Accelerating the LPS Uptake Using Virtual Reality and Serious Games: A Socio-technical Conceptual Framework

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The Last Planner System

From a technical standpoint, LPS facilitates

- Elaborating practical plans

- Reliable workflows

- Cost, time reduction (González et al. 2015, Schöttle and Nesensohn 2019)

From a social standpoint, LPS focus on controlling the production system by

- Managing conversations

- Relationships

- Commitments (González et al. 2015).
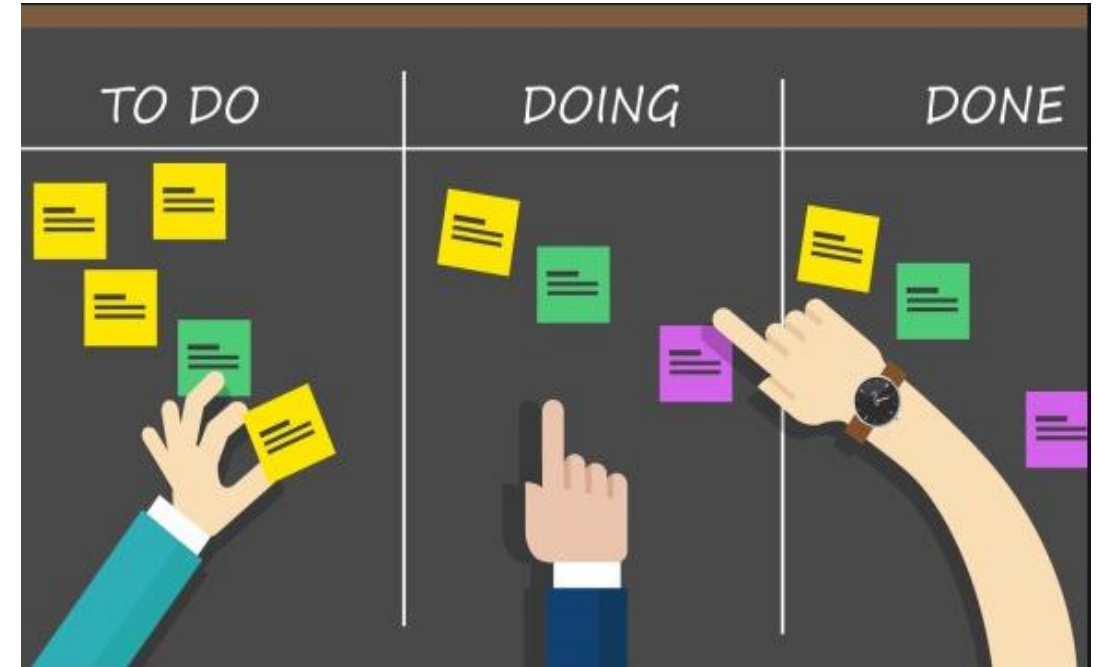
The LPS is a socio-technical system that fosters many of the desired lean behaviours. (Fauncier et al. 2013)

The research trend

Technical aspects

- IT softwares (Choo et al. 1999);

- Knowledge (Skinnarland 2012);

- Performance measurements (Alarcón and Serpell 1996);

- Integration (Bhatla and Leite 2012)

- Guidelines (Howell et al. 2002)

- Computer simulation (Abdelmegid et al.2019)………

Social aspects

- Understanding and acceptance (E. Daniel et al., 2017);

- Culture(Lühr et al. 2019);

- Training and education (Gonzalez et al. 2015) ;

- Commitments (Viana et al. 2013);

- Cooperation (Priven and Sacks 2015);

- Organisational structure (Pavez and Gonzalez 2012)

- Social interactions (Priven and Sacks 2013)

……..

Challenges in LPS practice

- **knowledge levels** of Lean construction and LPS are **low** across the wider industry, and there was a great deal of apprehension shown by participants about the chances of its widespread adoption throughout the industry (Fuemana et al. 2013).

- The challenge was an industry-level rather than an implementation challenge, in that it was seen as an **inhibitor of adoption in the industry as a whole**, rather than a problem experienced on a particular project (Hunt and Gonzalez 2018).

