From Immersion to Outcome: WhatsApp Nudges and 360° Video in Outcome-Based Curriculum Learning (A Synthetic-Data Demonstration)

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Abstract
This article demonstrates an analytic workflow for testing whether 360° video and WhatsApp nudges independently or jointly relate to outcome-based education (OBE) curriculum learning. The workflow was applied to a synthetic dataset structured as a six-week, counterbalanced 2 × 2 repeated-measures quasi-experiment, with 240 simulated Economics Education student records for four Indonesian universities. As stated in the Data Availability section, the dataset is synthetic: no real participants were recruited, and the results are workflow output, not empirical evidence about the effectiveness of either intervention. Each simulated intact class completed four parallel curriculum-analysis cases under standard video/no nudge, 360° video/no nudge, standard video/nudge, and 360° video/nudge conditions. The primary intention-to-treat analysis used weighted least squares on 16 site-period cells with site and period fixed effects, and as-treated models served as a sensitivity check. The demonstration shows that the workflow can separate main effects from the video-by-nudge interaction across achievement, presence, engagement, extraneous cognitive load, and on-time completion, and that the synthetic data produced an additive rather than an interactive pattern. Interpretation is limited by the synthetic origin of the data, the absence of ethical approval and consent records that a real study would require, the uniform six-month shift of all timestamps, the assignment of treatment at only 16 site-period cells, and the use of only four treatment sequences. Claims about effectiveness require re-analysis of verified data collected with ethical approval.

1. Introduction

Outcome-Based Education (OBE) directs curriculum design towards demonstrable student performance rather than content coverage. Its practical quality depends on constructive alignment: intended outcomes, learning activities, and assessment evidence must form a coherent chain (Biggs, 1996). Yet studies of OBE implementation show that formal curriculum mapping does not automatically help lecturers or students recognise alignment in authentic teaching situations (Katawazai, 2021; Mufanti et al., 2024). This challenge is especially relevant in teacher education, where students must learn to notice how classroom activities, feedback, and assessment collectively evidence a course learning outcome.

In Economics Education, the required outcomes extend beyond recall of concepts. Graduates are expected to interpret evidence, communicate economic reasoning, use digital resources critically, and design learning that connects disciplinary knowledge with entrepreneurship and sustainability. Indonesian research has linked digital literacy and learning motivation with stronger learning outcomes among Generation Z students (Lingga et al., 2024), while project-based entrepreneurship education has emphasised innovation, independence, and social responsibility as consequential educational outcomes (Sucipto et al., 2025). These expectations make authentic, assessable learning tasks particularly important in curriculum-development courses.

Panoramic 360° video may make this professional noticing more authentic. Unlike a fixed camera view, an interactive panorama allows learners to inspect simultaneous classroom events and select relevant evidence. Systematic reviews identify growing use of 360° video in teacher education and other context-dependent fields (Atal et al., 2023; Ranieri et al., 2022; Rosendahl & Wagner, 2024). Meta-analytic evidence, however, is mixed:

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average learning benefits can be positive, small, or contingent on design and comparison conditions (Jiang et al., 2024; Schroeder et al., 2023).

Evidence from Indonesian technology-enhanced learning also suggests that the value of video depends on how activity is organised around it. Microlearning videos divided into short, purposeful units have improved literacy performance and received positive learner responses (Kurniawan et al., 2024). H5P interactive video embedded in problem-based learning has likewise been associated with higher participation and mastery after guiding questions and individual accountability were strengthened (Prastya et al., 2025). Blended experiential learning in microteaching further indicates that digital components are most productive when they support observation, practice, reflection, and performance rather than operate as stand-alone content delivery (Sudarman et al., 2023).

The Cognitive Affective Model of Immersive Learning (CAMIL) proposes that immersive features influence learning partly through presence and agency (Makransky & Petersen, 2021). These mechanisms can support active observation, but visual freedom also creates an attentional cost. Stronger presence can coexist with weaker knowledge acquisition when environmental detail consumes cognitive resources unrelated to the learning goal (Makransky et al., 2019). Cueing studies in 360° environments similarly show that directional and textual prompts alter visual attention and reduce unnecessary search (Liu et al., 2022). Therefore, 360° video should be evaluated not only by perceived immersion but also by achievement, engagement, and extraneous cognitive load.

Digital nudges offer a low-cost means of directing attention and action without removing learner choice. In higher education, short prompts have been used to increase access to learning resources, participation, and timely engagement, although effects depend on timing, relevance, and message design (Brown et al., 2024, 2023; Graham et al., 2017; Plak et al., 2023). WhatsApp is a pragmatic channel in Indonesian multi-campus settings because it is familiar to students and does not require a common learning-management system (Mulyono et al., 2021). In the simulated design analysed here, the messages were specified as micro-alignment cues: each prompt linked the course learning outcome to observable evidence and a required analytic action.

Local evidence reinforces both the promise and the conditions of this channel. A local study reported that WhatsApp supported accessible and orderly learning, questioning, video distribution, and task collection, although connectivity still contributed to late submission (Pahlevi et al., 2024). Research on blended learning in Indonesian secondary education found that student engagement partly explained the relationship between blended learning and learning outcomes (Rufi'i et al., 2026). Together, these findings imply that a message channel should be judged by whether it activates relevant learning behaviour, not simply by whether a message was delivered.

