Advancing Design Communication in Multidisciplinary Teams: The Impacts of VR/AR-enhanced Representations on Landscape Design Practices

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Abstract: This research examines the impact of VR/AR-enhanced representations on Design Communication (DC) between professional landscape designers and other consultants involved in real-world design practices. Fourteen experienced landscape designers and design consultants are invited as participants and work on two different projects for six weeks. One group of them uses traditional design representation methods to support their work while the other group adopts both traditional approaches and VR/AR-enhanced representations. Surveys and in-depth interviews are arranged to understand their design perception, design cognition, and experience in overall DC process during the project phase of site analysis, concept initiation, and design development. In this way, the impacts of VR/AR technologies and project phase on DC among professional LA designers and other design consultants can be discussed. The findings indicate that VR/AR-enhanced design representations can significantly improve design perception of design details but show no obvious impacts on design cognition. VR/AR technologies also enhance the cross-disciplinary collaboration and reduce conflicts by providing immersive, interactive, and enjoyable DC experience for multidisciplinary designers. Overall, this research explores the potential of immersive technologies to improve DC in complex, collaborative, and practical LA projects, suggesting approaches to optimizing conventional design practice workflows and representation methods in landscape architecture.

Keywords: Design communication, VR/AR technologies, design representation, landscape design practice

1 Introduction

1.1 VR/AR-enhanced Representations in LA Design Practice

With the swift advancement of digital technologies in landscape design representation, achieving more realistic, interactive, and immersive design visualizations has become feasible (LOVETT et al. 2015). VR and AR technologies have emerged as innovative tools in LA design field to benefit the overall design process. New approaches for design representation and visualization, such as VR rooms, virtual tours, AR models, and interactive AR tables, have been developed and explored (BAIK 2021, HAYNES & LANGE 2016). Additionally, scholars have extensively investigated the impacts of VR/AR-enhanced representations on spatial perception, or using VR/AR simulation to help examine the impacts of factors such as scale, distance, color, materials on various aspects of LA performance and experience like visual aesthetics, and visual comfort (GE et al. 2023, GÓMEZ-TONE et al. 2021). To support design construction and collaboration, research has investigated how VR/AR visualization can support project construction and maintenance (CHALHOUB & AYER 2018). Furthermore, the integration of VR/AR technologies in LA not only enhances the designer's ability to foresee potential issues before physical implementation but also allows stakeholders and clients to experience the envisioned environment in a more tangible way (PORTMAN et al. 2015).

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This immersive interaction often leads to more informed decision-making and higher satisfaction with the final project outcome.

1.2 MDC among Multidisciplinary Designers in LA Design Practice

Accurate and effective design communication is crucial in contemporary LA practice, as the scope, goals, and forms of project requirements and collaborations are becoming increasingly complex and diverse (NETO 2003). VR/AR-enhanced representations have the potential to create more immersive, interactive, and realistic design perceptions, improving cognition and the overall DC process (GE et al. 2023). Incorporating these innovative representation methods into LA design practice can optimize traditional workflows and expand the range of representation tools available (YAN 2014). DC in LA design practice can be influenced by the role of participants in the team. For different types of firms and projects, the backgrounds and experiences of designers within the design team vary. Forming a team with multidisciplinary designers is a standard approach in nowadays LA design practice (ROGERS 2010). Regarding the topic of DC and design representations, many existing studies tend to involve design students or design teams comprising only designers with similar backgrounds as participants (JOHNSON et al. 2019, ÖZGEN et al. 2021). Therefore, DC research that investigates design perception and cognition among multidisciplinary teams in LA design practice holds significant meaning and potential. On the other hand, expanding this research could further enhance understanding of how diverse design participants influences design outcomes and client satisfaction. By integrating insights from various disciplines, VR/AR tools could be tailored to more effectively address the unique challenges of LA design project (AHN et al. 2019).