- The pace of uptake within the UK is slow, it has also been observed that the **uptake of lean production principles in construction is slow globally** (Stevens, 2014 and E. Daniel et al., 2017).

Slow uptake and Lack acceptance

WHY?

Critical Social and technical barriers

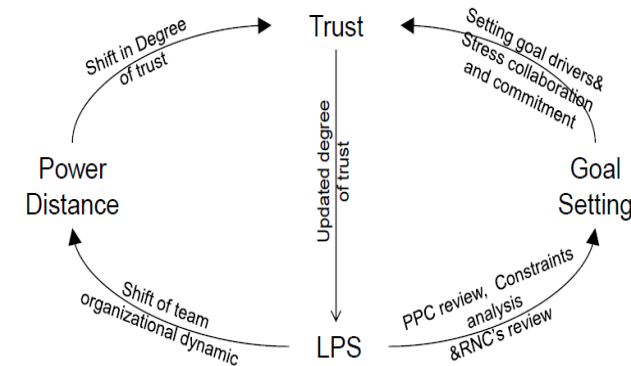**Social domain:**

- B1: Resistance to change

- B2: Lack of cooperation

Technical domain

- B3: Lack of understanding of LPS

Domains	Critical barriers	Influence Factors	References
Social	B1: Resistance to change	Lack of trust	(El-Sabek and McCabe, 2018); (Hamzeh 2011); (Poshdar et al. 2019)
		Ignore subcontractors' opinion when making decisions on site	
		Passionately subscribed to conventional production control methodology	
		Short term vision	
		Reluctant to learn	
		Lack of Leadership	
	B2: Lack of cooperation	Poor team chemistry	(Porwal et al. 2010); (Daniel et al. 2015) (El-Sabek and McCabe 2018)
		Lack of commitment to LPS implementation	
		Minimum involvement of construction workers and subcontractors	
		Weak communication and transparency	
		Commercial disputes	
Technical	B3: Lack of understanding of LPS principles and training methods	Partial implementation of LPS components	(Porwal et al. 2010) (Fernandez-Solis et al. 2013) (Hamzeh 2009)
		Learning component of the methodology remains at a basic level	
		Misunderstanding of guidelines	
		Lack of implementation Knowledge (inexperienced people)	
		Lack of staff training and teaching methods	
		Contractual conflicts	

Socio-technical dynamics when implementing LPS

- Power distance

- Goal settings

- Trust (Gonzalez et al. 2015, Pavez et al. 2012)

- Continuously implementing LPS and training causing a increment of **knowledge** and **experience**

Feedback loop and synergy between LPS and Social Dynamics(Gonzalez et al. 2015)

- A successful LPS implementation not only depends on facilitating **technical dynamics** (e.g. improvement of LPS knowledge) but also requires efficient management of **social dynamics** (e.g. encourage cooperation and change) (Gonzalez et al. 2015)

- *Proposition 1: Identifying the **socio-technical dynamics can provide insight on solving these LPS implementation barriers, A social behavior study** for these dynamics is necessary in this research.*

# Conceptualisation of Socio–technical dynamics

Social network analysis (SNA) conceptualises the **social dynamics** by (Priven and Sacks 2013):

- Communication frequency

- Target

- Duration

Language action perspective (LAP) conceptualises the **social dynamics** by (Viana et al. 2017):

- Communication channels;

