The Impact of Immersive Virtual Reality (IVR) on Learning in Higher Education: A Systematic Review of Empirical Evidence

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Introduction

- The extended experience which immerses learners in a short-term engagement in rich contexts with strong authentic practices (Dede et al., 2017)
- Immersion, presence, and interactivity are regarded as the core features of VR technologies (Ryan, 2015)
- Cognitive-affective model of immersive learning model, presence and agency were identified as general psychological affordances of learning in IVR (Makransky & Petersen, 2021).

Research questions

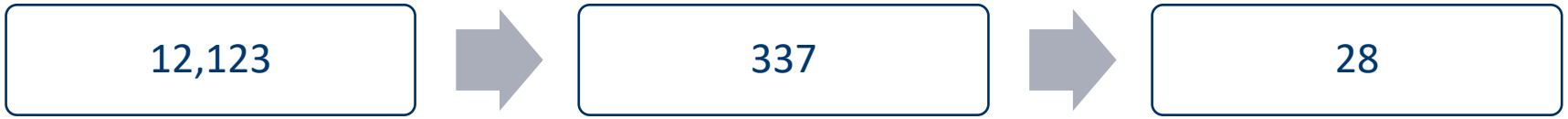
Less attention has been paid to detailed technical affordances and pedagogical affordances, though they are emphasized at similar importance to enhancing the learning experience in VR scenarios (Fowler, 2015).

- Whether it is necessary for teachers to develop their own IVR program for good learning performance? If not, what aspects should pay attention to when deciding on IVR programs used? :
  - What kinds of pedagogical and technical affordances were common in IVR-based instruction?
  - What kinds of interaction mechanisms were common in IVR-based instructional learning?
  - What were the relationships between those factors to learning outcomes?

Research methods

Search strategies

- PRISMA guidance in research review
- Web of Science, Scopus, and Google Scholar
- In Web of Science, the search string was “learn* OR educat* OR teach* AND universit* OR college* OR higher education AND headset* OR HMD* OR head-mounted display* OR immersive VR OR immersive virtual realit* OR immersive technolog*” in the title.



Research methods

Coding scheme

- The categories of the integration of design features in educational IVR applications to find the technical affordances (three levels) from (Won et al., 2022) and pedagogical affordances (categories) from (Merchant et al., 2014), e.g.,

Design features	Subcategories
Sensory	Visual, Audio, Haptic
Actional	Interactivity, Embodied movement
Narrative	Roles, Contexts and storyline, Challenges and achievement
Social	Social interaction

https://github.com/wentingsunhu/-Impact-of-Immersive-Virtual-Reality-IVR-on-Learning-in-Higher-Education.git

Results

Pedagogical affordances outside IVR.

pre-training was added, and after the IVR intervention practice testing, summarizing, learning by teaching, and self-explanation.

Table 1. Pedagogical affordances inside IVR

	Sub-categories	Number of cases
Mode of instruction	Practice	23
	Presentation	4
	Stand-alone	1
Type of feedback	Knowledge of results or response	13
	Elaborate explanation + knowledge of results or response	6
	Visual clues	10
Learning activities	Practice	16
	Respond	1
	Questions	1
	visualize	6
	Visit	2
	Roles	1
	Design	1

Results

Table 2. Comparison results with control groups

Comparison groups	subcategories	Whether IVR-based instruction produced better learning outcomes	Number of cases
Physical filed learning	Physical lab	25% better but not significantly, 75 % similar	4
	F2F one-to-one (peer)	Similar	1
Interactive online learning or e-learning	Mobile app	Similar	1
	PC (low immersion/high interactivity)	Similar	1
	online platform group (Kahoot)	Better but not significantly	1
Multimedia learning	PPT slides	50% better significantly, 50% worse significantly in transfer scores and not significantly in retention scores	2
	Video lecture	33% better significantly, 67% similar	3
	VR-video (high immersion/low interactivity)	Similar	1
	Auditory text first with prompt	Better significantly	1
	Webcam instruction (learning by observing)-online conventional lecture	Better significantly	1
Traditional methods	Lecture	67% better significantly, 33% better but not significantly	3
	Leaflet reading	Similar	1
	text	Better significantly	2
Desktop VR	-	67% better significantly, 17% worse significantly, 16% similar	6
Mixed Reality	-	Better but not significantly	1

Results

Table 3. Integration levels of technological affordances

	Visual	Audio	Haptic	Interactivity	Embod	Roles	Storyline	Challenge	social
Declarative knowledge (16)	3(7)	3(0)	3(0)	3(5)	3(6)	3(8)	3(6)	3(2)	3(1)
	2(6)	2(10)	2(0)	2(8)	2(10)	2(5)	2(10)	2(11)	2(13)
	1(3)	1(3)	1(6)	1(3)	1(0)	1(3)	1(0)	1(3)	1(2)
Procedural Knowledge (12)	3(5)	3(2)	3(0)	3(6)	3(8)	3(3)	3(2)	3(0)	3(2)
	2(4)	2(6)	2(1)	2(5)	2(4)	2(7)	2(6)	2(9)	2(7)
	1(3)	1(4)	1(11)	1(1)	1(0)	1(2)	1(4)	1(3)	1(3)

