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Moving Beyond the Display Effect: The Role of Student Characteristics in 360° Video-Based Learning Experiences

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Abstract. The educational use of 360° videos has gained significant ground in recent years. In parallel, a significant corpus of media comparison studies has examined whether the immersive affordances of display devices influence students' learning with 360° educational videos; however, findings remain inconclusive. Extending this research line, this work-in-progress paper investigates the effects of display device on learning gains and subjective experiences (learning motivation, immersion, cognitive load), while also accounting for the role of student characteristics (immersive tendencies, prior knowledge, and domain-specific interest). A total of 161 university students participated in this study: 104 viewed a 360° educational video on a desktop computer and 57 experienced the same video with a smartphone-based VR headset. Multivariate analyses indicated that, while there were no differences in factual learning gains and cognitive load across conditions, students in the VR condition demonstrated higher motivation and immersion. Moreover, a cluster analysis revealed two distinct learner profiles (high vs. low learning disposition students) within each display condition, characterized by significant differences in motivation, immersion, and knowledge acquisition. High learning disposition students in the VR condition demonstrated the most positive learning outcomes, surpassing all other groups. In contrast, low learning disposition students, assigned in the desktop condition, performed worst on the factual knowledge post-test and showed comparatively weaker motivation and immersion. Taken together, these findings highlight that learning with 360° educational videos cannot be generalized as equally effective for all students and suggest that learning outcomes may be contingent on student profiles.

Keywords: 360o Video-based Learning, Display Effect, Learner Profiles, Immersion, Learning Motivation, Cognitive Load.

1 Introduction and Theoretical Background

In the past few years 360^{O} videos have found application in education, as they are believed to provide immersive learning experiences at a scale, since they can be viewed with high-end head-mounted displays, but also with a variety of low-cost media (e.g., tablets, smartphones), including smart-phone based VR headsets [1]. More specifically, researchers have found that 360^{O} videos may foster students' engagement by enhancing their learning motivation and experienced immersion [2, 3], as they provide access to panoramic and realistic environments [4]. Moreover, it has been argued that 360^{O} videos can transform the learning process into a more enjoyable and memorable activity [5], while also providing opportunities for engagement with the educational content from multiple perspectives, which may foster reflection and deeper understanding [6]. Despite these arguments, recent meta-analysis studies have yielded inconclusive findings on the learning effectiveness of 360^{O} videos [7, 8].

One explanation for these findings is the immersiveness supported by the different display modes when experiencing 360^{O} educational videos [1]; put simply, since 360^{O} educational videos can be viewed on both low-immersive or high-immersive displays, the display medium may affect students' subjective experiences and learning outcomes. On the other hand, a second plausible explanation concerns student characteristics and their influence on cognitive and affective outcomes. However, despite acknowledging the potential role of student characteristics, only few empirical studies have investigated their influence on 360^{O} video-based learning, with scholars urging the need for further research in this area [9–11].

In this study, we argue that learner characteristics may be particularly consequential in 360° educational video-based learning due to the specific cognitive, perceptual, and attentional demands imposed by this medium. The production of 360° video relies on an audiovisual grammar that differs from that of conventional video formats, which may fundamentally shape how learners process instructional information [12]. Unlike traditional video, 360° educational videos allow learners to freely direct their gaze, meaning that only a portion of the scene is visible at any given moment [13]. While this affordance supports exploration and immersion, prior research suggests that it may also increase the risk of distraction, as learners may attend to visually salient but pedagogically irrelevant elements of the environment.

Toward the same direction, it has been argued that visually compelling immersive experiences supported by 360° educational videos may encourage learners to focus on exploring the environment rather than attending to auditory information, such as narration or voice-over, raising concerns that 360° videos may increase cognitive load [14], hindering comprehension and recall. Moreover, the requirement to actively choose where to look in a 360° environment may evoke fear of missing out (FOMO), whereby learners feel compelled to continuously scan the environment to avoid overlooking potentially relevant information [15, 16]. Such attentional uncertainty may further tax cognitive resources and contribute to fragmented processing of instructional content. These characteristics of 360° video suggest that learner differences may not merely influence learning outcomes, but may do so differently across immersive and non-immersive display conditions.