- Quality of commitment

Technical dynamics can be conceptualised as knowledge level

Social Networks

Commitment loop in Language action perspectives

Integration of SNA and LAP
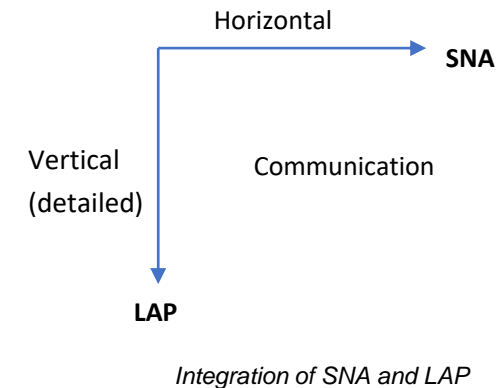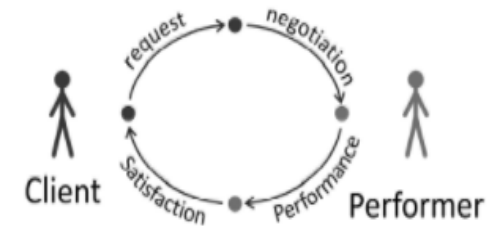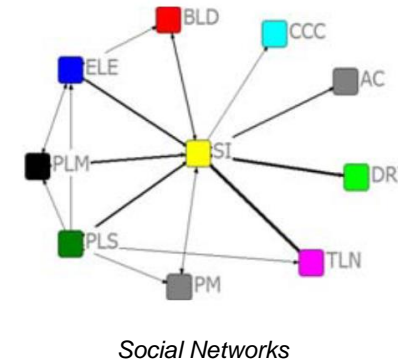
LPS training and simulation
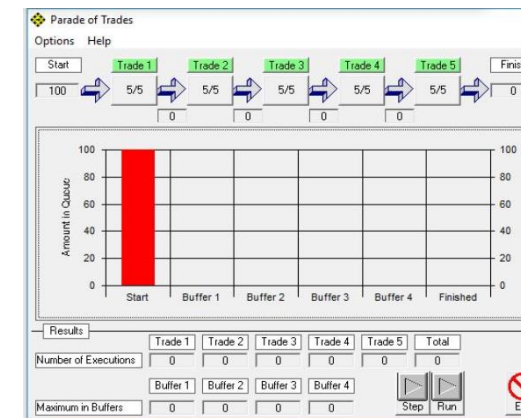
Traditional couching

Post-it's® Whiteboards Workshop
(Hackett et al. 2019)

Hands-on games

Villego®
(Villego 2014)

Digital simulation

The Parade of Trade Game (online version)
(Tommelein et al. 1993)

LPS training and simulation

|	**Traditional Couching**	**Hands On**	**Digital**
Pros	• Realism; • Reflective learning	• Engaging; • Accessible; • Popular	• Economical; • Accessible; • Remote training
Cons	• Time-consuming; • Space restriction; • Not flexible • High-investment	• Simplified; • Space restriction • Lack of realism and immersion • Lack of reflective learning	• Abstract; • Too simplistic

Hands on Simulation Game

Practical gap

Digital Game

Traditional Approaches
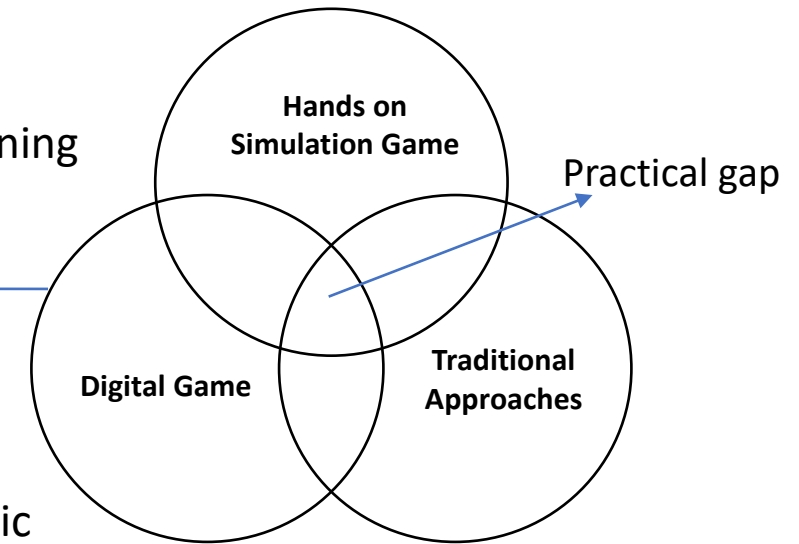
Gaps and Motivations

- **Knowledge Gap: Lack of research on uncovering these socio-technical dynamics**, the underlying mechanisms and conceptualisation of these need further investigation and test.

