Augmenting Learning of Design Teamwork Using Immersive Virtual Reality

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Abstract When it is done well, design teamwork is a fun, creative, and productive activity. However, the learning of effective design teamwork is hampered by lack of exposure to variation in design contexts, lack of deliberate practice and lack of appropriate feedback channels. In this chapter we present immersive Virtual Reality (VR) in accompaniment to action-reflection pedagogy as a solution to augmenting design team learning. A prospective case of using VR to augment design teamwork practice is discussed and a research agenda is outlined towards understanding VR as a medium for design teamwork, investigating its influence on design team self-efficacy and implementing it in design education courses.

1 Introduction

Multidisciplinary teamwork is a key value in design thinking (Dym et al. 2005). Effective design teamwork can be defined as the performance of interpersonal interactions in such a manner that design tasks are collaboratively completed with the result being greater than the sum of individual contributions. This occurs through each individual supporting, challenging and building on each other individual to deepen user insights, generate novel problem frames, develop bold concepts, and

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prototype effective solutions—ultimately resulting in an emergent design outcome that is beyond any individual imagination and capability. While this ability to work effectively as a design team is prized in the professional world, the learning of design teamwork in a design education is afforded a secondary importance. Students learn teamwork by participating in one or more design projects where the instruction is focused primarily on design process models. Team issues are dealt with as and when they emerge. This has the consequence of some students getting to work in mediocre or a priori effective teams and not learning to master the challenges of design teamwork, and some students getting to work in ineffective teams without having proper mechanisms for overcoming their ineffectiveness and developing team self-efficacy. These students often give up on design teamwork after having particularly painful team experiences. Is there a way to address this shortcoming by creating learning experiences for students to master design teamwork and build team self-efficacy?

In this chapter, we outline the key challenges we face as teachers and students in learning design teamwork, and propose immersive Virtual Reality as a technological accompaniment to action-reflection pedagogy to augment the learning of effective design teamwork.

2 Challenges to Design Team Learning

There are three key challenges to learning effective teamwork in design courses.

2.1 Lack of Exposure to Varying Context

Design is a context-dependent activity. The individual, organizational, task and environmental context in which a design team activity occurs influences the effectiveness of that activity. For example, when a design team meets to generate product solution concepts, the level of interpersonal hierarchy in the team, the team members energy levels and motivations, the nature of the design challenge—whether it's a consumer product or a systems level problem, the physical environment in which the team is meeting, all of these influence the interpersonal interactions that form design teamwork and make this team situation different from other concept generation sessions that same team may have had in the past. In spite of this, when we currently teach design, we teach it through a single design project or at best a few different short projects in a course setting. These hardly capture the contextual variability that a student would need to master in order to prepare for effective design teamwork in a professional setting. The key challenge here for design instructors is to comprehensively capture the context variables for design team activities and then create varying design situations for students to practicing their team performance.

2.2 *Lack of Deliberate Practice*

The project-based learning (PBL) pedagogy often used by design courses is helpful in facilitating active learning in students by giving them a realistic project situation. However, these PBL projects often are one-off experiences that do not afford students opportunities to practice and master design teamwork. Ericsson et al. (1993) in their seminal paper on acquisition of expert performance presented deliberate practice—a regimen of effortful activities targeted towards improving performance and overcoming motivational and external constraints—as an underlying determinant for developing expertise. Developing design teamwork effectiveness requires this deliberate practice more than mere exposure to team situations that is currently prevalent in design courses. This presents a unique challenge to design instructors—how to create an arena for students to practice design teamwork in a deliberate manner?

2.3 *Lack of Appropriate Feedback Channels*

The third challenge facing design team learning is the lack of feedback channels for improving design teamwork. For example, when a conflict situation arises in a team, the team members' own emotional maturity and social skills are relied on more than external feedback as to how the individuals are doing in their handling of the situation. The instructors at times may give feedback, but more often it is observed that instructors focus on product and process level feedback, while students are left to handle interpersonal team interactions, and interpersonal dialogue and feelings on their own. This is a function of instructors facing a shortage in time for coaching, and a lack of feedback channels and tools available to students to address teamwork issues. The result is that even if potential learning situation do occur in design teams, students are ill prepared to take advantage of them and learn through receiving and acting on appropriate feedback. As we address the first two challenges for design team learning—exposure to multiple contexts and creation of an arena for deliberate practice, the availability of feedback becomes the next important limiting factor. We propose that feedback needs to be built-into the practice arena for design teamwork such that students can self-correct and generate new interaction behaviors all by themselves as they keep on practicing.

