray and Nicole Lotz (2025), Bloomsbury Visual Arts, UK

Reviewed by Lyndon Buck, Franziska Conrad and Gary Underwood, University of Southampton, UK

There is something special about a studio as a place of practice and learning, and *Studio Properties* seeks to be a field guide to the design studio in education, presenting a single reference source for research and scholarship in this area. The authors explain that the *Studio Properties* project, and the *Studio Matters* project before it, were motivated by the absence of a comprehensive reference text of scholarship on studio pedagogy aimed at scholars and educators. Theoretical works and teaching guides exist but tend to focus on certain aspects of the studio and no single text brings these ideas together under the idea of *Studio*. It aims to allow educators and researchers to quickly find and directly apply content to their own disciplines and contexts.

In this non-linear book, six authors from various design disciplines explore aspects of studio education, citing 700+ articles, books, and other pieces of writing, with the references section accounting for nearly 10% of the book. The components of studio are broken down into individual properties, with descriptions and research references to help explain the relationships between properties. Studio teaching is undoubtedly different and special, it's a particular place and pedagogy that operates in a distinct way, and the authors here have presented studio as a series of 57 interconnected properties, rather than attempt to provide a definition. The book does not define studio, and it doesn't intend to, so those looking for a template or guidebook on studio teaching may be disappointed.

The authors liken the book to a combination of a wiki, a field guide, and a pattern language, which enables readers to navigate between the whole and its parts and understand the interconnections between the properties. The book comprises *properties*, *clusters*, and *narratives*. The 57 *properties* describe things, events, interactions, or experiences in studio education. The 9 *clusters* are groups of properties that are thematically related. 2 *narratives* offer a first-person account of studio, with a view to provide insight into how properties interrelate, overlap and depend on one another. The book has an unconventional structure; it uses the clusters as chapters, and it isn't linear, using the 57 properties clustered thematically to describe the studio experience. Each property references multiple other properties, creating a web of patterns but also making reading the book for reviewing quite a challenge. It is interesting to read on the *Studio Properties* website that there were over 100 properties considered over the book's gestation, so there has been a fair amount of editing to get this far.

Each of the 9 *clusters* is densely packed with theoretical and practical insights into studio teaching and the developmental journey of students immersed in studio practice. Together, the clusters map the visible places, working practices, and emerging selves of studio life. Their scholarship is impressive, yet their accessibility varies and may feel unsuitable to readers seeking clear-cut guidance on studio support or, from a student perspective, navigational cues. There is no defined order or preferred linear path through the clusters, but for the purposes of this review they were split into 3 sections of 3 clusters per reviewer.

Visibilities & Proximities describes the studio as a room with “no obvious front” where artefacts, people and ideas circulate freely. For students this cluster provides orientation points: the diagrams of public/private zones and informal learning niches explain why sketchbooks sometimes end up on walls and why critique often happens in corridors. Educators will read the same pages as a reminder of lived studio experience, both as teachers and, likely, as former students themselves. The argument is vivid and well-illustrated; only its rapid cross-referencing to other properties, and at times densely written text, risks disorienting newcomers.

Foundations & Methods shifts the focus more toward design educators. Its six properties, *Apprenticeship*, *Design Brief*, *Active Teaching*, *Feedback*, *Critique* and *Reflection*, supply studio tutors with critical lenses. The apprenticeship section, for example, unpacks how the master–novice bond doubles as a “socio-economic model” that can entrench power not necessarily in tune with current learning practices. Likewise, the design brief is recast as “combustible fuel” that sparks, rather than contains, creative inquiry. Students will still glean practical tips on crit formats or brief types, but the heavy theorising can feel more like a literature review rather than a guide to studio practice.

Expertise & Identity reconnects both main audiences by reframing mastery as a relational journey, “not a static state” but a constellation of competences measured against social reference points. For students this becomes a growth map: moving from novice to competent designer is shown as iterative and personal. Educators gain a diagnostic vocabulary: character, judgement and performance replace mentoring and assessment. The section’s critique of monolithic expert/novice binaries is timely, though examples drawn from non-Western studios would have strengthened its claim to universality.

