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Leveraging Digital Fieldwork Tools in Design Studios: Towards Affordable and Sustainable Education

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ABSTRACT

The rapid shift toward digital and learner-centred pedagogies has transformed how design education connects students with real-world contexts. This study explores the integration of Digital Fieldwork Tools (DFT) in the design studio as an innovative teaching strategy to strengthen teaching excellence and learner-driven engagement. Grounded in the principles of experiential and technology-enhanced learning, the study aims to evaluate DFT's contribution to affordable, sustainable, and inclusive educational practices. A quantitative approach was employed, involving all final-year planning students undertaking the design studio project during the current semester. The study investigates students' patterns of DFT utilisation, perceived learning effectiveness, and the pedagogical challenges encountered throughout the process. Preliminary findings reveal that DFT significantly enhances students' ability to collect, analyse, and interpret site data, while fostering critical thinking, collaboration, and digital literacy. However, issues such as uneven digital competence and infrastructure limitations continue to affect optimal adoption. The study concludes that integrating DFT into studio-based teaching not only enhances students' engagement and autonomy but also promotes affordable and sustainable approaches to higher education. These findings provide valuable insights for educators seeking to innovate teaching methods and align classroom experiences with the demands of contemporary digital learning environments.

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1. INTRODUCTION

The landscape of higher education in design and planning disciplines is experiencing a profound transformation driven by rapid technological advancements, evolving professional expectations, and a growing commitment to learner-centred pedagogies. Studio-based learning, long regarded as the cornerstone of design and planning education, encourages experiential engagement, iterative critique, and reflective practice through authentic, real-world problem-solving. Traditionally, fieldwork and site immersion have been integral to this approach, enabling students to contextualise spatial, social, and environmental dimensions of design. However, conventional fieldwork practices are often resource-intensive, time-consuming, and logistically demanding. These challenges have amplified the need for innovative, technology-enhanced pedagogies that maintain the experiential essence of studio learning while ensuring accessibility, affordability, and sustainability.

Within this evolving educational paradigm, Digital Fieldwork Tools (DFT), including mobile GIS applications, online survey instruments, and cloud-based collaborative platforms, have emerged as transformative mechanisms that extend studio-based learning beyond physical boundaries. These tools enable students to collect, visualise, and analyse spatial data in real time, thereby bridging the gap between on-site investigation and digital exploration. They facilitate remote and hybrid learning, offering authentic site engagement even when in-person fieldwork is constrained. Recent research affirms that integrating digital platforms into design education enhances interactivity, spatial reasoning, and learner motivation, particularly in flexible or hybrid environments (Kee, Zhang, & King, 2024; Süner-Pla-Cerdà, Öztürk, & Ünlü, 2025). Beyond improving accessibility, DFT also fosters digital literacy, data competence, and collaborative problem-solving skills that are essential for future urban and regional planners operating in data-driven professional contexts.

The pedagogical value of DFT can be theoretically understood through Experiential Learning Theory (ELT) and Activity Theory (AT). ELT posits that learning occurs through a cyclical process of concrete experience, reflective observation, abstract conceptualisation, and active experimentation (Lamb et al., 2023). In design studios, DFT mediate each stage: mobile applications facilitate field data collection, cloud platforms support reflection and discussion, digital mapping aids conceptual understanding, and design simulations promote iterative experimentation. Technology thus strengthens the reflective and feedback processes central to experiential learning. In contrast, Activity Theory (AT) provides a systemic lens that explains how learning is mediated by interactions among learners, instructors, tools, institutional norms, and communities (Lee, Lin, & Hou, 2025). It suggests that contradictions such as unequal digital competence or infrastructural limitations can either inhibit or stimulate innovation, depending on the level of pedagogical and institutional support.