- There is a need to explore solutions of critical barriers based on conceptualising and optimising the socio-technical dynamics

- **Practical Gap:** lack of theoretical evidence in pedagogy and practical flexibility in LPS simulation and training engender a **slow LPS and Lean uptake**, limited research can effectively resolving these lingering problems.

- There is a need to explore **a hybrid method** that has advantages of both traditional coaching and simulation games but has the potential to overcome constraints such as space restriction, simplified tasks, abstract and time-consuming.

Virtual Reality Serious Games (VR SG)

"Provides a synthetic or virtual environment which gives a person a sense of reality"
(Jayaram et al. 1997).

A game designed for a primary purpose other than pure entertainment (Connolly et al. ,2012)

- *Proposition 2: As a training tool, VR and SG could be more effective in spreading LPS by mitigating critical barriers than conventional approaches*

Advantages of Virtual Reality	References	Description
VR1: Immersion	(Heydarian and Becerik-Gerber 2017)	Create more "realistic feelings"
VR2: Realism	(LaValle 2016)	Simulate visual or interaction experience like real world
VR3: Highly engaging and perception	(Feng et al. 2018)	High emotional and physiological arousal
VR4: Concretisation of knowledge	(Winn 1999)(Krokos et al. 2019)	Bypassing abstract symbol systems to reinforce learning
VR5: Behaviour observation	(Lovreglio et al. 2018)	Flexible in collecting behaviour data

| Advantages of Serious Games	References	Description
S1: Reinforce learning	(Michael and Chen 2005)	Recall the memory more effectively
S2: Highly Engaging	(Lovreglio et al. 2017)	SG are able to entertain people
S3: Correct human behaviour	(Lovreglio et al. 2018)	Get immediate feedback from SG to rectify incorrect response
S4: Investigate human behaviour	(Connolly et al. 2012)	Enable tracking and recording decisions and behaviour
S5: Controlled environment	(Lovreglio et al. 2018)	The storyline can be easily edited

Critical barriers	Advantages of VR SG									
	V1	V2	V3	V4	V5	S1	S2	S3	S4	S5
B1: Resistant to change	√	√	√				√	√	√	√
B2: Lack of cooperation	√	√	√		√	√			√	√
B3: Lack of Understanding	√	√	√	√	√	√	√		√	√

Linking the VR SG to Critical Barriers

Proposed workflow to fill the gaps

- Observing behavior in VR based behaviour study to provide insight on **knowledge gap** (conceptualizing social-technical dynamics)

- Using VR SG based training platform to fill the practical gap (effective training tool to solve critical barriers)

Propose a framework to link the concepts for tackling barriers

- Design experiments by defining **anticipated behaviours** related back to critical barriers (shown as B1, B2, B3).

- Adopt **technical tools**(VR) to conduct experiment and observation.

- Use **sociological methodologies** (SNA/LAP) to explain social behaviour in this simulation.

- Involve **pedological approaches** to tackle these barriers.

- If needed, **further observations** can be applied to provide interventional strategies that will improve research outcomes.
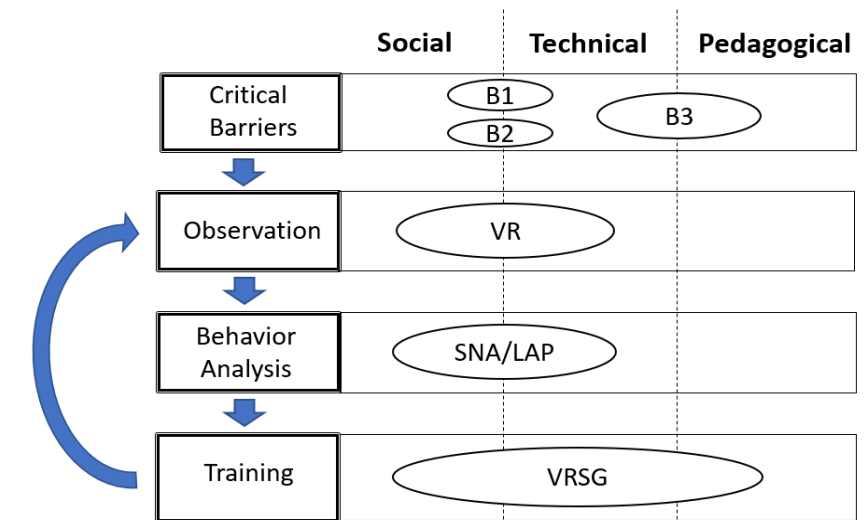
Conceptual framework