Time & Structures highlights how immersion, rhythms, and project cycles shape learning. The interplay of synchronicity and proximity - whether physical or digital - reveals the nuanced dynamics of studio learning environments and highlights the pressures design departments face in justifying the expense of such resources. Importantly, the authors critique assumptions around presenteeism and uniformity, advocating for flexible, inclusive approaches that accommodate diverse student circumstances. The theme of rhythms - of both students and educators - is particularly well addressed and offers a reminder of how easily this crucial and complex factor can be overlooked.

Artefacts and Making foregrounds the centrality of learning by doing, where making, prototyping, and play are not just activities but pedagogical tools. Artefacts emerge as boundary objects, mediating dialogue, reflection, and assessment. The authors also highlight the nuanced interplay between embodiment, intention, and context, and studio is framed as a dynamic site of experiential knowledge construction. Given the central role of physical and digital artefacts to studio, this chapter feels like it would benefit from additional content. For example, one element which is perhaps over-looked is the crucial role played by the teaching of practical and digital skills in enabling students to explore, make and communicate through their work.

Interactions and Sociality defines the studio as a collective space where learning is relational and dialogic. Listening-in, social networks, and confidence to speak are shown to be vital mechanisms for participation, identity formation, and professional development. The role of artefact-centred communication is highlighted and there is a pertinent reminder to educators to be mindful in the vocabulary they use in studio. The discussions on belonging and social comparison factors are also particularly enlightening and thought-provoking, and the book perhaps underplays the role of social media in this context.

Atmospheres and Place highlights the sense of belonging in studios and safe space is key to the concept of place and participants are key to placemaking. It is clear that a sense of belonging can affect positively affect wellbeing, motivation and engagement and it would be interesting to see some examples of how this has been achieved in various discipline specific situations. This cluster makes clear that emotions can have a significant impact on learning and staff-student relationships, and personal and creative transformation is an emotional process. Studio influences mental and physical wellbeing, those of us who have worked in studios will all have positive and negative experiences that we could share, and it would be interesting to see more of these shared. Informalities such as informal discussions and serendipity can create a relaxed and friendly atmosphere but these can also disenfranchise those who do not feel part of the studio culture. The cluster ends with a discussion on uncertainty and ambiguity - fundamental to design education but also one of the key stress raisers with students, especially in their early years of study.

Theories and Knowledge points out that creativity is assumed to be ubiquitous in studio environments but that this is sensitive to conditions and contexts. Risk and failure are necessary and central to creativity and learning from failure and risk taking requires certain conditions in studio, such as an open and playful atmosphere, adequate time, and opportunities to assess own performance. Risk and failure can develop capacities, attitudes, and resilience, this is all demonstrably true but there is little guidance about how this can be achieved while maintaining a creative and welcoming place. Educational studios aim to replicate or simulate those in professional practice yet with different pressures, with assessments and crits in studios rather than commercial or professional constraints. There is some discussion around discipline – with most studios being discipline specific or uni-disciplinary, with some studios working as multi-/inter-/trans-disciplinary and working across disciplinary boundaries in studio, but there could have been some specific examples of how these can work, and potential pitfalls of stepping outside of a single discipline per space. This cluster also discusses and defines some general education concepts and theories such as constructivism, experiential learning, threshold concepts, cognitive apprenticeships, communities of practice, problem-based learning, and project-based learning which could be useful for readers new to education. Finally, it looks at knowledge and knowing, with design knowledge taking varied forms such as precedent, intermediate-level, experiential and embodied, and tacit knowledge, and design knowledge also exists in things found in and around the studio. The authors point out that design knowledge is socio-political, and western design canon and biases exist in most literature around studio practices. This cluster ends with a discussion on the de-centring of western traditions to allow other forms of knowledge to be seen as relevant to studio practices.

Culture(s) and Power is the final cluster in the book where activities, spaces and interactions - the culture of studio - are discussed, and the issue of these often being pre-structured for the students so that it can be difficult for them to imagine how they might participate in shaping the culture and purpose of studio. Habits and rituals, contexts, beliefs, attitudes and norms, arrangements and choreographed interactions all form part of studio culture, and these can lead to a means of control or an unwritten way of controlling behaviours. There may be a hidden curriculum - knowledge and practices that students learn and incorporate into their praxis without being explicitly taught - such as studio crits.