1.3 Challenge and Significance

Regarding the topic of DC in LA design practice, current studies have already explored how different design representations affect design communication (CANTRELL & MICHAELS 2010, MCKOY et al. 2001, YAN 2014, YILDIRIM & YAVUZ 2012). However, it is still necessary to advance research that focuses specifically on VR/AR-enhanced representations, involves multidisciplinary design teams in professional firms, and covers the entire project design cycle. Meanwhile, current DC studies rarely incorporate evaluations across multiple dimensions, such as design perception, design cognition, and overall experience during communication. Additionally, most studies are conducted in classroom or simulated environments rather than the actual working environment of designers. Therefore, this research, conducted in the natural setting of design practice to explore DC among multidisciplinary designers and emphasizing the impacts of VR/AR-enhanced representations, fills a current knowledge gap and holds significance for advancing design processes, techniques, and theory in the field of LA.

2 Methodology

2.1 Participants and Research Projects

This research invites 14 professional designers and design consultants as participants who work in the firm collaborated with the research team. Among them, eight are LA designers, two are architectural designers, two are urban designers, two are civil engineers. Two medium-scale conceptual landscape architecture design projects (Project A and Project B) contracted by the participants' firm, have been selected for this study. Both projects are highway service zone LA design with different site locations. They share similarities in scale, scope, project cycle, clients, and cost, with a six-week completion deadline. Figure 1 shows the site contexts of Project A and Project B. Both projects have a six-week project cycle and progress through three project phases: site analysis (Phase 1), concept initiation (Phase 2), and design development (Phase 3) (Tab. 1).

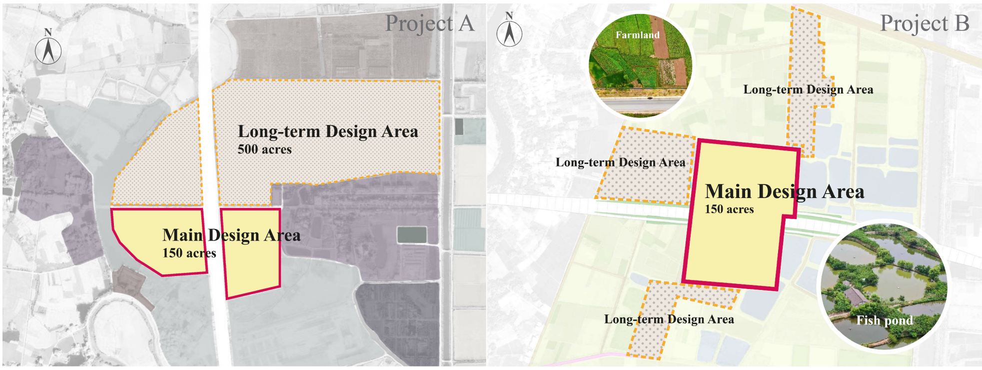

Fig. 1: Site contexts of Project A and Project B

Table 1: The arrangement of project phase

Project phase	Task	Time duration
Phase 1	Site analysis	1st week to 2nd week
Phase 2	Concept initiation	3rd week to 4th week
Phase 3	Design development	5th week to 6th week

2.2 Research Design

The participants are evenly split into Group 1 and Group 2. Each group has four LA designers, one architectural designer, one urban designer, and one civil engineer. Within 6 weeks, Group 1 is required to work on Project B while Group 2 should focus on Project A. Considering the staffing constraints of the partner firm and the differing project timelines, Group 1 and Group 2 do not work on the projects simultaneously. Group 1 worked on Project B for six weeks, and once it is completed, Group 2 begins working on Project A for six weeks. This arrangement ensures that participants from both groups do not influence each other during the study since they are in the same office.

Regarding the design representation methods, Group 1 participants use only traditional design representation methods based on their preferences and needs (no VR/AR-enhanced representations are adopted). These traditional design representations include widely used tools such as sketches, illustrative plans, diagrams, renderings, photographs, maps, sections/elevations, CAD drawings, and digital 3D models. Group 2 participants, while using traditional methods, are also asked to incorporate VR/AR-enhanced representations, including VR renderings, AR modelling, and AR model viewers. The typical workflow of using VR/AR tools in Group 2 includes: do 3D modelling through SketchUp or Rhino, render the 3D models through Twinmotion or Enscape, use VR (headsets) and AR (headsets and mobile devices) equipment to view simple 3D models in SketchUp and adjust the models, use VR and AR equipment to view rendered models in Twinmotion or Enscape. Table 2 summarizes the research settings interpreted above.