Equally significant is the principle of technology. Pedagogy alignment, which emphasises that digital tools must serve intentional educational purposes rather than act as supplementary features. Liu, Zhang, and Gao (2023) argue that the impact of educational technology depends on how well it aligns with learning outcomes, assessment design, and reflective engagement. In design studios, DFT should therefore be strategically embedded in core project stages such as site analysis, data synthesis, and design communication. It is to maximise their pedagogical effect. When effectively aligned, these tools reinforce experiential learning, deepening students' cognitive engagement and reflective capacity.

Despite its potential, challenges persist in effectively integrating DFT. Traditional fieldwork offers sensory and embodied experiences that digital environments cannot fully replicate, while digital fieldwork faces obstacles related to access, digital literacy, and infrastructure. These barriers are especially acute in developing contexts, where disparities in connectivity and technical readiness constrain equitable participation. Without structured pedagogical frameworks and institutional support, DFT risks being underutilised, leading to superficial rather than transformative learning outcomes. It is emphasised that successful digital transformation requires competency-based training, institutional investment, and equitable access to technology.

Against this backdrop, the objectives of this study are to (1) assess the level and patterns of DFT utilisation among design studio students; (2) evaluate their effectiveness in enhancing learning efficiency, site understanding, and engagement; and (3) identify challenges and institutional supports necessary for sustainable implementation. Employing a quantitative research design, the study involves final-year students enrolled in the Design Studio course in the Faculty of Built Environment. Beyond empirical analysis, the study contributes conceptually to discussions on digital innovation in design education, demonstrating how DFT advances affordability, inclusivity, and sustainability while nurturing autonomy, critical thinking, and digital competence attributes essential for future-ready professionals.

Ultimately, this research seeks to inform educators, curriculum developers, and policymakers seeking to strengthen technology-enabled studio pedagogy while preserving its reflective and collaborative core. It positions DFT as a catalyst for equitable access, lifelong learning, and professional readiness, aligning technological innovation with pedagogical intent to advance higher education's broader mission of balancing excellence, inclusivity, and sustainability in an increasingly digital era.

2. PEDAGOGICAL PERSPECTIVES AND SCHOLARLY CONTEXT

This section explores the pedagogical perspectives and scholarly foundations that frame the study. It synthesises theoretical frameworks and recent empirical evidence to explain how Digital Fieldwork Tools (DFT) have reshaped studio-based learning in design and planning education. The discussion highlights the relevance of Experiential Learning Theory (ELT) and Activity Theory (AT) in understanding student engagement with digital tools and examines how current scholarship addresses both the opportunities and challenges of embedding these tools within learner-centred and sustainable pedagogical models.

Digital Fieldwork Tools (DFT), encompassing mobile GIS applications, collaborative mapping platforms, digital field notebooks, and online survey systems, have become catalysts for rethinking technology's role in design education. Post-2022 research underscores that digital tools can retain the essential experiential qualities of traditional fieldwork while enhancing accessibility, scalability, and analytical capacity (Maddison, Bevan, & Marsham, 2023; Kee, Zhang, & King, 2024). DFT enable students to capture, organise, and interpret spatial information in real time, fostering critical and reflective engagement with site-specific contexts. Moreover, they extend the studio beyond geographical boundaries, aligning with the global transition toward hybrid, inclusive, and data-driven education models (Süner-Pla-Cerdà, Öztürk, & Ünlü, 2025). Through their integration, educators preserve the authenticity of field experiences while simultaneously promoting collaboration, sustainability, and digital competence.

Kolb's Experiential Learning Theory (ELT) (Kolb, 2015) provides a fundamental lens for understanding how DFT enhance learning processes in studio environments. ELT conceptualises learning as a cyclical process involving concrete experience, reflective observation, abstract conceptualisation, and active experimentation. Within digitally supported studios, each stage is mediated by technology: mobile GIS facilitates concrete experiences through site data collection; cloud-based platforms encourage reflective dialogue; digital mapping tools support conceptual understanding; and iterative simulations enable experimental testing of design ideas (Lamb et al., 2023; Kee et al., 2024). This digital mediation strengthens reflection-in-action (Schön, 1983), accelerating feedback loops and enhancing self-directed learning. Studies on immersive and hybrid education affirm that technology-mediated feedback fosters deeper engagement and iterative refinement of design ideas (Guillaume, Laurent, & Genge, 2023). However, Liu, Zhang, and Gao (2023) caution that technology's pedagogical value depends on how purposefully it is integrated into reflective, inquiry-based learning processes.