To address this issue, the present study focuses on how three particular student characteristics (prior knowledge, domain-specific interest, immersive tendencies), together with the display type (smartphone-based VR vs. desktop computer), may shape students' learning gains and subjective experiences, when viewing a 360^{O} educational video. More specifically, an underpinning hypothesis is that prior content knowledge may help learners interpret complex visual information and reduce disorientation, immersive tendencies may facilitate engagement and presence without overwhelming attentional resources, and domain-specific interest may support sustained motivation and task focus when experiencing a 360° educational video.

To date, however, few studies have examined how these learner characteristics relate to display immersiveness in shaping learning outcomes and subjective experiences in the context of 360° educational videos, particularly across high-immersive and low-immersive viewing conditions. Although related characteristics have been investigated in other immersive media, findings cannot be readily generalized across media types, as different immersive technologies afford distinct opportunities and constraints [17]. Moreover, given that students do not approach learning with isolated dispositions but with a constellation of co-occurring characteristics, it remains unclear how their combined influence shapes learning outcomes and subjective experiences in 360° educational video-based learning. In this context, this study seeks to answer the following two research questions: (a) To what extend does display type (desktop computer vs. VR headset) influence undergraduate students' factual knowledge gains and subjective experiences (learning motivation, immersion, cognitive load)?, and (b) Which distinct learner profiles emerge (based on prior knowledge, immersive tendencies, and domain-specific interest), and how are these profiles associated with students' factual knowledge gains and subjective experiences within each condition?

2 Methodology

2.1 Participants

One hundred and sixty-one (n=161) undergraduate students at a public university were recruited using convenience sampling; this sample included 90 women (55.9%) and 71 men (44.1%), as self-identified. 104 students viewed a 360° educational video on a desktop computer (DC condition) and 57 students viewed the same video with a smartphone-based VR headset (VR condition). Their ages ranged from 18 to 27 years (M=20.09, SD=1.60), with no statistically significant age difference between the two conditions (t=−1.80, p=.074). Moreover, a multivariate analysis of variance (MANOVA) indicated no baseline differences between groups, in terms of students' prior factual knowledge, domain-specific interest, and immersive tendencies. More specifically, the overall test using Pillai's Trace was nonsignificant [Pillai's Trace=.025, $F(3,157)=1.36$, p=.257, partial η^2 = .025], indicating no systematic multivariate differences between conditions. At the univariate level, no significant group effects were found for domain-specific interest [($F(1, 159)=0.66$, p=.417, partial η^2=.004)], immersive tendencies [($F(1, 159)=0.01$, p=.910, partial η^2<.001)], as well as for prior factual knowledge [($F(1, 159)=3.77$, p=.054, partial η^2=.023)].

2.2 Learning Intervention

The 360° video used in this study, titled *"Solar System-Step onto Every Planet's Surface"* [18], had a duration of 10:15 minutes. The 360^{O} video, which was available online, invited students to explore the solar system in 360^{O}, allowing them to virtually visit each planet to learn more about it.

In both conditions, each participant spent approximately 45 minutes during the experiment, which comprised three phases. In phase 1, all students initially received an overview of the study. They then completed an online pre-survey, which collected demographic information and assessed prior knowledge of the solar system, immersive tendencies, as well as interest into astronomy. Subsequently, students were assigned to one of two experimental conditions (Condition1: DC, Condition 2: VR). Finally, after watching the 360^{o} video, all students completed an online survey to assess their factual knowledge of the solar system again as well as their experienced immersion, learning motivation, and self-reported cognitive load.