The Indonesian evidence base nevertheless leaves an important design gap. Prior studies commonly examine a single technology, a single class, or broad perceptions of digital learning. Fewer studies separate the contextual contribution of immersive media from the regulatory contribution of brief mobile prompts while holding the learning case and assessment criteria constant. A factorial, counterbalanced design is therefore useful because it estimates what each component contributes, whether their effects combine, and which outcomes reveal possible costs.

The unresolved issue is whether such nudges amplify the effect of immersive video or contribute independently. A combined condition could be synergistic if nudges help learners convert panoramic presence into purposeful evidence selection. It could instead be merely additive if the video and nudge operate through largely separate mechanisms. This study examines these alternatives with a synthetic dataset structured as a counterbalanced repeated-measures design for a Curriculum Development and Review course across four universities. Because the dataset is synthetic, it is used to demonstrate the analytic workflow and not to provide empirical evidence about real learners.

The objective of this study is to demonstrate, with a transparently synthetic dataset, how a counterbalanced 2 × 2 repeated-measures design can be analysed to separate the independent and joint contributions of 360° video and WhatsApp nudges to OBE-aligned curriculum-analysis achievement, perceived presence, task-focused engagement, extraneous cognitive load, and on-time task completion. Specifically, the study aims to (a) estimate the average effect of 360° video relative to standard video, (b) estimate the average effect of WhatsApp nudges relative to no nudge, (c) test whether the two components interact, and (d) document the data-provenance, dependence, and sequence-design issues that must be resolved before the same workflow is applied to real data.

In line with these objectives, six hypotheses were specified. H1 states that 360° video increases OBE-aligned curriculum-analysis achievement relative to standard video. H2 states that WhatsApp nudges increase achievement relative to no nudge. H3 states that 360° video and WhatsApp nudges interact positively on achievement. H4 states that 360° video increases perceived presence. H5 states that 360° video and WhatsApp

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nudges increase task-focused engagement. H6 states that WhatsApp nudges reduce extraneous cognitive load and increase on-time task completion.

2. Method

2.1. Design and Setting

This article analyses a synthetic dataset structured as a six-week, multi-site, counterbalanced 2 × 2 repeated-measures quasi-experiment. The factors were media format (standard 2D video vs 360° panoramic video) and behavioural support (no nudge vs WhatsApp nudge), producing four conditions: C0 standard/no nudge, C1 360°/no nudge, C2 standard/nudge, and C3 360°/nudge. One simulated intact class was assigned to each university. To avoid permanently confounding an intervention with an institution, the four conditions were rotated across four intervention periods using the Latin-square schedule in Table 1. All simulated students were scheduled to experience every condition once, but in different orders across sites. Because the rotation uses only four of the 24 possible condition orders, sequence effects cannot be fully separated from site, period, and case effects (see Limitations).

Table 1. Counterbalanced Condition Rotation Across Universities

University	Period 1	Period 2	Period 3	Period 4
University A	C0	C1	C2	C3
University B	C1	C2	C3	C0
University C	C2	C3	C0	C1
University D	C3	C0	C1	C2

Note. C0 = standard video/no nudge; C1 = 360° video/no nudge; C2 = standard video/WhatsApp nudge; C3 = 360° video/WhatsApp nudge. Cases K1–K4 denote the four learning cases (K = kasus, "case"; see Section 2.3) and are distinct from C0–C3, which denote the four experimental conditions. For example, K1 is the inflation and household decision-making case, whereas C1 is the 360° video/no nudge condition. Cases K1–K4 were delivered in Periods 1–4, respectively, at every university; because the conditions rotated across universities, each case was delivered under four different conditions.

2.2. Data Source, Ethical Status, and Participant Records

The analysed workbook is synthetic. It was generated to illustrate and test the analytic workflow and contains no records from real students, lecturers, or institutions. The university names identify the hypothetical sites of the design and do not imply that any institution participated, and the student counts, demographic variables, scores, and timestamps are simulated values. The workbook has two sheets: a student-level sheet, Data_Mahasiswa ("Student Data"), and a measurement-level sheet, Data_Pengukuran ("Measurement Data").

No ethical approval or informed-consent record exists for this dataset, because no real participants were recruited, and none is claimed. The eligibility and consent fields in the workbook are simulated variables and do not document real consent. Any application of this workflow to real learners must first obtain approval from the relevant ethics committee and informed consent and must document the collection process.

The analytic participant file contained 240 simulated undergraduate Economics Education student records: 60 for each university. Every participant had four scheduled measurement records, yielding 960 site-period observations. The supplied file coded all 240 simulated students as eligible and consented; these codes are simulated variables, not evidence of consent. Mean age was 20.67 years (SD = 1.74); 62.5% were women, 16.7% reported prior 360°-video experience, and 70.0% primarily used a smartphone. Mean digital-literacy score was 3.52 (SD = 0.60) on the recorded five-point scale. The status field classified 210 students as completed, 20 as withdrawn, seven as incomplete, and three as active; because scheduled records remained in the long file, outcome-specific available-case counts are reported throughout. The status field is not consistent with the availability of pre-test and post-test scores. Table 2 summarises the participant characteristics by university.