While ELT addresses individual cognitive cycles, Activity Theory (AT) (Engeström, 2015) situates learning within a wider socio-institutional context. AT views learning as a dynamic system involving learners, instructors, tools, rules, and communities. Within this framework, DFT act as mediating artefacts that connect students to design tasks, peer collaboration, and collective studio goals. Engeström (2015) and subsequent scholars argue that contradictions such as limited digital training, misaligned institutional policies, or unequal access often shape the success or failure of technological integration (M. Kamaruzzaman, 2013). AT thus emphasises that educational transformation relies not only on adopting digital tools but also on establishing supportive structures, equitable access, and coherent pedagogical alignment across curricula.

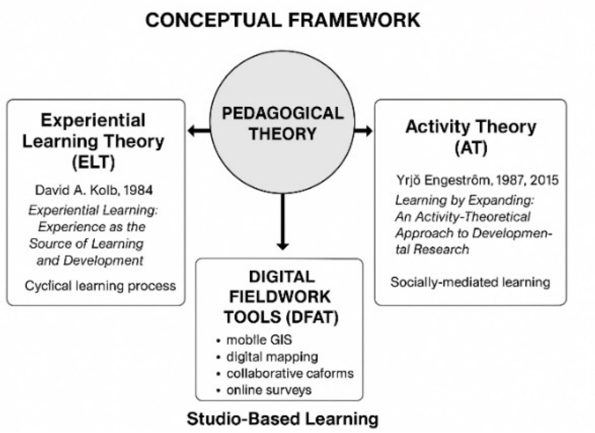

Fig. 1 *Conceptual Framework integrating Kolb's Experiential Learning Theory (ELT) and Engeström's Activity Theory (AT) in Digital Fieldwork Tools- enabled Studio Learning. Modified from Kolb D.A. (2015) and Engeström, Y. (2015).*

The conceptual framework of this study integrates ELT and AT to explain how DFT functions at the intersection of experiential and systemic learning processes (see Fig. 1). ELT addresses the micro-level learning cycle of reflection and experimentation, while AT situates these activities within the macro-level ecosystem of institutional and social interactions. At their intersection, DFT serve as a pedagogical mediator that bridges individual experience with collective, technology-enhanced collaboration. Tools such as mobile GIS, collaborative mapping, and online surveys enable students to efficiently collect, analyse, and communicate spatial data, thereby establishing DFT as the operational link between reflective learning and participatory studio practice.

Beyond these theoretical foundations, contemporary scholarship emphasises technology–pedagogy alignment, the principle that technological adoption must directly serve educational intent. Liu, Zhang, and Gao (2023) and Rossiter (2022) argue that effective learning design requires clear alignment between tool affordances, learning objectives, and assessment rubrics. In design studios, DFT should therefore be embedded throughout project workflows from site analysis to proposal development. It's to ensure meaningful engagement and authentic assessment (López-Núñez et al., 2024). When digital activities are disconnected from grading or studio critiques, their pedagogical impact is often diminished.

Despite strong pedagogical potential, barriers persist. Unequal access to devices, inconsistent internet connectivity, and varying levels of digital literacy continue to limit the integration of DFT (Mejías-Acosta, Vargas-Cano, Cárdenas-Cobo, & Vidal-Silva, 2024). Addressing these gaps, this study investigates how final-year planning students utilise DFT within their Design Studio: Special Area Plan (SAP) projects. It examines how these tools influence learning efficiency, engagement, and reflective practice, and identifies the institutional support mechanisms necessary for sustainable and inclusive integration. By situating DFT within the dual frameworks of ELT and AT, the study bridges theory and practice, contributing new insights into how digital innovation fosters affordable, equitable, and sustainable studio-based learning.