2.3 Data Collection

Students' motivation was measured with the 'Reduced Instructional Materials Motivation Survey' [RIMMS] which includes 12 five-point Likert items, distributed across four scales ("Attention", "Relevance", "Confidence", "Satisfaction") [19, 20]. Psychological immersion was measured with 7 seven-point Likert items distributed across the "Flow" and "Presence" scales, derived from the Virtual Reality Immersion [VRI] questionnaire [21]. Cognitive load was measured with Leppink's Cognitive Load Scale, which includes 6 five-point Likert items, for measuring "Intrinsic" and "Extraneous" cognitive load [22], as adapted by Andersen and Makransky [23]. Students' immersive tendencies were assessed using the "Immersive Tendencies Questionnaire–Short Form" (ITQ-10), validated by Rózsa et al. [24], which includes 10 five-point Likert items, distributed across two scales ("Focus", "Involvement"). Domain-specific interest -in the case of our study, interest in astronomy- was assessed using Kelly's (2007) single-item question (i.e., "Astronomy is interesting/appealing as a vocation") measured on a 7-point Likert scale [25]. Finally, students' factual knowledge gains were evaluated with a pre-post knowledge test with 10 multiple-choice questions.

2.4 Data Analysis

To address RQ1, a MANCOVA was conducted to examine differences between the two conditions (DC vs. VR) on students' learning and subjective experiences (learning motivation, immersion, and cognitive load), while controlling for students' pre-test scores, immersive tendencies, and interest in astronomy. Significant multivariate effects were then analyzed with univariate analyses to identify which dependent variables contributed to group differences.

To address RQ2, we clustered students based on three variables (prior knowledge, domain-specific interest, immersive tendencies) to identify distinct learner profiles. More specifically, hierarchical cluster analysis was conducted separately for each condition using Ward's method with squared Euclidean distance as the measure of dissimilarity, followed up by a K-means clustering analysis. These analyses yielded two core clusters representing distinct student profiles, according to their individual characteristics, in each condition, resulting in four clusters overall. Finally, students' learning outcomes and subjective experiences (learning motivation, immersion, cognitive load) were compared across the four derived clusters using the MANOVA statistical test.

3 Findings

3.1 Display Effect on Factual Knowledge and Subjective Experiences

The analyses indicated that the multivariate effect of display condition was statistically significant [Pillai's Trace=.116, $F(9,148)=2.16$, $p=.028$, partial $\eta^2=.116$], suggesting that the type of display was associated with differences in the combined dependent variables. Follow-up ANCOVAs revealed that, after adjusting for covariates, students in the VR condition reported significantly higher immersion in terms of flow [$F(1,156)=7.78$, $p=.006$, partial $\eta^2=.048$], and presence [$F(1,156)=11.92$, $p<.001$, partial $\eta^2=.071$], compared to those in the desktop condition. In addition, students in the VR condition reported higher motivation in the dimensions of relevance [$F(1,156)=7.45$, $p=.007$, partial $\eta^2=.046$], and satisfaction, [$F(1,156)=5.81$, $p=.017$, partial $\eta^2=.036$]. No significant group differences were found for post-test knowledge [$F(1,156)=0.03$, $p=.869$], for the motivational dimensions of attention or confidence, or for intrinsic and extraneous cognitive load ($ps \geq .152$).

Table 1. Estimated marginal means (±SE) and ANCOVA results for display condition (Desktop vs. VR).

	Dependent Variable	Desktop M (SE)	VR M (SE)	F(1,156)	p	Partial η²
Factual knowledge	Post-test knowledge	6.44 (0.16)	6.49 (0.22)	0.03	.869	.000
Motivation	Attention	3.49 (0.08)	3.63 (0.11)	1.05	.308	.007
	Relevance	3.50 (0.06)	3.78 (0.08)	7.45	.007*	.046
	Confidence	3.59 (0.06)	3.74 (0.08)	2.07	.152	.013
	Satisfaction	3.62 (0.06)	3.87 (0.08)	5.81	.017*	.036
Immersion	Flow	4.21 (0.12)	4.79 (0.17)	7.78	.006*	.048
	Presence	3.44 (0.12)	4.14 (0.16)	11.92	<.001*	.071
Cognitive load	Intrinsic load	2.22 (0.07)	2.15 (0.09)	0.37	.542	.002
	Extraneous load (	2.10 (0.07)	2.08 (0.09)	0.03	.866	.000