Table 2: The group design and representation methods of research

Group	Participants	Design representation method	Tool	Project
Group 1	4 professional LA designers and 3 design consultants	Traditional methods (sketches, illustrative plan, diagram, renderings, photograph, mapping, section/ elevation, CAD drawings, and digital 3D model)	Computer, paper, iPad	Project B
Group 2	4 professional LA designers and 3 design consultants	Traditional methods + VR renderings + AR collaborative modeling + AR model viewer	Tools used in Group 1, Hololens (AR), Meta quest (VR)	Project A

At the end of all three project phases, a survey and in-depth interview are employed to assess participants' DC. Each round of survey includes 11 questions (Q1 to Q11) along with inquiries about participants' age, gender, education level, and occupation. Among the 11 questions, there are four fill-in-the-blank questions, two multiple-choice questions, and five evaluation questions. Table 3 explains the goals of designing different survey questions and the measurements of answers. The design of survey questions is decided with the evaluation criteria for DC developed by the research team, which primarily covers the aspects of design perception (how individuals interpret and perceive design information, including spatial awareness, aesthetic appreciation, and emotional reactions to measurements, colors, materials, and spatial arrangements), design cognition (how individuals infer and understand the function, intent, and idea of the design, including problem-solving, decision-making, and memory related to spatial organization, functionality, and meaning), and experience during the overall communication process (Tab. 4). Based on this evaluation framework, the goals and measurements of each survey questions are determined. For each round of interview, three questions (Q1*, Q2*, and Q3*) are designed to investigate participants' understanding of their work in a specific project phase, feelings about the DC process, and views on the design representation methods adopted in this project phase. In summary, participants basically have ten minutes to complete the survey, five minutes for the interview, and they can request more time if needed.

Table 3: Types of data measured and collected in the survey

	Q1 and Q2	Q3 and Q4	Q5 and Q6	Q7 to Q11
Goal	Assessing participants' perceptions of specific spatial scales and distances	Assessing perceptions of the overall design-related data	Assessing participants' cognition regarding design information	Investigating participants' ratings of MDC
Data type	The error ratio (the absolute value of the difference between the participant's response and the correct answer divided by the correct answer)		1: true answer 0: wrong answer	Likert scale from 1 to 5

Table 4: Overall evaluation criteria of DC

	The contents of the evaluation		
	Design perception	**Design cognition**	**Communication process**
Phase 1	Recognize geographical features of the site; Recognize site transportation	Understand site context (spatial, cultural, and economic); Understand design problems	Interaction; Collaboration; Conflicts; Enjoyment
Phase 2	Recognize spatial scale, depth, length, and elevation; Recognize the type of designed element	Understand design concepts and positioning; Understand spatial framework	Interaction; Collaboration; Conflicts; Enjoyment
Phase 3	Recognize materials; Recognize vegetation; Recognize program	Understand the function/ use of design; Understand the cost of design	Interaction; Collaboration; Conflicts; Enjoyment
Assessment methods	Survey, in-depth interview	Survey, in-depth interview	Survey, in-depth interview

The survey data is analyzed using descriptive statistics and ANOVA, while thematic and content analysis are applied to the qualitative data gathered from interviews. However, the number of participants is fewer than 20, whereas this number should be increased to at least 50 for more valid ANOVA results. However, such an improvement would require a longer time frame and the involvement of more researchers. Since this research relies on ANOVA and T-Test to help explain the results of descriptive statistics and guide future in-depth research, this limitation can be temporarily permitted.