Table 2. Participant Characteristics by University

University	n	Age, M (SD)	Women, %	Prior 360°, %	Smartphone, %	Pre-test, M (SD)	Post-test, M (SD)
A	60	20.57 (1.61)	61.7	11.7	71.7	50.67 (21.20)	63.28 (19.56)
B	60	20.82 (1.61)	70.0	20.0	76.7	53.00 (19.11)	68.61 (19.34)
C	60	20.43 (1.92)	55.0	20.0	60.0	50.67 (17.63)	66.28 (18.82)
D	60	20.85 (1.80)	63.3	15.0	71.7	49.33 (20.90)	65.44 (21.67)
Overall	240	20.67 (1.74)	62.5	16.7	70.0	50.92 (19.68)	65.90 (19.84)

Note. University labels are shortened for table width. Pre-test and post-test scores range from 0 to 100.

2.3. Learning Cases and Interventions

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Four parallel curriculum-analysis cases, labelled K1–K4 (K = kasus, "case"), addressed inflation and household decision-making (K1), entrepreneurship learning (K2), green-economy education (K3), and digital financial literacy (K4). Every case required students to identify the intended course learning outcome (CLO), select observable evidence, judge alignment among activities and assessment, and recommend a curriculum revision. Standard and 360° versions used the same case structure and core content. The 360° version permitted panning by touch or mouse on the student's smartphone or computer; no head-mounted display was required. The labels K1–K4 identify learning content and period, whereas the labels C0–C3 identify experimental conditions (Table 1). The cases, rubric, and messages describe the protocol that the synthetic data represent; no real teaching sessions were observed.

In nudge periods, students received three brief WhatsApp messages linked to the weekly learning outcome: a goal-framing message before viewing, an evidence-selection prompt during work, and a deadline-linked action prompt. Messages did not use rankings, fabricated social norms, or private-chat content. Delivery indicators for the three messages were recorded in the long-format file, and a period-level fidelity flag summarised whether implementation was complete.

2.4. Measures

Baseline and post-course knowledge/application were measured with 30 dichotomously scored items and transformed to 0–100 scores. The weekly primary outcome was curriculum-analysis achievement, scored independently by two raters on five four-level rubric criteria and rescaled to 0–100; the final score was the mean of both raters. Perceived presence used six Likert items, task-focused engagement used 12 items, and extraneous cognitive load used six adapted items (all 1–5). On-time completion was coded 1 when the recorded submission timestamp was on or before the pre-announced deadline and 0 otherwise. Table 3 reports the reliability of these measures. A date correction was applied to the workbook before analysis: every deadline and submission timestamp was shifted by exactly six calendar months, whereas durations, ordering, time of day, condition assignments, and outcome values were unchanged. Because the synthetic workbook contains no real teaching events, the shifted dates cannot be checked against academic calendars or learning-management-system logs. The shift preserves the intervals between timestamps, and all analyses in this article use only condition, period, site, and outcome variables, so none depends on absolute calendar dates; the shift is nevertheless reported as a data-provenance limitation (see Limitations).

Table 3. Reliability of Study Measures

Measure	Structure	Complete n	Coefficient	Estimate
Pre-test	30 dichotomous items	240	KR-20	0.841
Post-test	30 dichotomous items	240	KR-20	0.858
Perceived presence	6 Likert items	909	Cronbach's α	0.864
Engagement	12 Likert items	910	Cronbach's α	0.869
Extraneous load	6 Likert items	911	Cronbach's α	0.667
Achievement rubric	2 raters	907	ICC(A,2)	0.910

Note. KR-20 is algebraically equivalent to coefficient alpha for dichotomous items. ICC(A,2) is a two-way absolute-agreement coefficient for the mean of two raters. The extraneous-load coefficient (α = .667) is marginal and is treated as a limitation.

2.5. Procedure

Week 1 included consent/eligibility recording, demographic and device information, the pre-test, and orientation to panoramic navigation. Weeks 2–5 contained the four intervention periods following the rotation in Table 1. In each period, lecturers introduced the same type of OBE-aligned task; students accessed the assigned media; nudge-condition students received the standardised prompts; all students submitted the analytic task; and all students completed the three brief self-report scales. Week 6 contained the post-test. The timestamp fields in the workbook cover only the four intervention periods (Weeks 2–5). After the six-month shift, the first deadline falls on 15 March 2026, the fourth deadline on 6 April 2026 (22 days later, consistent with approximately weekly deadlines), and the latest submission on 7 April 2026, so the timestamps span 24 calendar days. The workbook contains no timestamps for the pre-test (Week 1) or the post-test (Week 6). The six-week duration is therefore the nominal programme length (orientation and pre-test, four intervention periods, and post-test) and cannot be verified from the dates in the file; the 24-day timestamp span should not be read as the study duration.