An Example for explaining the proposed frameworks
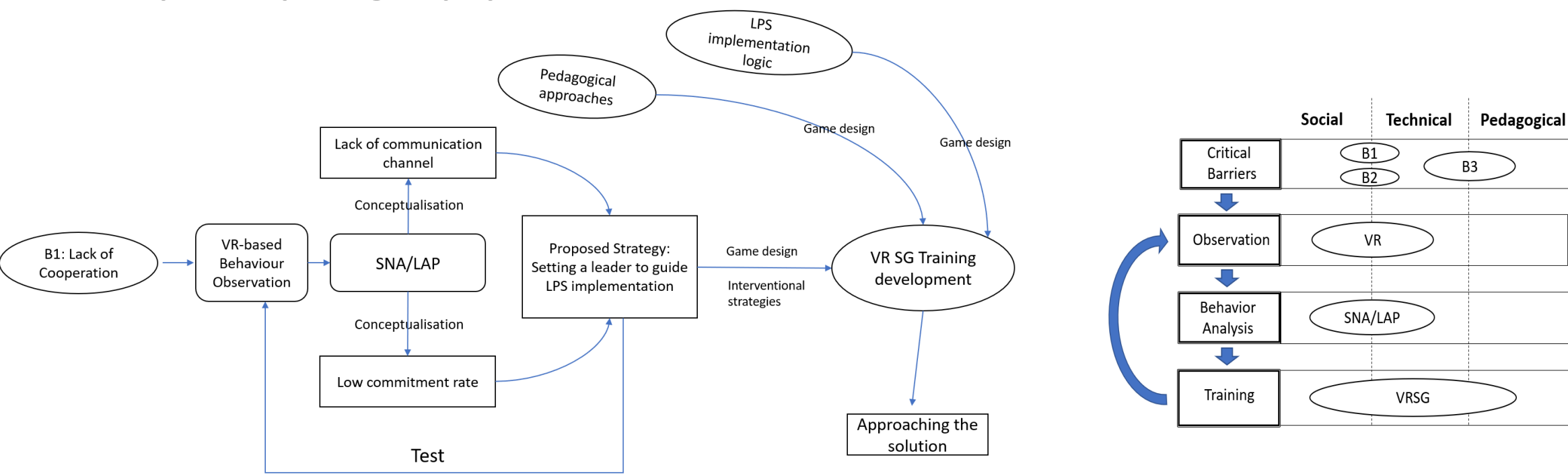
Future works: Prototyping for LPS training and behaviour experiments