3 Results and Discussion

3.1 Survey Results

Descriptive Statistics

Based on the descriptive statistics of the survey data (Tab. 5 to Tab. 8), it can be found that, during Phase 1, a team with experienced LA designers and other design consultants can benefit from VR/AR-enhanced design representations in perceiving specific dimensions within smaller spaces. However, these technologies' impacts on improving the perception of overall design information (investigated by Q3 and Q4) fail to show a clear pattern. In terms of design cognition, the responses from Group 1 and Group 2 show no significant differences in Phase 1. Q7 to Q11 are designed for participants to evaluate their experience during the overall DC process. Among these questions, Q7 aim to assess the efficiency of communication, Q8 focuses on the collaboration during DC, Q9 aims to assess the interaction and immersion of DC, Q10 examines the participants' enjoyment and engagement during DC process, and Q11 assesses frequency and level of conflicts during DC. For Q7 to Q11, Group 2 consistently provided higher average ratings across all questions compared to Group 1 in Phase 1, especially Q8, Q9, and Q10. The survey results from Phase 2 indicate that VR/AR-enhanced representations are effective for grasping the overall design information, while their positive effects on understanding specific dimensions and distances remain evident. However, similar to Phase 1, VR/AR technologies do not significantly enhance design cognition among participants. The insignificant impact of VR/AR on design cognition in Phase 1 and Phase 2 may be due to the fact that the general understanding of design information relies more on the integration of project-related data, images, text, and verbal communication rather than primarily on visual communication. Therefore, while VR/AR technologies serve as effective tools for immersive and interactive design representation, they may not be the most suitable approach for enhancing design cognition. For the overall DC process, the pattern in this phase is similar to that of Phase 1, but Group 2 participants' ratings of immersion and interaction in the MDC process increase significantly compared to those of Group 1. In Phase 3, the survey results indicates that VR/AR-enhanced representations may improve the perception of both site-specific and overall design information. They also begin to show a subtle positive influence on participants' design cognition. This may be because, unlike Phase 1 and Phase 2, the design cognition addressed in Phase 3 places greater emphasis on specific design details, including dimensions, materials, location, and colors, which are closely related to specific design perception. Therefore, VR/AR-enhanced representations, which have significant impacts on design perception, begin to slightly work for design cognition in Phase 3. Regarding the overall DC process, Group 2's average ratings are slightly higher than those of Group 1, with more noticeable differences in their evaluation of enjoyment and engagement compared to the previous two phases.

Table 5: Descriptive statistics of survey results in Phase 1

Group (n=14)		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
Group B-1	Mean	0.17	0.07	0.06	0.29	0.71	1.00	3.29	3.14	2.43	2.71	4.00
	SD	0.06	0.03	0.05	0.26	0.49	0.00	0.49	0.38	0.53	0.49	0.00
Group B-2	Mean	0.11	0.05	0.07	0.15	1.00	1.00	3.57	3.86	4.29	3.86	4.14
	SD	0.04	0.03	0.04	0.10	0.00	0.00	0.53	0.38	0.49	0.38	0.38

Table 6: Descriptive statistics of survey results in Phase 2

Group (n=14)		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
Group B-1	Mean	0.09	0.24	0.29	0.05	0.71	0.57	3.14	3.29	2.71	3.71	3.00
	SD	0.02	0.13	0.14	0.08	0.49	0.53	0.38	0.49	0.49	0.49	0.00
Group B-2	Mean	0.04	0.16	0.22	0.05	1.00	0.86	3.29	4.00	4.29	4.29	3.14
	SD	0.02	0.10	0.10	0.08	0.00	0.38	0.49	0.00	0.76	0.49	0.38

Table 7: Descriptive statistics of survey results in Phase 3

Group (n=14)		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
Group B-1	Mean	0.19	0.13	0.11	0.18	0.57	0.57	3.43	3.43	3.00	3.57	3.00
	SD	0.11	0.08	0.05	0.07	0.53	0.53	0.53	0.53	0.00	0.53	0.00
Group B-2	Mean	0.10	0.10	0.08	0.18	0.86	0.71	3.43	4.00	4.29	4.43	3.29
	SD	0.06	0.06	0.03	0.06	0.38	0.49	0.53	0.58	0.49	0.53	0.49