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Results

Table 4. Correlation relationships among technical features

	Visual	Audio	Intera	Embod	Roles	Storyline	Challenge	Social
Visual	1	.202	.190	-.074	-.027	.051	.120	.027
Audio	.086	1	-.032	.086	-.347	-.059	.420	.158
Intera	-.299	-.046	1	.184	.525	.347	.376	.695*
Embod	-.086	.333	.788**	1	-.460	-.171	.000	.184
Roles	.081	-.357	.628**	.357	1	.600*	.376	.424
Storyline	.258	-.200	.046	-.067	.693**	1	.420	.347
Challenge	-.263	-.320	.667**	.320	.632**	.320	1	.526
Social	-.340	.188	.236	.113	.249	.414	.509*	1

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Discussions and conclusions

- Different correlation relationships of technical affordances were found between declarative or procedural knowledge learning-stressed articles.
- Generally, for better learning outcomes, more attention to interactivity, embodied movement, roles, storytelling, and challenges is suggested in the technical affordance design part.
- 85% of IVR programs were developed by the authors in the procedural knowledge-stressed articles, this ratio in declarative knowledge-stressed articles was 56%.
- In terms of pedagogical affordances, generative learning strategies (GLS) were found to be combined with the intervention of IVR and generally produced better learning performance.

Future studies

Relationship exploration:

e.g., the relationships between technical affordances, pedagogical affordances, and psychological affordances in IVR.

whether the measurement of learning performance should be different between IVR-based instruction and traditional online or F2F teaching?

IVR-based instruction:

e.g., outside IVR software, which generative learning strategies would be chosen and in which sequence according to specific learning objectives.

inside IVR software, what kind of prompt in the development should be stressed to reduce the time and cost investment?

Reference

Dede, Christopher J., Jeffrey Jacobson, and John Richards. "Introduction: Virtual, augmented, and mixed realities in education." Virtual, augmented, and mixed realities in education (2017): 1-16.

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Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. Computers & Education, 70, 29-40.

VR game design engines:

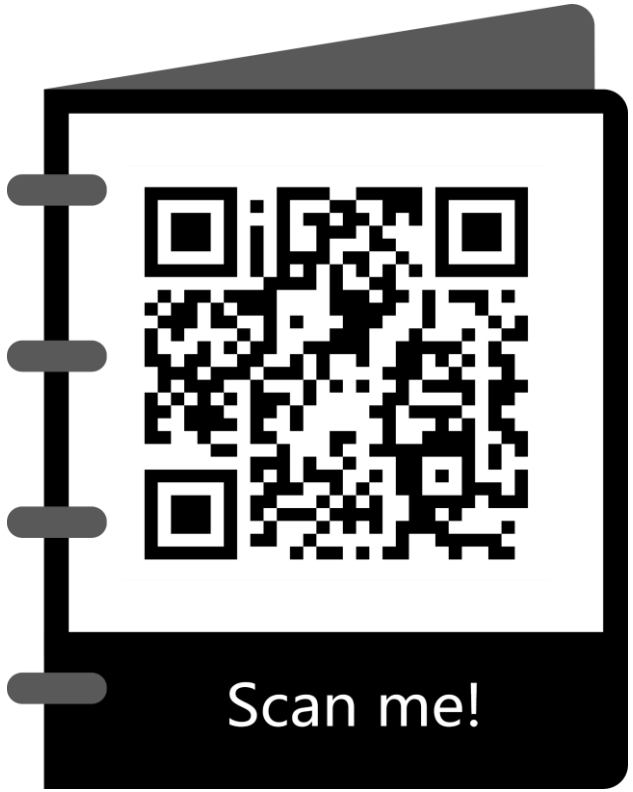
Unreal

Unity

VR game store:

STEAM

VR glass companies (e.g., Oculus Quest)



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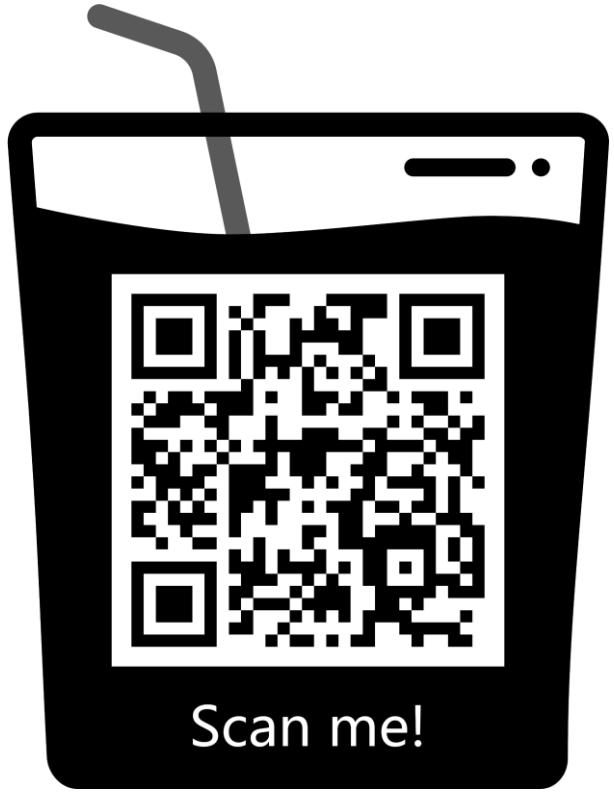

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