- **Strategy input**

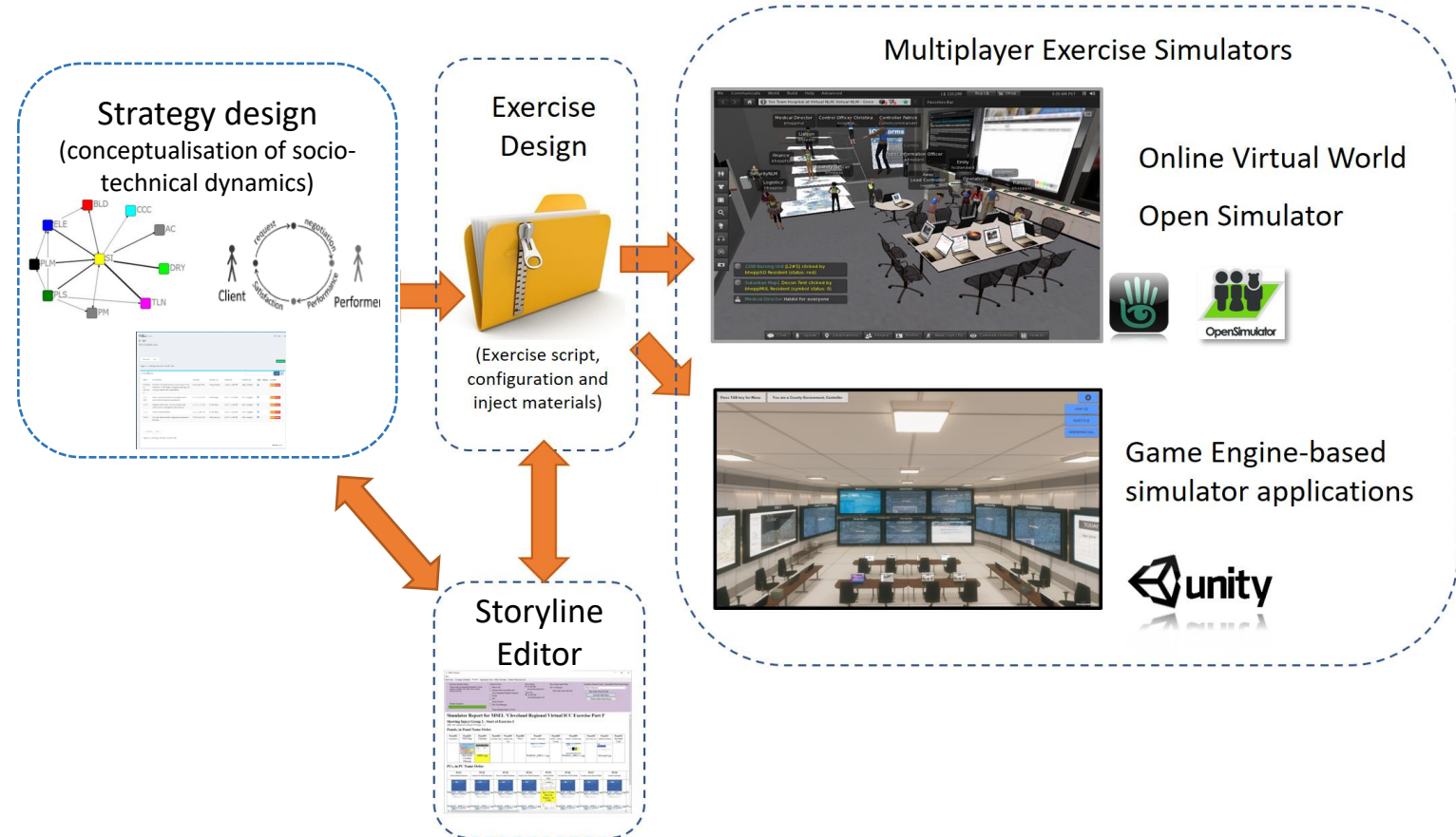Theoretical basis for game design and storyline.