Table 8: Descriptive statistics of survey results (by groups)

Group (n=14)		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
Group B-1	Mean	0.15	0.14	0.15	0.17	0.67	0.71	3.29	3.29	2.71	3.33	3.33
	SD	0.09	0.11	0.13	0.18	0.48	0.46	0.46	0.46	0.46	0.66	0.48
Group B-2	Mean	0.08	0.10	0.12	0.12	0.95	0.86	3.43	3.95	4.29	4.19	3.52
	SD	0.05	0.08	0.10	0.10	0.22	0.36	0.51	0.38	0.56	0.51	0.60

ANOVA Analysis

To better understand whether VR/AR technologies and project phase can affect participants' experience during the overall DC process, the ANOVA and Post Hoc analysis are conducted. The ANOVA test (Tab. 9) shows that employing VR/AR-enhanced design representation methods can significantly improve the collaboration (p= 0.000), immersion/ interaction (p= 0.000), and enjoyment (p=0.000) through the entire project cycle. It also helps design participants avoid conflicts during MDC to some extents (p= 0.027). Consistent with the descriptive statistics discussed earlier, the ANOVA test reveals that VR/AR technologies do not significantly enhance efficiency, as the results for Q7 are not statistically significant (p= 0.436). The role of participants primarily fails to show a significant effect on all questions except Q8 (p= 0.049). it can be learned that other design consultants tend to have more positive and affirming attitudes towards collaboration in design communication. More insights about these findings are articulated based on the in-depth interviews in Section 3.2.

The ANOVA test also shows that the project phase has a significant impact on Q10 (p= 0.001) and Q11 (p= 0.000). Based on the Post Hoc analysis and previous descriptive statistics, it can be concluded that participants experience greater enjoyment and satisfaction during Phases 2 and 3 of the MDC process compared to Phase 1. Additionally, participants encounter significantly fewer conflicts during the site analysis phase than in the later phases.

Table 9: ANOVA analysis of the survey results (Q7 to Q11)

Source	Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Q7	1.893a	11	.172	.666	.758
	Q8	6.238b	11	.567	3.002	.008
	Q9	29.833c	11	2.712	12.205	.000
	Q10	13.369d	11	1.215	4.420	.001
	Q11	10.119e	11	.920	12.737	.000
Intercept	Q7	466.716	1	466.716	1806.644	.000
	Q8	544.794	1	544.794	2884.202	.000
	Q9	508.008	1	508.008	2286.036	.000
	Q10	580.716	1	580.716	2111.696	.000
	Q11	484.198	1	484.198	6704.286	.000
Group	Q7	.161	1	.161	.622	.436
	Q8	4.571	1	4.571	24.202	.000
	Q9	26.698	1	26.698	120.143	.000
	Q10	7.383	1	7.383	26.847	.000
	Q11	.389	1	.389	5.385	.027

Phase	Q7	.409	2	.204	.791	.463
	Q8	.361	2	.181	.956	.396
	Q9	.599	2	.300	1.348	.275
	Q10	4.861	2	2.431	8.838	.001
	Q11	8.290	2	4.145	57.390	.000
Role	Q7	.240	1	.240	.929	.343
	Q8	.794	1	.794	4.202	.049
	Q9	.389	1	.389	1.750	.196
	Q10	.050	1	.050	.180	.674
	Q11	.008	1	.008	.110	.743

a. R Squared = .196 (Adjusted R Squared = -.098)
b. R Squared = .524 (Adjusted R Squared = .349)
c. R Squared = .817 (Adjusted R Squared = .750)
d. R Squared = .618 (Adjusted R Squared = .478)
e. R Squared = .824 (Adjusted R Squared = .759)

3.2 Interview Results

After transcribing and coding the participants' answers to interview questions, thematic and content analysis are conducted through NVivo 14 and key results are summarized.