3. RESEARCH METHOD

This study employed a quantitative research design to examine the utilisation, perceived effectiveness, and implementation challenges of Digital Fieldwork Tools (DFT) in studio-based learning. Grounded in a positivist paradigm, the methodological framework facilitated objective measurement and statistical analysis of students' experiences with DFT during design studio activities. A structured questionnaire served as the primary data collection instrument, addressing three key objectives: (1) to assess the level of DFT utilisation among students, (2) to evaluate students' perceptions of DFT effectiveness in enhancing studio learning, and (3) to identify challenges and institutional support mechanisms for sustainable integration. The research was undertaken within the Design Studio: Special Area Plan (SAP)

Project, a core capstone course for final-year students of the Bachelor of Urban and Regional Planning programme. This real-world, field-based learning environment provided an ideal setting for students to employ DFT for digital mapping, mobile data collection, spatial analysis, and collaborative communication. A total of 60 final-year students participated through a census sampling method, ensuring full representation. The questionnaire utilised a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree), and its content validity was confirmed by three experts in studio pedagogy and digital education. A pilot test with 10 students produced Cronbach's Alpha values exceeding 0.70, indicating high internal consistency. Data were collected online over seven weeks and analysed using SPSS through descriptive and inferential statistics. This systematic approach enabled a robust evaluation of how DFT contribute to experiential engagement, reflective learning, and sustainable pedagogical practices within studio-based education.

4. RESULTS AND DISCUSSION

This section presents the results and discussion of the quantitative findings concerning students' utilisation patterns, perceived effectiveness, and challenges in adopting Digital Fieldwork Tools (DFT) in the design studio. The discussion is structured according to the study objectives and interpreted in light of relevant empirical and theoretical literature. The analysis aims to demonstrate how DFT enhance affordability, inclusivity, and sustainability in contemporary studio-based education.

4.1 Utilisation Patterns of Digital Fieldwork

The results demonstrate a high level of engagement with Digital Fieldwork Tools (DFT) among students in the planning studio. As shown in Fig. 2, 94.2% of respondents reported using DFT during their studio projects, with 46.2% using it very frequently and 40.4% frequently. This pattern reflects the progressive integration of digital tools into the design studio environment. The finding indicates that digital tools have become fundamental components of studio pedagogy, enhancing students' ability to collect, interpret, and communicate spatial data efficiently.

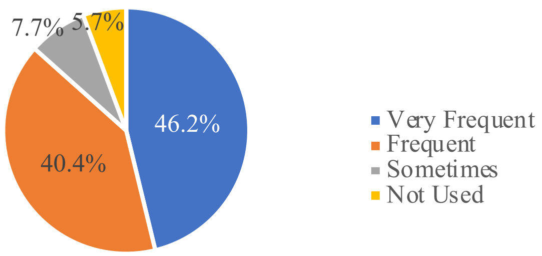

Fig. 2 *Frequency and Level of Use of Digital Fieldwork Tools (DFT) among Planning Studio Students.*
Source: Author (2025)

Among the DFT platforms adopted, Carry Map, Google Forms, and ArcGIS Field Maps were the most frequently used (see Fig. 3). These tools serve specific functions, including location monitoring, digital mapping, and cloud-based data collection. Their use demonstrates a pragmatic selection pattern: students choose tools based on accessibility, affordability, and ease of integration into collaborative studio workflows. This pattern aligns with the Technology Acceptance Model (López-Pastor et al., 2022), which emphasises perceived usefulness and ease of use as drivers of adoption. Similarly, Phantuwongraj, S. et al. (2021) reported that mobile GIS platforms improve spatial reasoning and field-based comprehension, reinforcing the pedagogical value of digital mapping tools in planning education.