3.2 The Impact of Student Profiles on Factual Knowledge and Subjective Experiences

To address RQ2, a cluster analysis categorized students into two homogeneous groups (clusters) in both VR and DC conditions, resulting in the identification of two student profiles per condition: "High Learning Disposition" and "Low Learning Disposition" students. Students assigned to the "High Learning Disposition" (HLD) profile reported higher levels of prior knowledge, domain-specific interest and immersive tendencies, whereas students assigned in the "Low Learning Disposition" (LLD) profile showed lower levels on these measures. In terms of distribution, in the VR condition, 24 students were classified as HLD and 33 as LLD; in the DC condition, 57 were HLD and 47 were LLD (Table 2). Furthermore, an ANOVA analysis indicated that, in both conditions, prior knowledge, domain-specific motivation, and immersive tendencies significantly distinguished the clusters ($p<.001$).

Table 2. Summary of Cluster Analysis Findings.

Condition	Cluster	N	Prior knowledge (M ± SD)	Domain-specific interest (M ± SD)	Immersive tendencies (M ± SD)
VR	HLD	24	0.82 ± 0.92	0.84 ± 0.86	0.69 ± 1.01
	LLD	33	-0.24 ± 0.95	-0.46 ± 0.77	-0.52 ± 0.83
DC	HLD	57	0.25 ± 0.86	0.57 ± 0.70	0.43 ± 0.82
	LLD	47	-0.55 ± 0.86	-0.82 ± 0.69	-0.51 ± 0.85

A multivariate analysis of variance (MANOVA) was then conducted to examine differences among the four student clusters (DC-HLD, DC-LLD, VR-LLD, VR-HLD) on post-test knowledge, motivation (attention, relevance, confidence, satisfaction), immersion (flow, presence), and cognitive load (intrinsic, extraneous). Pillai's Trace was used again as the multivariate test statistic.

The results revealed a significant multivariate effect of cluster [Pillai's Trace=.408, $F(27,453)=2.64$, $p<.001$, partial $\eta^2=.136$], indicating that students' trait-based clustering was associated with differences in the combined dependent variables (Table 1). Follow-up ANOVAs showed significant group differences for post-test knowledge [$F(3,157)=8.32$, $p<.001$, partial $\eta^2=.137$] as well as for immersion, in terms of flow [$F(3,157)=6.65$, $p<.001$, partial $\eta^2=.113$] and presence [$F(3,157)=6.33$, $p<.001$, partial $\eta^2=.108$]. For learning motivation, significant differences were observed in relevance [$F(3,157)=8.89$, $p<.001$, partial $\eta^2=.145$], confidence [$F(3,157)=7.45$, $p<.001$, partial $\eta^2=.125$], and satisfaction [$F(3,157)=5.72$, $p<.001$, partial $\eta^2=.099$]. In contrast, no significant cluster differences emerged for attention [$F(3,157)=1.85$, $p=.140$, partial $\eta^2=.034$]. Finally, significant group effects were found for both intrinsic cognitive load [$F(3,157)=3.66$, $p=.014$, partial $\eta^2=.065$] and extraneous cognitive load [$F(3,157)=5.04$, $p=.002$, partial $\eta^2=.088$].