Q1* asks participants to briefly describe their work during a specific phase of the project. The total number of codes summarized from responses to Q1* across all three project phases for both Group 1 and Group 2 are basically the same. Both groups consistently and accurately described site information, design concepts, and design details. However, Group 2 produced more codes related to design details, such as specific materials, facilities, and plant species, particularly in the design development phase. As each group's responses to Q1* were based on their specific project designs, direct comparisons between the groups cannot be made at this point. Consequently, additional analysis and comparative studies were utilized in the discussions of Q2* and Q3* to investigate inter-group differences more thoroughly.

Q2* aimed to understand participants' perceptions of the communication process, encouraging them to provide examples of both challenges and achievements encountered during the DC process. Figure 2 and Figure 3 show the number of coding references for Q2* in both Groups. It can be learned that, during Phase 1, Group 1 participants were more aware of the importance of interdisciplinary collaboration, whereas Group 2 did not particularly mention this. Instead, Group 2 had more opinions about design representations and VR/AR technologies. In Phase 2, both groups emphasized the importance of communication, discussion, and collaboration, particularly the teamwork among multidisciplinary designers. Both groups believed that their workflow and division of labor were well-structured. Not much information about design representation was discussed, except that Group 2 noted that sketches are an effective tool for concept development, especially when VR/AR-enhanced representations are used as supplements to traditional methods. This result suggests that VR/AR technologies may not significantly enhance design concept initiation for experienced designers. For Phase 3, both groups consistently stressed the importance of interdisciplinary communication and collaboration. Moreover, both groups mentioned the facts that their practical experience and professional background benefit the work during design development phase. In addition, compared with Group 1, participants in Group 2 responded more about design representation methods. They reported that they had positive experience with VR/AR-enhanced representations. At the same, participants in Group 2 emphasized that they found the communication process interesting and enjoyable, and they believed that design details should be discussed more in DC at this stage. This suggests that the use of VR/AR technologies made the design communication in design development phase more engaging and helped participants pay more attention to design details.