3 Virtual Reality as a Medium to Augment Design Team Learning

As instructors and students of design teamwork, we ourselves grappled with the three challenges presented in Sect. 2. Our prior work dealt with the creation of a pedagogical framework that involved creation of multiple situational learning experiences

followed by embodied reflection (Mabogunje et al. 2018). We were still missing a way to create a distinct arena for deliberate practice along with the capability to vary design context parameters at low cost. While looking for solutions to overcome this challenge, we found immersive Virtual Reality to be a promising technological solution.

Immersive Virtual Reality (VR) refers to the experience of being immersed in a virtual world through the use of head-mounted display and sensors that track head and body movement in space. This is an embodied experience that is different from the sensory experience of watching a virtual environment on a 2-D or even a 3-D screen. The ability to move your head and your body and access the different perspectives in a virtual world as if 'you are there' is key to achieving a simulation of reality in which you could practice design team behaviors (Bailenson 2018). See Fig. 1 for a visual of two designers wearing VR headsets and interacting in a virtual world.

VR with multiple users in a shared world has been studied for decades (Takemura and Kishino, 1992; Churchill and Snowdon 1998). One of the canonical use cases within this area of work is using virtual reality as a collaborative design tool (e.g., Leigh et al. 1996). The spatial nature of VR has lent itself to design tasks, especially in architecture (Rosenman et al. 2007). Furthermore, the unique aspects of mediated small-group behavior have been studied in virtual environments (Slater et al. 2000).

What is new in the current study is the simulation of the social situation a designer may find him or herself in. We propose creating virtual environments that mirror the various physical environments in which design teams might operate in, and then let students wear headsets to be immersed in that environment and interact as a team to achieve pre-specified design tasks. A variation of this VR arena for design teamwork might include pre-set characters and situations which ground the team in behaving in a certain way to practice dealing with specific design team situations. For example, we could create a conflict scenario involving a social loafer character who is not working as much as his team members and is actively shirking responsibility. Team members could then practice having an alignment conversation with this team member, who could be played by one of the students. By practicing such interactions over and over again, each time trying out something different, the students gain deliberate practice in handling difficult team situations. In more technologically advanced version of the VR teamwork arena, pre-set characters could be programmed virtual agents that

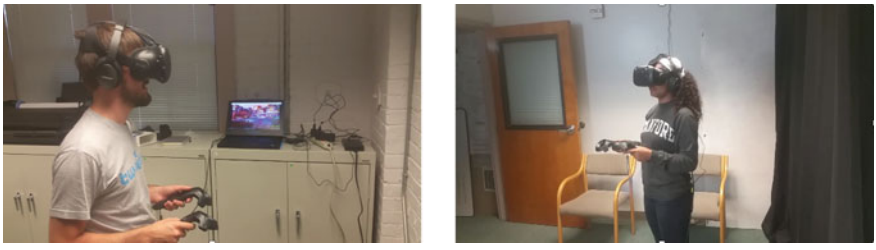

Fig. 1 Two designers wearing VR headsets and interacting in a virtual world

students could practice interacting with. VR could then enable students to overcome two of the limitations related to learning design teamwork – variation in contexts and availability of an arena for deliberate practice. The third limitation of the feedback channel could be addressed through embodied reflection tools coupled with team interaction analytics such as the Interaction Dynamics Notation (Sonalkar et al. 2013) that could be used to give meaningful feedback to teams practicing VR team simulations.

4 Affordances and Limitations of VR

While VR seems a promising medium for deliberate practice of design teamwork, it is important to be cognizant of its affordances and limitations as a design team simulation medium.