Examination of the descriptive statistics demonstrated a consistent hierarchical ordering across clusters. VR-HDL students achieved the highest post-test scores (M=7.58), followed by DC-HDL (M=7.04), VR-LDL (M=6.21), and DC-LDL (M=5.36). Post hoc tests confirmed significant advantages for VR-HDL and DC-HDL over DC-LDL. For motivation (relevance, confidence, and satisfaction), VR-HDL students significantly outperformed all other clusters, while DC-LDL consistently ranked lowest. Similarly, the VR-HDL students reported the higher sense of flow (M=5.46) and presence (M=4.64), whereas the remaining clusters did not differ significantly from one another. Regarding cognitive load, high-disposition students (VR-HDL and DC-HDL) reported lower intrinsic and extraneous load than low-disposition groups (VR-LDL and DC-LDL). Notably, VR-HDL students showed the lowest levels overall (Intrinsic: M=1.93; Extraneous: M=1.74), with post hoc tests confirming significant differences compared to DC-LDL for intrinsic load and to both DC-LDL and VR-LDL for extraneous load. Taken together, although not all contrasts reached statistical significance, the descriptive means indicate a stable pattern, with VR-HDL being the profile associated with the highest learning gains overall and DC-LDL the profile associated with the lowest, while DC-HDL and VR-LDL lie in between. This pattern implies that students' learning dispositions systematically shape how they experienced and benefitted from the different immersive conditions while interacting with the 360^{O} educational video.

4 Discussion

This study explored how both display medium (desktop vs. VR) and learner characteristics influence students' learning outcomes and subjective experiences with 360^{O} educational videos. Therefore, this study responds to recent calls to move toward learner–treatment interaction approaches, when investigating the effectiveness of immersive learning media [26].

Results showed that the impact of 360^{O} video-based learning on students' outcomes was influenced by the students' profiles (defined by prior knowledge, domain interest, and immersive tendencies), rather than by display modality alone. More specifically, students with high disposition toward learning (HLD) consistently outperformed those with low disposition (LLD), with the VR-HLD group demonstrating the highest gains in factual knowledge, learning motivation, immersion, as well as optimal cognitive load. In contrast, students with low learning disposition using desktops reported the least favorable learning outcomes. Importantly, however, the presence of VR in both HLD and LLD profiles suggests that immersive displays do not confer uniform benefits across learners. This pattern indicates that while VR may support certain experiential aspects of learning across student groups, its contribution to learning outcomes depends on how well learners are able to manage the cognitive and attentional demands of immersive viewing.

These findings indicate the significance of accounting for the impact of student characteristics in immersive learning research [17, 27], not as a general principle, but as a display-contingent phenomenon, suggesting that the effectiveness of a given immersive display may strongly depend on learner characteristics. For instance, the analysis of student data as a homogenous group yielded no factual knowledge gains among the two display conditions. However, when the data were analyzed according to the students' learning dispositions, high-learning disposition (HLD) students in the VR condition exceeded their counterparts in terms of their post-test learning scores. This pattern suggests that the potential advantages of VR may be more pronounced for learners who are already better equipped to manage immersive learning demands, rather than indicating a general superiority of VR over desktop-based 360° video. Collectively, these findings highlight that understanding *who* benefits most is just as important as examining *whether* immersive media are effective.

5 Limitations and Future Research

Despite the contributions of the present study, several limitations should be acknowledged, which also point to directions for future research.

First, the 360° educational video used in this study exceeded ten minutes, which is longer than what is often recommended for sustaining attention in video-based learning [28, 29]. Although engagement over time was not measured in this study, video length may have acted as a confounding factor, particularly for students with low learning disposition who may be more susceptible to disengagement during prolonged learning activities. Future work should therefore examine the role of video duration and segmentation strategies in 360° educational video-based learning and assess how shorter or modularized content may differentially support learners across immersive and non-immersive display conditions.

Second, the sample was unevenly distributed across display conditions, with fewer participants assigned to the VR condition than to the desktop condition. This distribution resulted from practical and logistical constraints, including the availability of smartphone-based VR headsets and the scheduling of experimental sessions, rather than from a theoretically motivated allocation strategy. In turn, this imbalance may have affected statistical power for some comparisons and warrants cautious interpretation of interaction effects. Future studies should therefore employ more balanced experimental designs and larger samples to strengthen the robustness of learner–display interaction analyses.

Third, the learner profiles identified in this study should not be interpreted as stable or general learning dispositions. While immersive tendencies may reflect relatively stable individual differences, prior knowledge and domain-specific interest are inherently topic-dependent. Accordingly, given that the instructional content in this study focused on the solar system, different subject domains may yield different learner profile distributions and outcomes. For this reason, replication across diverse content areas would help clarify how topic-specific motivation and learner characteristics interact with immersive and non-immersive learning environments.