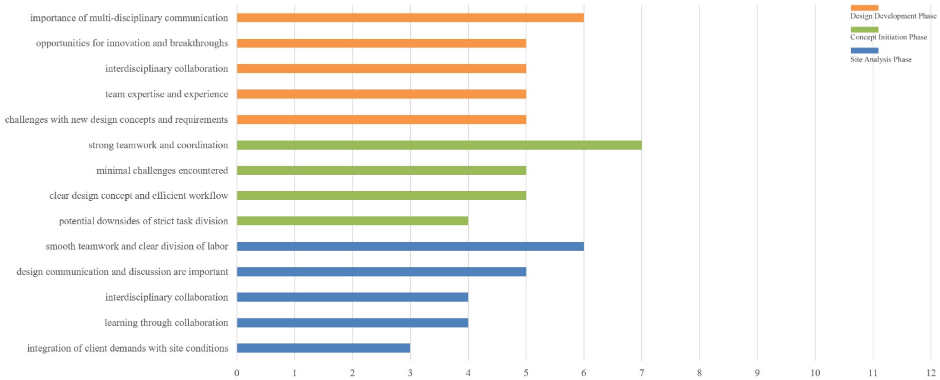

Fig. 2: Number of coding reference of Q2* for Group 1

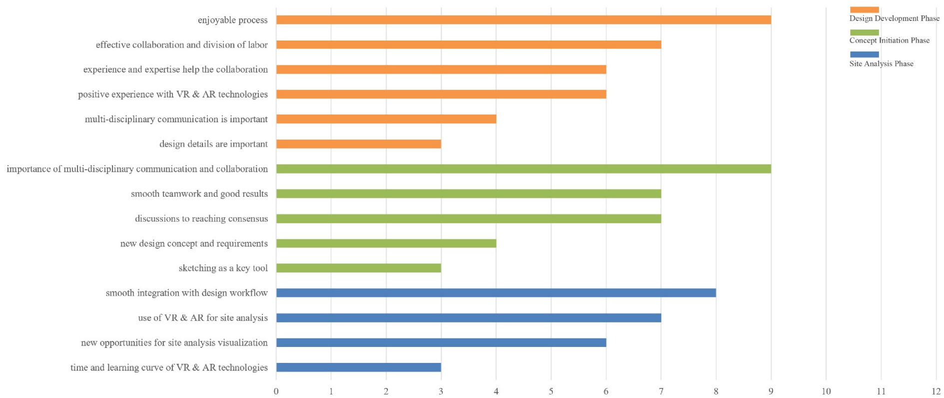

Fig. 3: Number of coding reference of Q2* for Group 2

The word cloud analyses shown in Figure 4 and Figure 5 summarize the high-frequency words from Group 1 and Group 2's responses to Q2*, further underscoring that communication, collaboration, and discussion are central themes for both groups, which indicates the importance of multidisciplinary teamwork throughout the entire DC process. Both groups more or less mentioned a series of terms related to design representation methods, indicating that the impact of design representation on design communication remains significant. Additionally, Group 2 frequently mentioned words related to “efficiency,” which might suggest that the use of VR/AR technology has, to some extent, affect the efficiency of the MDC process. However, this impact is not unclear since some people mentioned that VR/AR-enhanced representations make the design workflow more inefficient.

Fig. 4: Word clouds of Q2* for Group 1

Fig. 5: Word clouds of Q2* for Group 2

Q3* explores the design representation methods used in the project. Participants are asked to assess the methods applied during a specific phase and to share their insights on the advantages, drawbacks, and potential of various design representation techniques. Compared to Group 1, participants in Group 2 addressed a broader range of topics and themes. Although most were not directly related to VR/AR technologies, Group 2 participants tended to engage more in discussions about design representations. This suggests that when VR/AR technologies are incorporated, participants are more likely to reflect on design representations, related methodologies, and their implementation.

Figure 6 and Figure 7 show the number of coding references for both Group 1 and Group 2's responses to Q3*. In Phase 1, both groups recognized the importance of GIS as a critical tool and found online maps such as Google Earth and Baidu Map useful as well. Both groups agreed that site analysis does not require complex representation methods, they recognized the efficiency of traditional design representation approaches and related workflow in site analysis phase. For Phase 2, both groups emphasized the effectiveness of traditional representation methods, and they agreed that there is no need to use complex representation tools at this stage. Aligning with their responses to Q2*, interdisciplinary collaboration and communication were considered more crucial for optimizing concept development. Many participants in Group 2 felt that the contribution of VR/AR technologies during the concept initiation phase was limited, suggesting that more research is needed to explore their better application in this phase. For Phase 3, both groups agreed that the extensive use of conventional representation tools was essential. They also emphasized the importance of 3D modeling and rendering in refining design details. Group 1 participants highlighted the need for advanced techniques to produce fast and immersive renderings. At the same time, participants from Group 2 believed that VR/AR technologies improved design communication and engagement, which are critical for design practices involving multidisciplinary teams. Additionally, Group 2 participants felt that VR/AR-enhanced representations have the potential to offer more immersive, interactive, and real-time design visualization when integrated with advanced rendering and modeling approaches.