4.1 Affordances of VR for Simulating Design Teamwork

1. Immersion: The key affordance of VR that makes it particularly suitable for simulating design teamwork is that it is an immersive experience. Design teamwork is not a purely cognitive activity. It involves interacting with objects in the studio environment—markers, whiteboard, paper, prototypes etc.—and with people who are there in the space with you. VR can enable us to have this immersive experience of a design situation while working in a programmed virtual world.
2. Ability to change context variables: Multiple immersive VR environments could be programmed to match the variety of physical environments in which design teamwork activities occur in. Moreover, the avatars that people embody in VR could be changed to match the environments. For each of these environments, we could then create scenarios that outline the other context variables such as organizational hierarchy differences, motivational differences, task differences etc. The immersive nature of VR makes it easier to role-play these different variables than a real-life setting.
3. Repeatability of experience: Once a VR environment or scenario is programmed, it is available for repeated use. Students could interact multiple times with the scenario each time varying a certain element of their interaction to prototype new outcomes. This repeatability of experience is a key element to VR being suitable for deliberate practice.
4. Ease of use: Engaging with team members in VR is as easy as putting on a VR headset. The current level of consumer grade VR equipment is designed to be comfortably worn for an extended period of time and works with most laptops with a dedicated graphics card.
5. Low cost: The cost of using VR for deliberate practice of design teamwork requires the creation of multiple VR environments, team scenarios and the avail-

ability of physical space where a team can wear headsets and step into the virtual world. The creation of multiple VR environments for team interaction can be achieved through platforms such as High Fidelity, Sansar, VR Chat, Rec Room etc. and the programming is low cost. We envision design courses having a dedicated studio space for VR design teamwork in the future.

4.2 Limitations of VR for Simulating Design Teamwork

VR for simulating design teamwork has a few limitations that could be overcome with suitable scenario design.

1. 20 min time-limit: In general, it is advisable to keep activities to a 20-min time limit, per design activity scenario. It is not recommended to exceed this time limit since extended VR presence could disorient a person from their real-world situation. The physiological effects of very long-term VR use are still unknown.
2. Lack of facial expressions: Faces in VR do not currently transmit facial expression of the participants, since the head-mounted display impedes facial tracking sensors. We expect this situation to improve with time as the technology develops. In absence of facial expressions, emotions can be conveyed effectively using tone of voice. Thus, VR teamwork might need to emphasize the use of voice modulation to a greater extent than is usual in the physical world.
3. Caring for physical safety when in virtual world: When a participant is immersed in the virtual world, they do not have an awareness of the physical world they are moving in while wearing their headsets. Hence researchers have a 'spotter' available to each participant who ensures that the person wearing the headset doesn't run into physical barriers while moving in the virtual world. This necessitates having one support person per participant while using VR.

5 Prospective Case: Using VR for Augmenting Design Team Learning

In order to further clarify the role of VR in augmenting design team learning, we present the following prospective case. A prospective case is similar to a case study except that it outlines a prospective scenario rather a scenario from the past.

John, Jill and Emily are team members in a senior design course at a university in the US. Along with the studio component in which they work on a company sponsored project, the course has a design teamwork lab component in which students get to practice their design teamwork. John, Jill and Emily are going to attend their first lab session.

John is the last to arrive at the lab, which is a dedicated space for team VR. The lab instructor welcomes the team and guides each team member to their individual VR stations. Each individual gets a small 2 m by 2 m space in which to move around when wearing a headset. John is excited to try out VR. He has heard a lot about it and has even played a few games with his friend's VR set. Jill is a bit nervous. She is a bit wary of the new technology, but keen to see what it would feel like to work in a team in VR. Emily is quite eager to get on with the activity. She believes that she is not a great team player and wants to do all she can to improve her teamwork.