- **Storyline Editor**

Editable storyline for enhancing the adaptivity for

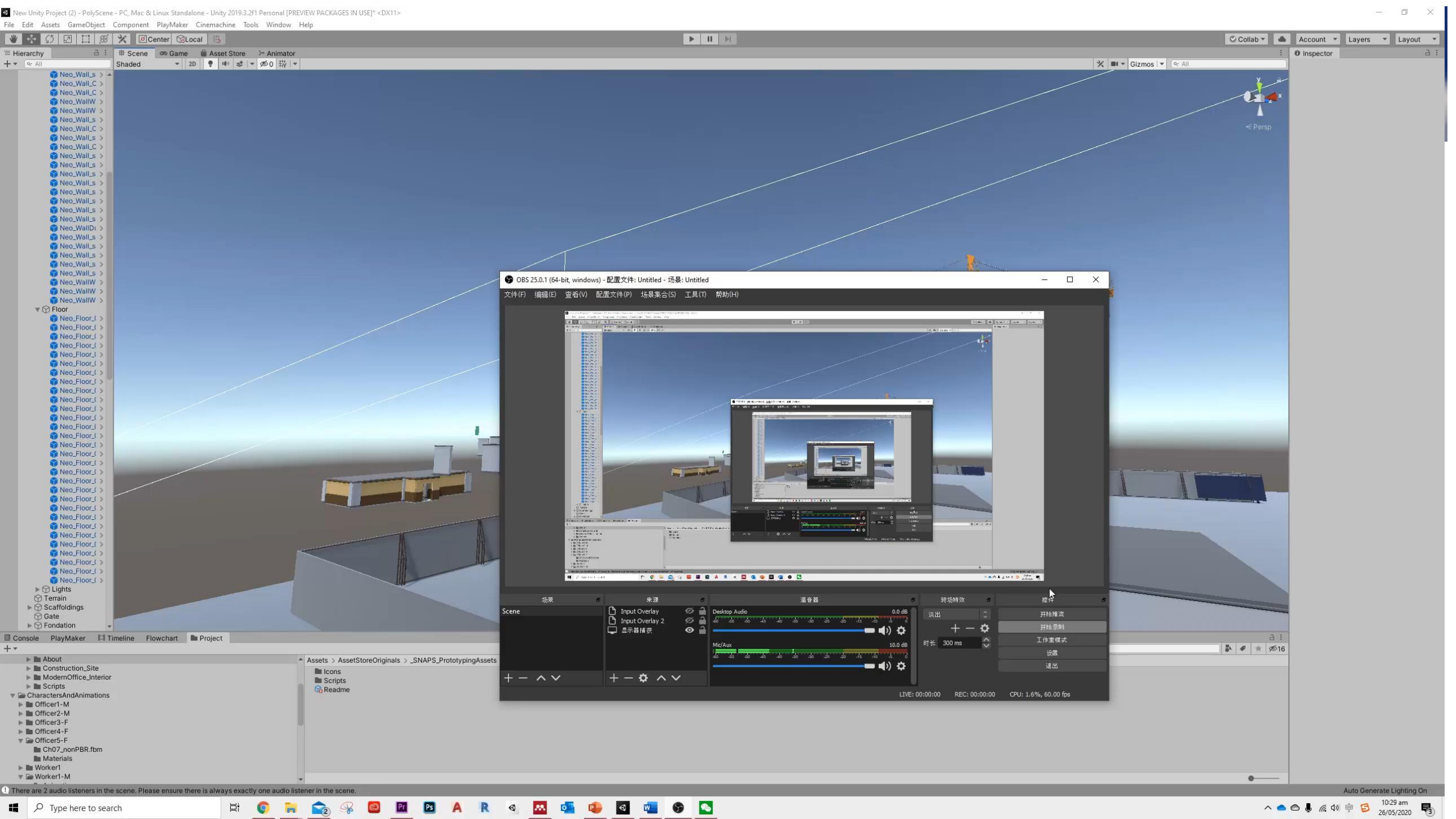test and validation.

- **Training platform design**

Coding, game logic, pedagogical approaches.

- **Multiplayer training environment**

User interface, virtual environment, human

computer interaction, server.

*LPS training prototype components
(Inspired by VIX-S: https://disasterinfo.nlm.nih.gov/virtual-reality)*

Six research questions

- What **behavioural patterns** related back to critical socio-technical barriers can be observed in the experiment?

- How can the **socio-technical dynamics** in LPS implementation be more comprehensively analysed by using **SNA/LAP**?

- Which **socio-technical dynamics/aspects** can significantly improve LPS implementation?

- What are the **intervention strategies** that have the potential to be considered to tackle critical barriers?

- Can **LPS be more effectively delivered by VR SG** compared to traditional methods?

- How **user-friendly** and **engagement** of VR SG are in terms of LPS training?

Conclusion

- This paper explored the **critical barriers** in LPS implementation and categorised them into **social and technical** domains.

- The specific concepts such as **socio-technical dynamics**, **SNA**, and **LAP** that might be used to tackle critical barriers were extensively explored, highlighting the importance of socio-technical dynamics in LPS implementation.

- Findings indicate the **significant potential** of **VR** and **SG** in delivering knowledge than traditional training approaches even though they have some limitations.

- A **conceptual framework** for studying socio-technical dynamics and LPS training based on a discussion of these concepts.

- **Six questions** were asked and to be answered in future research

- Further work is required to conduct **behaviour experiment and explore a VR SG prototype** with validating it through case studies.