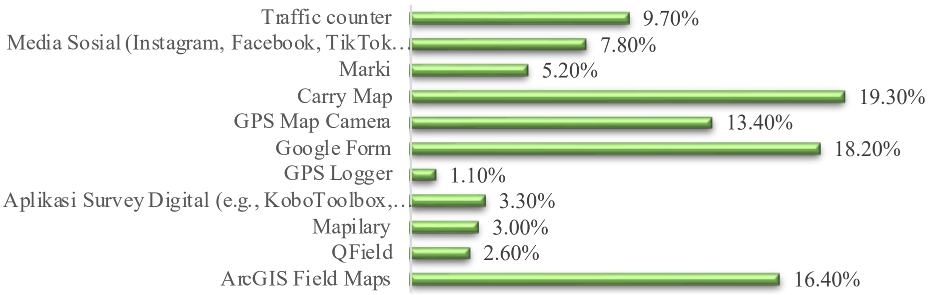

Fig. 3 *Categories of Digital Field Assistance Tools Preferred by Students.*
Source: Author (2025)

The analysis of the purposes of DFT utilisation, as in Fig. 4, reveals that students primarily used DFT for efficient data management (39.3%) and rapid data analysis (29.5%), followed by real-time feedback collection (23.8%). These outcomes reflect the growing importance of DFT in enhancing affordability by reducing reliance on physical surveys and printed materials. By streamlining data workflows, DFT enable cost-effective, sustainable learning models consistent with Sustainable Development Goal 4 (Quality Education), which advocates for equitable access to digital learning resources.

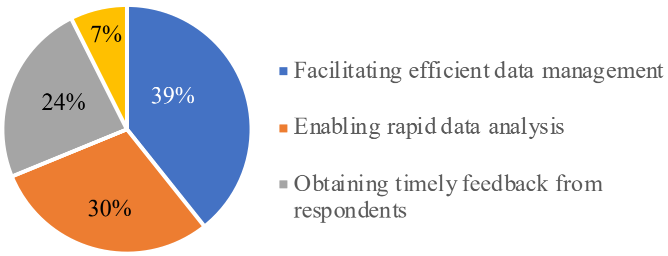

Fig. 4 *Purpose of Using Digital Field Assistance Tools (DFAT)*
Source: Author (2025)

4.2 Perceived Effectiveness of DFT in Studio Learning

Students' perceptions of DFT effectiveness were evaluated using a set of seven items with strong internal reliability (Cronbach's Alpha = 0.90; Table 1), exceeding the 0.70 threshold recommended by Hair et al. (2019). This confirms that the scale used to measure perceived effectiveness was both valid and internally consistent.

Table 1
Summary of Reliability Analysis

Item	Statement	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
C7	Assisting in site understanding	0.866	0.882
C8	Confidence in using data	0.875	0.876
C9	Facilitating interaction	0.705	0.897
C10	Saving time and effort	0.619	0.907
C11	Enhancing students' motivation	0.736	0.893
C12	Data accuracy	0.622	0.918
C13	Understanding user require-ments	0.823	0.885
Overall Cronbach's Alpha	—	**0.90**	

Source: Author (2025)

Descriptive findings in Table 2 indicate generally positive student perceptions of DFT effectiveness, with mean scores ranging from 4.04 to 4.71 on a 5-point Likert scale. The item "saving time and effort" (M = 4.71, SD = 0.498) received the highest rating, demonstrating students' recognition of DFT as efficient, time-saving tools that streamline fieldwork processes. This finding supports Musa et al. (2025), who noted that digital learning platforms enhance productivity by reducing manual repetition. Conversely, the lower mean for "Data accuracy" (M = 4.04, SD = 1.047) reflects uneven technical proficiency, echoing Silva-Quiroz et al. (2024)'s call for systematic digital training and quality assurance in geospatial data handling.