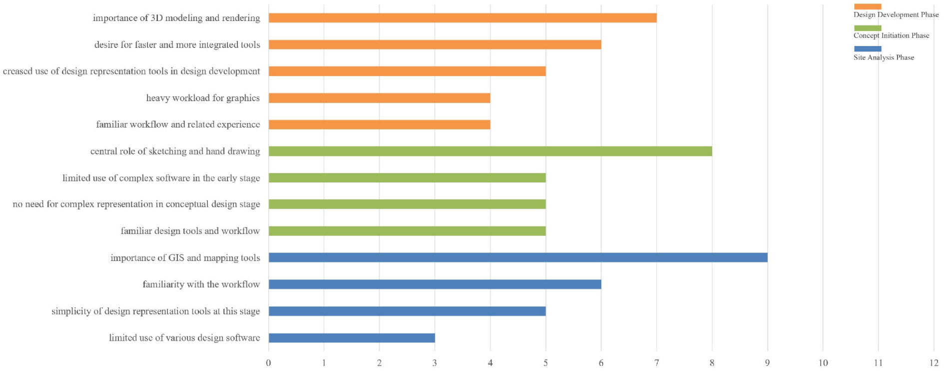

Fig. 6: Number of coding reference of Q3* for Group 1

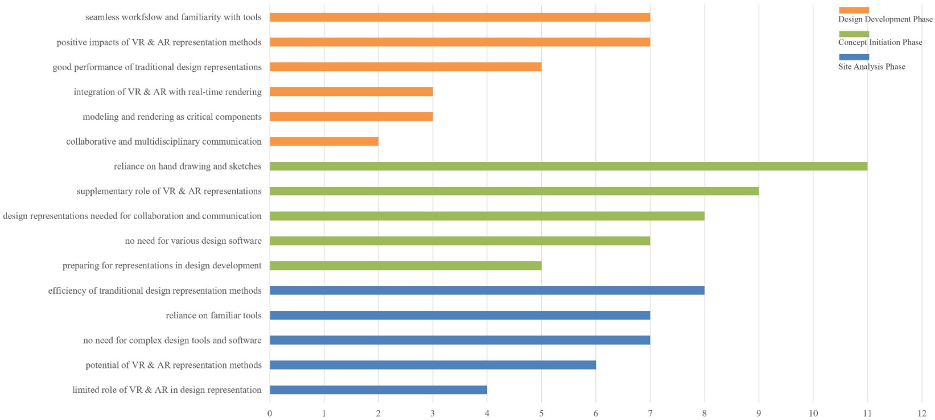

Fig. 7: Number of coding reference of Q3* for Group 2

Figure 8 and Figure 9 present word cloud analysis summarizing the high-frequency words from Group 1 and Group 2's responses to Q3*. The words frequently mentioned in the interview responses from both groups are actually quite similar, focusing on areas such as communication, representation, rendering, tools, sketches, and drawings. This indicates that the use of VR/AR technologies did not significantly change the groups' evaluation of various representation methods in DC process. However, compared to Group 1, Group 2 mentioned more words like efficiency, experience, and direct when describing the topic of design representation. This, from another perspective, suggests the impact of VR/AR technologies on participants' work efficiency and spatial experience.

Fig. 8: Word clouds of Q3* for Group 1

Fig. 9: Word clouds of Q3* for Group 2

4 Conclusion and Limitations

This research explores the impact of VR/AR-enhanced representations on Design Communication (DC) between professional and multidisciplinary designers. The findings indicate that VR/AR-enhanced design representations can significantly improve design perception of design details but they show no obvious impacts on design cognition. The benefits of VR/AR technologies during the design development phase are more significant, while their assistance in the design concept initiation phase is quite limited. At the same time, the impacts of VR/AR-enhanced representations on communication and working efficiency among multidisciplinary designers are uncertain; they may negatively affect the work efficiency of experienced designers. However, similar to many related findings, VR/AR technologies perform well in promoting a more immersive, interactive, and enjoyable DC experience among multidisciplinary designers, especially non-LA designers involved in this research. Additionally, for design teams comprising LA designers and other design consultants, the use of VR/AR-enhanced representations can improve collaboration and reduce conflicts to some extent.

However, this research faces various limitations that must be addressed in future studies. First, the sample size needs to be increased and the involvement of design firms from diverse regions should be considered. Second, more advanced VR/AR-enhanced representation methods and related technologies should be adopted. At the same time, allowing participants the flexibility to choose their preferred representation approaches for working makes it difficult to control and precisely measure the time and effort they invest in each method, which can affect the validity of the research. Therefore, a better method of categorizing traditional and VR/AR-enhanced representation approaches should be developed. Third, this research only involves architectural designers, urban designers, and civil engineers as design consultants; more roles of design participants should be included in future research.

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