2.6. Data Quality and Statistical Analysis

Analyses used the synthetic workbook described in Section 2.2, comprising the student-level sheet Data_Mahasiswa (Student Data) and the measurement-level sheet Data_Pengukuran (Measurement Data). The four conditions each had 240 assigned records. Actual condition was missing for 48 records; among the 912 known exposures, 39 differed from assignment. Fidelity was incomplete in 57 observed records and unavailable in 48. Available outcome counts were 907 for achievement, 909 for presence, 910 for engagement, 911 for

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extraneous load, and 912 for on-time completion. No out-of-range values were found for age, pre/post scores, achievement, presence, engagement, or load. Missing outcomes were not imputed.

The primary analysis followed intention-to-treat assignment. Because the intervention was assigned at the site-period level, treating 960 student-period rows as independent assignments would understate uncertainty. We therefore calculated the available-case mean within each of the 16 site-period cells and fitted weighted least-squares models using cell size as the weight. Each model included fixed effects for site and period, effect-coded indicators for 360° video and WhatsApp nudge, and their interaction. Effect coding makes each main-effect coefficient the average effect across levels of the other factor. The design supplied 16 cells, model rank 10, and six residual degrees of freedom. Achievement, presence, engagement, and load were analysed in their original units; on-time completion was analysed as a cell proportion and reported in percentage points. Two-sided $\alpha = .05$ and 95% confidence intervals were used. Standard errors are model-based and are not cluster-robust. Because every student contributed to all four cells of the same university, student-level differences are largely removed from contrasts between conditions, and site fixed effects remove university-level mean differences. Dependence among cell residuals within the same university, for example class-specific shocks or carry-over, is not modelled, and cluster-robust standard errors by university cannot be estimated reliably from four clusters; the confidence intervals should therefore be regarded as potentially optimistic.

A paired t test described overall pre-to-post change but was not interpreted as a condition-specific effect because every participant experienced all four conditions. As-treated sensitivity models used the known actual condition, participant and period fixed effects, and two-way cluster-robust standard errors by participant and site-period (16 site-period clusters; df = 15). Reliability was evaluated with KR-20/coefficient alpha and the absolute-agreement intraclass correlation for the mean of two raters, ICC(A,2). Analyses were run programmatically on the synthetic workbook. These cell-level and as-treated analyses, not the SPSS specification in Section 2.7, are the analyses reported in this article.

2.7. Planned Individual-Level Analysis (Not Yet Executed)

The analyses reported in this article are the cell-level weighted least-squares and as-treated models described in Section 2.6, which were run programmatically; no analysis was performed in SPSS. The mixed-model specification below is a plan for a future dataset whose origin, ethical approval, and collection records can be verified, and it has not been executed. The planned analysis will use IBM SPSS Statistics (version 29 or the currently licensed equivalent). Descriptive checks will inspect missingness, impossible values, response patterns and distributional characteristics. Scale scores will be calculated only after the planned validity and reliability checks. The principal analysis will use SPSS MIXED with student as a random intercept to account for four repeated observations per student. Fixed effects will be 360° video (0/1), WhatsApp nudge (0/1), their interaction, period, university/site and baseline pre-test. University will be treated as a fixed site effect because four institutions are too few to support a stable population-level random-site variance estimate.

The planned primary model is: $\text{Achievement}_{it} = \beta0 + \beta1(360)_{it} + \beta2(\text{Nudge})_{it} + \beta3(360 \times \text{Nudge})_{it} + \beta4(\text{Pre-test})_i + \text{Period}_t + \text{Site}_i + u_i + \varepsilon_{it}$. Parallel mixed models are planned for presence, engagement and extraneous cognitive load. On-time completion is binary and will be analysed with a repeated-measures generalised model. Unstandardised coefficients, 95% confidence intervals, p values and interpretable effect estimates will be reported. Sensitivity analyses will check whether conclusions change when prior 360° experience and primary device are included as covariates.

3. Results and Discussion

All estimates in this section were computed from the synthetic workbook. They illustrate how the analytic workflow behaves and are not evidence about the effectiveness of 360° video or WhatsApp nudges for real learners.

3.1. Overall Learning Change and Measurement Quality

All 240 simulated participants had pre-test and post-test scores, including the 30 whose status field was withdrawn (20), incomplete (seven), or active (three). In a real study, withdrawal or non-completion would normally leave post-test scores missing, so this combination is an inconsistency in the synthetic file: the status field was not used to determine whether scores were present, and no collection log exists that could explain why withdrawn or incomplete participants have complete post-test scores. The paired t test was therefore computed on all 240 records. A sensitivity analysis restricted to the 210 participants with completed status was not performed and is recommended for any dataset in which status and score availability can be reconciled. The mean increased from 50.92 (SD = 19.68) to 65.90 (SD = 19.84). The mean change was 14.99 points (95% CI [13.39, 16.58], $t(239) = 18.55$, $p < .001$, Cohen's $dz = 1.20$. This large within-participant change describes learning across the full course and should not be attributed to a single treatment condition. Reliability was good for the pre-test, post-test, presence, and engagement measures (coefficients .841–.869; Table 3). The two-rater achievement score showed strong absolute agreement, ICC(A,2) = 0.910. Extraneous-load reliability was lower ($\alpha = 0.667$).