Table 2
Students' Perceptions of DFAT Effectiveness

Item	Statement	Mean	Standard Deviation
C7	Assisting in site understanding	4.50	0.642
C8	Confidence in using data	4.37	0.886
C9	Facilitating interaction	4.40	0.634
C10	Saving time and effort	4.71	0.498
C11	Enhancing students' motivation	4.35	0.789
C12	Data accuracy	4.04	1.047
C13	Understanding user requirements	4.29	0.696

Source: Author (2025)

The one-sample t-test, as shown in Table 3, confirmed that students' perceptions were significantly positive (M = 4.38, SD = 0.61, t(51) = 16.29, $p < 0.001$). The statistical evidence reinforces the argument that DFT contribute substantially to improving studio learning efficiency and engagement. Similar to the findings of Panchbudhe et al. (2024) and Sethapong, L et al. (2024), integrating accessible digital tools such as Google Forms facilitates immediate feedback, reflective learning, and sustained participation—key factors for affordable and interactive education.

Table 3
One-Sample T-Test Results for Students' Perceptions of DFT Effectiveness

Variable	N	Mean	Standard Deviation	Test Value	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference
Perception	52	4.38	0.61	3.0	16.29	51	0.000	1.38	[1.21, 1.55]

Source: Author (2025)

4.3 Challenges and Support Mechanisms for Sustainable Implementation

Despite high adoption and satisfaction levels, several challenges hindered the optimal integration of DFT. As shown in Fig. 5, the three most significant issues identified were unstable internet connectivity (69.2%), limited digital skills (55.8%), and time constraints in mastering new tools (53.8%). These constraints mirror systemic barriers highlighted in the higher education literature, particularly in developing regions where digital infrastructure remains unevenly distributed (López-Núñez et al., 2024; Musa et al., 2025).

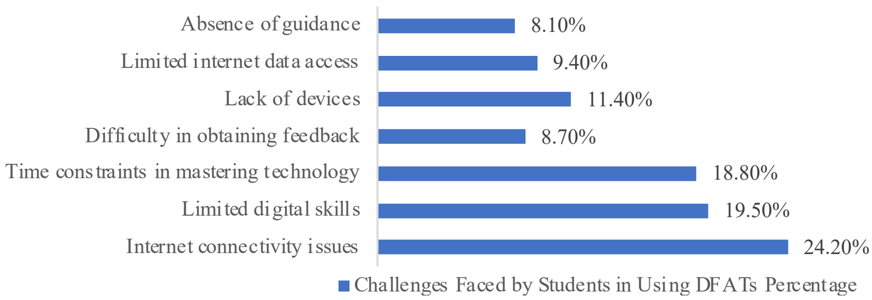

***Fig. 5** Challenges Faced by Students in Using DFTs.*
Source: Author (2025).

The cluster analysis, as in Table 4, grouped students into three distinct challenge categories:
(i) Technology & Support Challenges – dominated by connectivity and device limitations;
(ii) Skills & Interaction Challenges – reflecting insufficient digital literacy and difficulty in receiving feedback; and
(iii) Time & Mastery Challenges – representing learning fatigue and limited exposure to advanced DFT features.

Table 4
Cluster Groups Based on Students' Challenges in Using Digital Tools

Cluster	Key Challenge Characteristics	High Challenge Items (Score = 2)	Cluster Label
1	Technical access and support issues	Internet, Devices, Limited data, Lack of guidance	Technology & Support Challenges
2	Limited skills and interaction	Limited digital skills, Difficulty in feedback, Devices	Skills & Interaction Challenges
3	Time constraints and mastery of technology	Limited digital skills, Time to master tools, Limited data, Guidance	Time & Mastery Challenges

These clusters underline that sustainable DFT integration requires differentiated interventions. For instance, Cluster 1 issues call for infrastructure improvements and offline-compatible applications, while Cluster 2 and 3 issues highlight the importance of continuous training and incremental learning modules. Successful hybrid studios depend not only on digital access but also on pedagogical scaffolding that balances innovation with inclusivity.