The instructor assists them with wearing the headsets and takes them to a virtual tutorial room where they get to select their avatar, look themselves in the mirror and play catch with a virtual ball. Emily and John take to the VR world with ease. Jill takes some time to figure out how to operate in the virtual world, but soon joins John and Emily in playing catch and starts having fun. After 5 min, the instructor guides them to return to the real world and take off the headset. He then hands each person their first design task. It is a concept generation task in which they are embodying the role of startup founders in a suburban garage developing a personal mobility solution. The team wears their headsets and now they are transported to a virtual garage complete with a Toyota in the driveway! The garage has a small desk and a whiteboard with markers. The team has 10 min to complete their concept generation task. Emily initiates the discussion and soon the entire team is busy conversing and discussing solutions for personal mobility. John gets up (in virtual world) and goes to the whiteboard and starts drawing a sketch. Emily and Jill join him in the sketching. 10 min go past quickly, and the instructor has to call them twice to step back out in the physical world. When they step out, the instructor hands them a personal reflection sheet for embodied reflection which they fill out in a couple of minutes. Next, they are given their interaction analytics feedback computed with the Interaction Dynamics Notation and they discuss how they performed in terms of supporting, building on and deepening concepts in their discussion. John realizes he needs to be more supportive of his team members rather than pushing his own ideas.

After a 10 min debrief, it is time for the next task. The team now gets a boardroom decision making task. They are part of a corporate design team that has a meeting with their chief product officer to determine which of three promising product lines to pursue. John, Emily and Jill don their headsets again and quickly become immersed in the world of corporate design decision making. This is followed by four more design scenarios and associated post-activity debriefs. Over a period of two hours, the team has practiced six different design scenarios and greatly broadened their teamwork repertoire. As John, Emily and Jill head home, Jill comments that this was the most intense and productive lab session she has ever been to at her university.

6 Research Agenda to Realize the Promise of VR

What are the research questions that need to be answered in order for us to realize the prospective case discussed above? In this section we discuss the research agenda

that needs to be implemented to realize the promise of VR for augmenting design team learning.

The research agenda for investigating the use of VR for design team learning can be divided into three sections.

6.1 Research Targeting the Fidelity of VR Teamwork to Real Teamwork

An important requirement for VR to be an effective medium for deliberate practice of design teamwork is that it is able to render design team activity with sufficient fidelity to real teamwork. Our early exploration of VR as a teamwork medium are promising for design activities such as concept generation and decision making. However, the following research questions need to be investigated systematically before proceeding with VR.

What elements of design team activity translate to virtual world and what elements do not?
What characteristics of interpersonal interactions differ in a VR setting vs real world setting?

6.2 Research Targeting the Influence of VR Team Work on Participant Learning

Once we establish that design teamwork can be rendered in VR with sufficient fidelity, we need to investigate the influence on participating in VR design teams on participant learning. The following questions are relevant in this research.

What is the influence of VR team work on participants' team self-efficacy when compared to influence of similar teamwork in real world and its influence on participant team self-efficacy?
Do behavioral changes adopted in the virtual world in the domain of design teamwork translate to behavioral changes in real world design teamwork?
What is the frequency of exposure to different design scenarios needed to build design team self-efficacy?
What is the variety of scenario exposure needed to build design team self-efficacy?
What individual participant characteristics influence the building of design team self-efficacy using VR?
What are the feedback parameters that need to be included post-VR activity to build participants' design team self-efficacy?

Note that the key measurement of participant learning is team self-efficacy. Following Bandura's Social Cognitive Theory (Bandura 2001), self-efficacy is an effective predictor of future performance.

6.3 Research Targeting the Conditions for Designing an Optimal VR Experience for Design Team Learning

The third section of the research agenda pertains to building an effective VR practice arena for implementing the role of VR for deliberate practice in design courses.

How might design instructors engage with VR within the design course frameworks?
What is the optimal team size for maximizing the building of design team self-efficacy in VR?
What is the influence of having physically distributed team members participating in the same virtual team on the building of design team self-efficacy?

The question above pertains to the use of VR for distributed education as an immersive alternative to MOOCs.

7 Conclusion

With advances in technology and the availability of low-cost headsets, VR is becoming a promising technological medium to augment design team learning through deliberate practice and reflection. In this chapter we highlighted the key challenges facing design team learning and proposed the use of a VR based arena for augmenting design team learning. We outlined a research agenda for investigating and realizing the promise of VR. We have started implementing this agenda and hope that other researchers interested in design teamwork will take up this agenda so that collectively we can achieve the goal of helping students learn the art and science of effective design teamwork.

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