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3.2. Descriptive Outcomes by Assigned Condition

Table 4 reports the raw descriptive outcomes for each assigned condition. The outcome-specific numbers of observations differ slightly because of missing observations. These unadjusted values are compared with the adjusted estimates in Table 5.

Table 4. Raw Descriptive Outcomes by Assigned Condition

Assigned condition	Achievement n	Achievement, M (SD)	Presence, M (SD)	Engagement, M (SD)	Extraneous load, M (SD)	On-time, %
C0 Standard	232	69.84 (8.87)	2.86 (0.45)	3.04 (0.39)	2.99 (0.45)	75.0
C1 360°	223	78.17 (9.35)	4.01 (0.40)	3.16 (0.39)	3.28 (0.44)	79.1
C2 Standard + nudge	225	76.12 (9.72)	2.84 (0.45)	3.76 (0.34)	2.74 (0.43)	91.7
C3 360° + nudge	227	83.87 (8.76)	4.00 (0.40)	3.90 (0.36)	3.04 (0.39)	92.5

Note. Scale ranges: achievement 0–100; presence, engagement, and extraneous load 1–5. Outcome-specific n varies because of missing observations; the displayed n is for achievement.

As shown in Table 4, the combined C3 condition had the highest raw achievement (M = 83.87) and engagement (M = 3.90), while C1 and C3 had similarly high presence (M = 4.01 and 4.00). On-time completion was 75.0% in C0, 79.1% in C1, 91.7% in C2, and 92.5% in C3. Extraneous load was lowest in C2 (M = 2.74), whereas C1 had the highest mean (M = 3.28). These unadjusted patterns suggested positive main effects but did not by themselves establish interaction.

The descriptive pattern also clarifies the practical profile of the combined condition. Compared with C0, C3 was 14.03 points higher in raw achievement, 0.86 points higher in engagement, and 17.5 percentage points higher in on-time completion. Presence differed mainly by media format rather than by nudging: the two 360° conditions were both near 4.00, whereas the standard-video conditions were near 2.85. Conversely, the lowest load occurred in C2, indicating that the nudge benefit for task regulation did not require immersion. These contrasts are descriptive and are interpreted alongside the adjusted factorial estimates below. Figure 1 shows the adjusted achievement means for the four conditions.

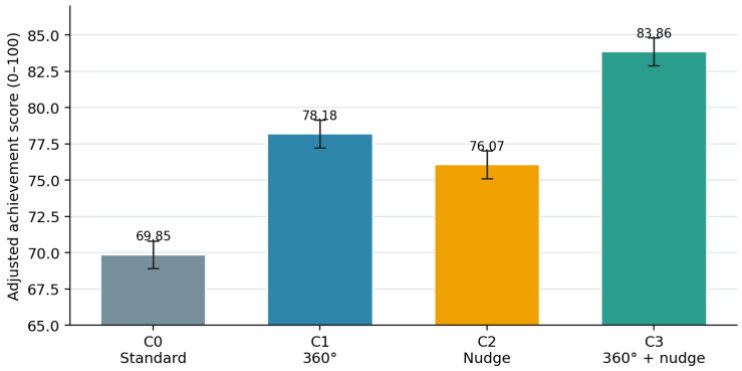


Figure 1. Adjusted Achievement Means by Assigned Condition

Note. Means and 95% confidence intervals are estimated from the 16-cell intention-to-treat model with site and period fixed effects; cells are weighted by available outcome count.

3.3. Intention-to-Treat Effects

Table 5 presents the cell-level intention-to-treat models. Each coefficient is an average effect from the 16-cell weighted least-squares model with site and period fixed effects, and the confidence intervals use the t distribution with six residual degrees of freedom. Repeated measurement within students is addressed through the within-university crossover design: every student contributed to all four cells of the same university, so student-level differences are largely removed from the contrasts between conditions. Dependence among the cells of the same university is addressed only through the site fixed effects. Any remaining within-university correlation of cell residuals, such as class-specific shocks or carry-over, is not modelled, and cluster-robust standard errors by university cannot be estimated reliably from four clusters. The standard errors and confidence intervals in Table 5 should therefore be regarded as potentially optimistic and interpreted as descriptive measures of precision in the synthetic data.