Finally, the quasi-experimental design of the present study limits the strength of causal conclusions, and the observed relationships between display modality, learner characteristics, and learning outcomes should be interpreted as associative rather than causal. Future research employing fully randomized or experimental designs is needed to strengthen causal inferences in this area.

6 Conclusions and Instructional Design Implications

Notwithstanding the aforementioned limitations, the present study contributes to a more nuanced understanding of learning with 360° educational videos by highlighting the role of learner–display interactions. Taken together, 360° educational videos cannot be considered a one-size-fits-all approach. Their impact is shaped not only by the immersiveness of the chosen display medium but also by the learners' individual dispositions, which may relate differently to learning gains and subjective experiences depending on the display modality. Our findings indicate that pre-existing learner characteristics, as the ones investigated in this study (i.e. prior knowledge, domain-specific-interest, immersive tendencies), vary in their predictive strength across immersive and non-immersive viewing conditions.

Collectively, rather than advocating the uniform adoption of 360° educational videos, the study findings suggest that instructional decisions regarding display modality should be guided by pedagogical goals and learner–display alignment. Therefore, to promote equitable learning outcomes, their integration should be carefully aligned with instructional objectives as well as with the cognitive and attentional demands of the selected display. In practice this may involve considering whether immersive and non-immersive viewing conditions are more appropriate given learners' prior knowledge, immersive tendencies, and domain-specific interest, rather than implementing uniformly across diverse student populations.

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References

1. Rupp, M.A., Odette, K.L., Kozachuk, J., Michaelis, J.R., Smither, J.A.A., McConnell, D.S.: Investigating learning outcomes and subjective experiences in 360-degree videos. Comput. Educ. 128, 256–268 (2019). https://doi.org/10.1016/j.compedu.2018.09.015
2. Christopoulos, A., Pellas, N., Bin Qushem, U., Laakso, M.: Comparing the effectiveness of video and stereoscopic 360° virtual reality-supported instruction in high school biology courses. British Journal of Educational Technology. 54, 987–1005 (2023).
3. Jacobs, C., Maidwell-Smith, A.: Learning from 360-degree film in healthcare simulation: a mixed methods pilot. J. Vis. Commun. Med. 45, 223–233 (2022).
4. Elmezeny, A., Edenhofer, N., Wimmer, J.: Immersive storytelling in 360-degree videos: An analysis of interplay between narrative and technical immersion. Journal For Virtual Worlds Research. 11, (2018).
5. Evens, M., Empsen, M., Hustinx, W.: A literature review on 360-degree video as an educational tool: towards design guidelines. Journal of Computers in Education. 10, 325–375 (2023).
6. Rosendahl, P., Wagner, I.: 360° videos in education – A systematic literature review on application areas and future potentials. Educ. Inf. Technol. (Dordr). 29, 1319–1355 (2024). https://doi.org/10.1007/s10639-022-11549-9
7. Schroeder, N.L., Siegle, R.F., Craig, S.D.: A meta-analysis on learning from 360° video. Comput. Educ. 206, (2023). https://doi.org/10.1016/j.compedu.2023.104901
8. Snelson, C.L., Hsu, Y.: Educational 360-Degree Videos in Virtual Reality: a Scoping Review of the Emerging Research. TechTrends. 64, 404–412 (2020). https://doi.org/10.1007/s11528-019-00474-3
9. Huang, X., Zhao, Q., Liu, Y., Harris, D., Shawler, M.: Learning in an immersive VR environment: Role of learner Characteristics and relations between learning and psychological outcomes. Journal of Educational Technology Systems. 53, 3–29 (2024).
10. Lawson, A., Martella, A.M.: Critically reflecting on the use of immersive virtual reality in educational settings: What is known and what has yet to be shown? Journal of Applied Learning and Teaching. 6, 121–133 (2023).