Critical pedagogy is discussed again here, with design studio practice not being a universal approach, but developed initially by European schools and thus embodies European values and definitions of what design is and what a designer could/should be. The authors ask what new knowledge, practices, and ways of being could studio educators value as they co-construct curricula with students of diverse backgrounds? The cluster ends by considering the studio power transaction – the asymmetrical power distribution, the structured environment with formal rules and implicit and explicit structures, and how this is defined by social, historical and cultural power and how these in turn influence studio experiences and curricula. Enculturation, acculturation, and indoctrination are discussed as well as studio practices act as a means of controlling entry to a discipline, showcasing acceptable studio culture, and as a way of learning the language of a discipline through ritualised transactions such as the desk crit.

Narratives is the final part of the book if it is treated as a linear read, and this consists of 2 narratives without further explanation. In some ways, these work as a useful introduction to the language and structure of the book, and perhaps they should be read first, although they are perhaps a little crudely drawn. It isn't clear whether these are fictional or based on real experience, and at times they have overly detailed descriptions of the contexts but it is useful to see one narrative based on traditional studio teaching, and one on hybrid, and the challenges and benefits of each. It would certainly be interesting to read more of these from a more widely drawn circle of design educators, perhaps including school design educators.

Across the *clusters* the tone is scholarly yet personable, providing a balanced view of positives and negatives of studio practice, pointing out the difference that both online and offline studio environments can make to the visibility, motivation and engagement of different characters, students and educators alike. Praise is consistently paired with self-questioning, for example the defence of critique is followed by warnings about judgement eclipsing exploration. There is an acute awareness of the ongoing limitation of cultural diversity in design and the negative impact that can have on a student's design journey. This dialogue approach keeps the reader engaged; however, citation strings, foot-noted cross-links and nested definitions are likely to overwhelm less experienced readers, especially students, who may lack studio learning as well as design and educational experience. Novice designers will find some *clusters* digestible, some more theoretical, and a few potentially motivational. Educators, curriculum leads and researchers, meanwhile, could potentially receive a well-stocked critical toolkit from the complete 9 *clusters*. The book's ambition, to be both primer and provocation, is largely met, but newcomers may need more specific case studies to unlock its full potential.

While the structure and sub-headings offer a clear breakdown of the themes and reflect the breadth of the content well, the layout of the book can sometimes be distracting. The constant cross-referencing of words and page numbers can be off-putting and some of the diagrams add limited value. However, the tone of the book is approachable and thought-provoking, highlighting the complexity and depth of studios within a design context. Learning in studio is not linear or isolated but iterative, embodied, and deeply relational. It challenges reductive views of design education and offers a rich framework for understanding studio as a transformative space where knowledge, identity, and community are continuously negotiated and redefined.

The elephant in the studio is that this is not a field guide – generally a book for the identification of animals, birds, or flowers in their natural environment. It aims to be a practical and academic text - practical in that it addresses the reality of being an educator or student in studio, academic in that it is informed by relevant, rigorous scholarship and research but it reads as much more of an academic than a practical one. This may limit its relevance to students and those starting out on their studio journeys. Each time a property is mentioned it is highlighted in the text with page numbers to aim navigation, but this can be very distracting. There are maps and figures but no images - these add little to the understanding of the text, and some images of studio environments to give context would really help at times, such as when discussing the Importance of artful surfaces and personal workspaces and the act of gathering to positive student agency in studio.

The ***Studio Properties*** will continue beyond this as an online resource where audience participation is encouraged. Those interested in exploring, developing, or thinking about studio properties and practices are asked to get in touch with the authors. By expanding the range and scope of the examples and narratives of studio and incorporating some compelling visual content of studio environments across various educational settings, the authors should be able to maintain the momentum of exploration into the design studio that this book has started.

Studio Properties: A Field Guide to Design Education is published by Bloomsbury Visual Arts and is also available as open access under a Creative Commons international licence (CC BY-NC-ND 4.0) funded by the Open University and is supported by additional online resources at https://studioproperties.org/ including upcoming events (autumn 2025) and articles.