Table 5. Cell-Level Intention-to-Treat Models

Outcome	Effect	b	SE	95% CI	p

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Achievement (0–100)	360° video	8.06	0.39	[7.10, 9.02]	< .001
Achievement (0–100)	WhatsApp nudge	5.95	0.39	[4.99, 6.91]	< .001
Achievement (0–100)	Video × nudge	-0.54	0.78	[-2.45, 1.38]	= .519
Presence (1–5)	360° video	1.153	0.038	[1.059, 1.247]	< .001
Presence (1–5)	WhatsApp nudge	-0.014	0.038	[-0.108, 0.080]	= .732
Presence (1–5)	Video × nudge	0.007	0.077	[-0.181, 0.195]	= .934
Engagement (1–5)	360° video	0.132	0.021	[0.081, 0.183]	< .001
Engagement (1–5)	WhatsApp nudge	0.727	0.021	[0.676, 0.779]	< .001
Engagement (1–5)	Video × nudge	0.008	0.042	[-0.094, 0.111]	= .853
Extraneous load (1–5)	360° video	0.291	0.027	[0.225, 0.356]	< .001
Extraneous load (1–5)	WhatsApp nudge	-0.245	0.027	[-0.310, -0.179]	< .001
Extraneous load (1–5)	Video × nudge	0.011	0.053	[-0.120, 0.141]	= .850
On-time completion (pp)	360° video	2.56	2.33	[-3.15, 8.26]	= .315
On-time completion (pp)	WhatsApp nudge	15.14	2.33	[9.43, 20.84]	< .001
On-time completion (pp)	Video × nudge	-3.22	4.66	[-14.63, 8.19]	= .515

Note: Each outcome model used 16 site-period cells, fixed site and period effects, cell-size weights, and six residual degrees of freedom. Main effects are average effects from effect coding. For on-time completion, b and SE are percentage-point changes; all other coefficients are in the outcome's original units. pp = percentage points

For achievement, 360° video was associated with an average difference of 8.06 points (95% CI [7.10, 9.02], $p < .001$), and WhatsApp nudges were associated with an average difference of 5.95 points (95% CI [4.99, 6.91], $p < .001$). The interaction was small and non-significant ($b = -0.54$, $p = .519$). Adjusted achievement means were 69.85 in C0, 78.18 in C1, 76.07 in C2, and 83.86 in C3. Thus, the high C3 mean reflected the accumulation of two positive main effects rather than statistical synergy.

360° video increased presence by 1.153 scale points ($p < .001$), while the nudge effect on presence was near zero ($b = -0.014$, $p = .732$). Both components increased engagement, although the average nudge effect ($b = 0.727$, $p < .001$) was considerably larger than the video effect ($b = 0.132$, $p < .001$). Video also increased extraneous cognitive load by 0.291 points ($p < .001$), whereas nudges reduced it by 0.245 points ($p < .001$). WhatsApp nudges increased on-time completion by 15.14 percentage points (95% CI [9.43, 20.84], $p < .001$); the average video effect on completion was not significant. None of the five interaction tests was significant.

The adjusted results therefore separated two benefit pathways. The panoramic format produced the larger achievement coefficient and the only substantial change in presence, whereas the nudge produced the larger engagement coefficient, the only reliable improvement in timely completion, and a reduction in extraneous load. The combined condition exceeded C0 by 14.01 adjusted achievement points, but its estimated advantage was almost completely explained by adding the two main effects. This outcome profile illustrates how complementary functions can be distinguished, which a single omnibus claim that digital technology improved learning cannot do.

3.4. Sensitivity Analysis and Hypothesis Decisions

As-treated models based on known actual condition produced the same substantive pattern. Video effects remained positive for achievement ($b = 8.38$, 95% CI [7.46, 9.31]), presence ($b = 1.207$, 95% CI [1.152, 1.261]), and engagement ($b = 0.144$, 95% CI [0.105, 0.182]), and remained positive, rather than beneficially negative, for extraneous load ($b = 0.305$, 95% CI [0.249, 0.362]); all $p < .001$. Nudge effects remained positive for achievement ($b = 6.78$) and engagement ($b = 0.782$) and negative for load ($b = -0.253$), all $p < .001$, while presence remained non-significant ($p = .293$). Interactions remained non-significant for all four continuous outcomes ($p = .622–.955$). Table 6 summarises the hypothesis decisions for the synthetic dataset.

Table 6. Hypothesis Decisions

Hypothesis	Prediction	Decision
H1	360° video increases achievement	Supported
H2	WhatsApp nudges increase achievement	Supported
H3	Positive video × nudge interaction on achievement	Not supported
H4	360° video increases presence	Supported
H5	Both components increase engagement	Supported
H6	Nudges reduce load and improve on-time completion	Supported

Note. H6 concerns the nudge effect. The additional finding that 360° video increased extraneous load qualifies the interpretation of the immersive condition. Decisions refer to the synthetic dataset only and are not evidence about real learners.

This discussion interprets the output of the analytic workflow on the synthetic dataset. The patterns are illustrative, and any statement about benefits describes what the simulated data show, not what real learners experienced. In the synthetic data, panoramic video and WhatsApp nudges showed distinct, additive patterns across the four simulated university settings. The 360° format was associated with higher OBE-aligned curriculum-analysis achievement, perceived presence, and engagement. Nudges were associated with higher achievement and engagement, lower extraneous load, and more timely submission. The combined condition had

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the highest adjusted achievement and engagement, but no outcome showed a statistically detectable interaction. If the same pattern were reproduced in verified empirical data, it would support combining the two components for accumulated benefits, rather than claiming that one intervention amplified the effect of the other.