11. Makransky, G., Petersen, G.B.: The cognitive affective model of immersive learning (CAMIL): A theoretical research-based model of learning in immersive virtual reality. Educ. Psychol. Rev. 33, 937–958 (2021).
12. Dooley, K.: Storytelling with virtual reality in 360-degrees: a new screen grammar. Studies in Australasian cinema. 11, 161–171 (2017).
13. Liu, R., Xu, X., Yang, H., Li, Z., Huang, G.: Impacts of cues on learning and attention in immersive 360-degree video: An eye-tracking study. Front. Psychol. 12, 792069 (2022).
14. Barreda-Ángeles, M., Aleix-Guillaume, S., Pereda-Baños, A.: Virtual reality storytelling as a double-edged sword: Immersive presentation of nonfiction 360-video is associated with impaired cognitive information processing. Commun. Monogr. 88, 154–173 (2021).
15. Aitamurto, T., Won, A.S., Sakshuwong, S., Kim, B., Sadeghi, Y., Stein, K., Royal, P.G., Kircos, C.L.: From fomo to jomo: Examining the fear and joy of missing out and presence in a 360 video viewing experience. In: Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. pp. 1–14 (2021).
16. Tan, S., Wiebrands, M., O'Halloran, K., Wignell, P.: Analysing student engagement with 360-degree videos through multimodal data analytics and user annotations. Technology, Pedagogy and Education. 29, 593–612 (2020).
17. Lui, A.L.C., Not, C., Wong, G.K.W.: Theory-based learning design with immersive virtual reality in science education: A systematic review. J. Sci. Educ. Technol. 32, 390–432 (2023).
18. Seymour, Lerhn: Solar system - Step onto every planet's surface. (2021).
19. Keller, J.M.: Development and use of the ARCS model of instructional design. Journal of instructional development. 10, 2–10 (1987).
20. Keller, J.M.: Motivational design for learning and performance: The ARCS model approach. Springer Science & Business Media (2009).
21. Georgiou, Y., Kyza, E.A.: The development and validation of the ARI questionnaire: An instrument for measuring immersion in location-based augmented reality settings. International Journal of Human Computer Studies. 98, (2017). https://doi.org/10.1016/j.ijhcs.2016.09.014
22. Leppink, J., Paas, F., Van der Vleuten, C.P.M., Van Gog, T., Van Merriënboer, J.J.G.: Development of an instrument for measuring different types of cognitive load. Behav. Res. Methods. 45, 1058–1072 (2013).
23. Andersen, M.S., Makransky, G.: The validation and further development of a multidimensional cognitive load scale for virtual environments. J. Comput. Assist. Learn. 37, 183–196 (2021).
24. Rózsa, S., Hargitai, R., Láng, A., Osváth, A., Hupuczi, E., Tamás, I., Kállai, J.: Measuring Immersion, Involvement, and Attention Focusing Tendencies in the Mediated Environment: The Applicability of the Immersive Tendencies Questionnaire. Front. Psychol. 13, (2022). https://doi.org/10.3389/fpsyg.2022.931955
25. Kelly, W.E.: Interest in astronomy and interest in night-sky watching: Evidence for separate but related constructs. Psychology Journal. 4, (2007).
26. Buchner, J., Kerres, M.: Media comparison studies dominate comparative research on augmented reality in education. Comput. Educ. 195, 104711 (2023).
27. Šikl, R., Brücknerová, K., Švedová, H., Děchtěrenko, F., Ugwitz, P., Chmelík, J., Pokorná, H., Juřík, V.: Who benefits and who doesn't in virtual reality learning: An experimental study comparing two types of school. J. Comput. Assist. Learn. 40, 1591–1604 (2024). https://doi.org/10.1111/jcal.12973
28. Brame, C.J.: Effective educational videos: Principles and guidelines for maximizing student learning from video content. CBE—Life Sciences Education. (2017).
29. Seidel, N.: Short, long, and segmented learning videos: From YouTube practice to enhanced video players. Technology, Knowledge and Learning. 29, 1965–1991 (2024).