5. FINDINGS AND SYNTHESIS

The findings confirm that integrating Digital Fieldwork Tools (DFT) within design studios establishes a transformative model for affordable, efficient, and sustainable learning. High utilisation levels and positive student perceptions demonstrate that DFT significantly enhance productivity, engagement, and experiential understanding. These outcomes correspond with global shifts toward blended, data-driven pedagogies that unite fieldwork authenticity with digital flexibility (Urban Design International, 2025). From an affordability standpoint, DFT reduce logistical costs related to transportation, printing, and manual data handling, while cloud-based platforms promote real-time collaboration at minimal expense, supporting López-Pastor et al.'s (2022) assertion that sustainable education depends on accessibility and affordability. Sustainability also extends to digital equity and capacity building, which require institutional support for micro-credential training in GIS, mobile mapping, and digital ethics (Silva-Quiroz et al., 2024). Pedagogically, the findings reaffirm Schön's (1983) reflective practitioner model, demonstrating how DFT fosters iterative reflection, feedback, and critical engagement, which are fundamental to sustainable, high-quality design education.

6. SUGGESTIONS

To ensure the sustainable integration of Digital Fieldwork Tools (DFT) into design studio education, institutions should strengthen their digital infrastructure, particularly connectivity and access to devices. Embedding structured digital literacy and micro-credential programmes in mobile GIS, data management, and digital ethics can enhance long-term competence. Educators should align the use of DFT with learning outcomes, project assessments, and reflective practices to maximise pedagogical value. Institutionalising collaborative cloud platforms will foster teamwork and peer learning, while continuous monitoring and feedback mechanisms are essential for evaluating effectiveness, addressing challenges, and ensuring equitable, affordable, and pedagogically relevant technology adoption across diverse learning environments.

7. CONCLUSION

This study concludes that integrating Digital Fieldwork Tools (DFT) in design studio learning offers a transformative pathway toward affordable, efficient, and sustainable higher education. High utilisation and positive student perceptions highlight DFT's role in enhancing engagement, collaboration, and spatial understanding. Beyond improving data collection and analysis, DFT promote reflective and independent learning. Nonetheless, challenges such as uneven digital competence and connectivity issues underscore the need for institutional support, structured training, and competency frameworks. When strategically integrated, DFT serve as a foundational infrastructure linking technology and pedagogy, advancing inclusive, accessible, and future-ready design and planning education.

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9. FUNDING

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10. AUTHORS' CONTRIBUTION

This study was collaboratively developed and written by all authors. Author 1 served as the principal researcher and lead writer, responsible for conceptualising the study, developing the research framework, synthesising theoretical perspectives, interpreting results, and ensuring academic quality. Authors 2 and 3 contributed to the research design, data collection, and analysis, including survey development, data coding, and preliminary statistical interpretation. Authors 4 and 5 refined, restructured, and edited the manuscript, improving clarity, coherence, and alignment between findings and pedagogical implications. All authors reviewed and approved the final manuscript, sharing equal responsibility for its scholarly integrity and overall contribution.

11. CONFLICT OF INTEREST DECLARATION

We hereby confirm that this manuscript represents the original work of the authors and co-authors. It has neither been previously published nor is it currently under review by any other journal or publication. This study has not been submitted, in whole or in part, to any other outlet. Furthermore, all authors have made substantial contributions to the research, including the development of the study, the integrity and accuracy of the data, and the interpretation of findings for submission to IJELHE.

12. DECLARATION OF GENERATIVE AI IN THE WRITING PROCESS

In this manuscript, AI-based tools were utilised to enhance its clarity and linguistic quality, including ChatGPT to improve readability and Grammarly to refine grammar. After using these tools, the manuscript was thoroughly reviewed and verified for accuracy and coherence. The authors take full responsibility for the integrity and content of the final published work

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