The 360° achievement and presence results align with the premise that interactive viewpoints can strengthen contextual access and professional noticing (Kosko et al., 2021; Theelen et al., 2020). Students could inspect multiple classroom cues and connect observable behaviour with OBE criteria rather than relying on a fixed-camera selection. The large presence effect is consistent with CAMIL, in which immersive features alter psychological presence and agency (Makransky & Petersen, 2021). In the synthetic dataset the achievement difference accompanied the presence difference, but whether presence is more than experiential can only be tested with verified empirical data.

At the same time, 360° video was associated with higher extraneous load in the synthetic data. That result is theoretically plausible because learner-controlled visual search makes more environmental information available and requires decisions about where to look. It echoes evidence that immersive environments can heighten presence while imposing cognitive costs (Makransky et al., 2019; Rupp et al., 2019). The pattern is consistent with rejecting a uniformly beneficial account of immersion. If verified data show the same pattern, instructors should pair panoramic cases with concise orientation, visible analytic criteria, and opportunities to revisit evidence rather than increasing visual complexity indiscriminately.

In the synthetic data, the nudge pattern was more behavioural and regulatory. Achievement and engagement were higher, on-time completion was approximately 15 percentage points higher, and extraneous load was lower. Goal-linked prompts may have externalised part of the task-management burden by specifying when to attend, what evidence to record, and when to submit. This interpretation is consistent with research showing that relevant, timed digital nudges can increase resource use and engagement (Brown et al., 2024, 2023; Plak et al., 2023). The absence of a presence effect is also informative: WhatsApp prompts did not make the environment feel more immersive; they were associated with action within the task.

The missing interaction deserves emphasis because the original conceptual argument allowed for synergy. Under synergy, the nudge would have made the 360° effect systematically larger. Instead, interaction estimates were near zero and imprecise across achievement, presence, engagement, load, and completion. If verified data replicated this pattern, a practical reading would be that the components can be selected modularly. Institutions with limited capacity to produce panoramic media may still obtain meaningful benefits from carefully designed nudges, while programmes that adopt 360° video should manage its cognitive demands even when nudges are present.

The overall pre-to-post gain was large, but the design does not attribute that change to a single component because every student experienced all four conditions and progressed through course content. The treatment estimates are more informative for comparative effectiveness. Even so, inference is anchored to 16 assignment cells rather than 960 independent treatment assignments. Reporting cell-level models and six residual degrees of freedom prevents the precision from being overstated. Because the data are synthetic, the large pre-to-post change reflects the simulated score structure and carries no information about actual learning.

3.5. Limitations Governing Interpretation

The first and most important limitations concern data provenance and ethics. The workbook analysed here is synthetic, so the results are not evidence about real learners, and no claim of effectiveness can be drawn from them. The way the file was generated must be documented before its numbers are treated as anything other than workflow output. No ethical approval or informed-consent record exists for the dataset, because no real participants were recruited; any application to real students requires ethics committee approval, informed consent, and documentation of the collection process. In addition, all deadline and submission timestamps were shifted by exactly six calendar months. The shift preserves intervals and ordering and does not affect the analyses, but its reason could not be verified against external records, and the timestamps span only 24 days, which is shorter than the nominal six-week schedule (Section 2.5). Finally, the status field is inconsistent with the availability of post-test scores.

The second group of limitations concerns the treatment sequences and the design. Condition, period, and case were structurally linked within the rotation, and the Latin square used only four of the 24 possible condition orders, so each sequence appeared in exactly one university and treatment sequence is completely confounded with university. Period fixed effects absorb common case and period differences, but differential carry-over, case difficulty, and site-specific sequence effects cannot be separated from site effects. Treatment assignment also occurred in only 16 site-period cells, with one simulated intact class per university, leaving six residual degrees of freedom after adjustment; the findings should not be generalised to Indonesian higher education as a whole. Standard errors are model-based and do not account for residual dependence among the cells of the same university (Sections 2.6 and 3.1.3).

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Measurement and implementation limitations also apply. Actual condition was missing for 48 observations, 39 known observations deviated from assignment, and fidelity was incomplete in 57 observed periods. Intention-to-treat and as-treated analyses agreed, but missing exposure and implementation variation would remain potential sources of bias in any real application. The extraneous-load scale had marginal internal consistency ($\alpha = .667$), so its magnitude should be interpreted more cautiously than that of the presence and engagement effects. Outcomes covered a nominal six-week course, so longer-term retention, transfer to school placements, cost-effectiveness, and accessibility for students with device or connectivity constraints were not measured.

3.6. Main Findings and Potential Educational Benefits

The points below describe what the synthetic results would imply if they were replicated with verified data. They are conditional on the limitations above and are not recommendations derived from evidence.

First, the magnitude of the achievement pattern would be educationally consequential if replicated with verified data. The adjusted mean for C3 was 83.86 compared with 69.85 for C0, a 14.01-point advantage. Because the interaction was not significant, this difference should be understood as the accumulated contribution of contextual observation and behavioural support. For an OBE curriculum, the potential benefit is not simply a higher test score but stronger evidence-based analyses of learning outcomes, classroom activity, and assessment alignment. This is directly relevant to the capacity to review and improve curricula rather than merely describe OBE terminology.

Second, the difference of 1.153 points in presence illustrates what panoramic media could add. The 360° environment allowed students to choose where to look and to compare simultaneous classroom evidence, which is close to the observational judgement required in professional practice. The result is consistent with evidence that immersive VR can improve engagement and learning experience when exploration is integrated with a structured project (Untari et al., 2026). The potential practical benefit would be a more authentic rehearsal space: preservice educators can practise noticing and justification repeatedly without interrupting a live lesson or depending on a fixed camera operator's selection.

Third, the WhatsApp pattern in the synthetic data suggests that a familiar communication platform could deliver more than administrative reminders. The 0.727-point engagement gain, 0.245-point reduction in extraneous load, and 15.14-percentage-point increase in on-time completion indicate a coherent self-regulation pattern. Short prompts appeared to make the goal, evidence criterion, and next action easier to retrieve at the point of need. This complements local evidence that WhatsApp can support accessible questioning, video distribution, and task collection (Pahlevi et al., 2024), while illustrating how verified data could extend it with comparative estimates across four sites and with behavioural as well as cognitive outcomes.

Fourth, the joint pattern offers a tentative design principle for managing immersion. In the synthetic data, panoramic video was associated with higher achievement and presence but also with higher extraneous load, whereas nudges were associated with lower load. The messages did not statistically eliminate the video-related load increase through an interaction, yet their independent regulatory benefit can still improve the overall learning experience. Microlearning research by Kurniawan et al. (2024) and interactive-video work by Prastya et al. (2025) similarly suggest that concise units, guiding questions, and individual accountability help convert digital content into purposeful activity. The benefit of the combined design is therefore balance: rich contextual evidence is retained while task structure remains visible.

Fifth, the absence of synergy in the synthetic data would, if replicated, strengthen the case for modular and scalable adoption. Universities would not need to purchase immersive hardware before gaining value from well-designed nudges, and the study's browser- or smartphone-based 360° format avoided dependence on head-mounted displays. Institutions could begin with standard video plus WhatsApp prompts, then add panoramic cases only where simultaneous spatial information is essential to the learning outcome. This staged approach is compatible with blended experiential learning, which connects observation, reflection, and performance (Sudarman et al., 2023), and with evidence that engagement is a mechanism linking blended learning to outcomes (Rufi'i et al., 2026). The potential benefit is a clearer allocation of development effort to the component that addresses the local problem.

3.7. Conditional Implications for OBE Curriculum Learning

These implications are conditional on the limitations above. They follow from the design logic of the synthetic demonstration and should not be implemented as evidence-based recommendations until verified data with documented ethical approval are available. For curriculum-development courses, 360° cases are most defensible when panoramic information is necessary for the intended outcome, for example, when students must compare simultaneous learner actions, teacher feedback, and assessment evidence. The nudge messages

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should then reference a specific CLO and an observable decision rather than serve as generic reminders. A scalable sequence is to orient students to navigation, state the evidence criterion, deliver one mid-task prompt, and close with a deadline-linked action cue. Standard and panoramic versions should retain equivalent content so that media effects are not confounded with different explanations.

For multi-campus implementation, WhatsApp offers platform neutrality but limited research analytics. Delivery flags and timestamps can document implementation, but message read receipts should not be treated as valid exposure measures when users can disable them. A common task form and scoring rubric remain necessary for cross-site comparability. The rater ICC in the synthetic file cannot be taken as evidence of rubric reliability; an empirical study should report rater agreement from real scoring, and future work should also report expert content-validity evidence and factor-analytic evidence for adapted self-report scales.

4. Conclusion

This article demonstrated, with a synthetic four-university dataset, how a counterbalanced 2 × 2 repeated-measures design can be analysed to distinguish the separate and joint contributions of 360° video and WhatsApp nudges to OBE-aligned curriculum-analysis achievement. In the synthetic data, both components were associated with higher achievement through different outcome profiles: panoramic video was associated with markedly higher presence, slightly higher engagement, and higher extraneous cognitive load, whereas WhatsApp nudges were associated with higher engagement, lower load, and about 15 percentage points higher on-time completion. The combined condition had the highest achievement and engagement means, yet no statistical interaction supported a synergistic mechanism. These results are workflow output and not empirical findings, because the dataset is synthetic, no ethical approval or consent records exist, all timestamps were shifted by six months, and the design used only four treatment sequences. A modular implementation strategy, using panoramic video where contextual observation is essential, explicit evidence criteria, and task-linked nudges, is therefore a hypothesis for testing and not a finding. Claims about effectiveness require replication with real data from more independent classes, documented collection records and ethical approval, stronger load measurement, and longer follow-up; if such records become available, the results should be re-estimated and reported as limited empirical findings.

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Data Availability

The numerical dataset analysed in this article is synthetic; it contains no records from real participants and is not evidence of intervention effects. The workbook comprises the sheets Data_Mahasiswa (Student Data) and Data_Pengukuran (Measurement Data). To allow replication of the workflow, the workbook and the analysis syntax should be archived in a public repository in accordance with journal policy. For any future empirical study, a de-identified dataset and analysis syntax should be archived in accordance with ethics approval, participant consent, and journal policy.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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